ICAR Summer School

September 04-24 2018

Emerging Post-Harvest Engineering and Technological Interventions for Enhancing Farmer's Income

Sandeep Mann

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ICAR-Central Institute of Post-Harvest Engineering & Technology

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(An ISO 9001:2015 Certified Institution)

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COMPENDIUM

ICAR Sponsored Summer School

Emerging Post-Harvest Engineering and Technological Interventions for Enhancing Farmer's Income

September 04-24, 2018

Course Director
Dr. Sandeep Mann

Course Co-Director
Dr. Renu Balakrishnan
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Disclaimer

This compendium is a compilation of the lectures which are undertaken during organization of ICAR sponsored Summer School on "Emerging Post-Harvest Engineering and Technological Interventions for Enhancing Farmer's Income" at ICAR-Central Institute of Post-Harvest Engineering & Technology, Ludhiana, (Punjab) India with Dr. Sandeep Mann (Course Director), Dr. Renu Balakrishnan and Er. Yogesh Bhaskar Kalnar (Course Co-Directors). It is understood that the views expressed on various topic are the prerogative and responsibility of concrened authors.

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21 August, 2018

MESSAGE

I am happy to know that ICAR-CIPHET, Ludhiana is organizing a 21 day ICAR sponsored Summer School on "Emerging Post-Harvest Engineering and Technological Interventions for Enhancing Farmers Income" during September 4-24, 2018.

Quantity of inputs in agricultural business increases steadily with continuous way which diminishes the net profit of the farmers. Enhancing farmer's income is worth serious attentionable issue. This laudable work could not only improve the well-being of our farmers but can also be a trigger to boost agro-based manufacturing growth in rural India. Raising farmers income comes in effect to large extent with value addition and processing of agricultural products (such as cereal grains, dairy, honey, legumes, pulses, vegetables, fruits, oilseed crops etc.) The post-harvest losses can be minimized to a great extent utilizing appropriate post-harvest engineering and technological interventions.

It is necessary to provide a safe nutritious food (processed or unprocessed) in order to maintain human health. At present, food and crop processing is generally considered to be the largest industry in most countries. Large as well as cottage level food industries are emerging by adopting the concept of manufacturing and selling of ready-to-eat meals. They need special processing and packaging to protect them for required storage life. The processing sector with improved technologies and interventions can be a source of enrichment of income for large number of people involved in this sector.

I am sure that this summer school will provide a platform for the participants to understand, share and discuss issues and challenges in post-harvest sector and ways to minimize these losses to enhance farmer's income utilizing emerging post-harvest engineering and technologies.

I wish this Summer School a great success in achieving its goal.

Rathore

(Narendra Singh Rathore)

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27/08/2018

MESSAGE

The Government of India is envisaging on doubling farmers' income by 2022. Cultivation of cash crops, integrated farming (including agriculture, animal husbandry, fishries, and allied sectors, improving the input-use efficiency and enhancing the yield potential of the land are some of the areas in which we have to focus for enhancing the farmers' income.

On the other hand, we have been observing that India has experienced huge post-harvest losses due to inadequate post-production processing facilities and technologies. These losses as estimated by AICRP-PHET centres translates to a whopping Rs. 94,000 crores per annum (according to 2014 cost estimates).

Reducing these losses and appropriately value-adding them are two major areas that India needs to focus for enhancing the farmers' income.

I am very glad that ICAR-CIPHET, Ludhiana is conducting a 21-day sponsored Summer School on 'Emerging Post-Harvest Engineering and Technological Interventions for Enhancing Farmers' Income during 04-24 September, 2018. This is a timely theme and is in line with our motive of popularizing post-harvest technologies among all stake-holders. The participants of this Summer School must take with them the knowledge that will be shared in these 21 days, so that they can spread the knowledge to the farmers, traders, and other stake-holders of their respective regions.

I wish the Summer School a grand success.

(K. Alagusundaram)

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FOREWORD

In recent years, the agro-processing industry in India has gained considerable growth owing to availability of raw materials, changing lifestyles and liberal government policies. Agro processing industry conserve and handle agricultural produce making it usable as food, feed, fiber, fuel or industrial raw material. The scope of the agro-processing industry encompasses all operations from the stage of harvest till the produce reaches the consumers in the desired form, packaging, quantity, quality and price. Agro processing industry thus processes raw materials and intermediate products, transforming products originating from agriculture, fisheries and forestry.

In India, past strategy for development of the agriculture sector has mainly focused on raising agricultural production and improving food security but, the strategy did not revealed any direct measure to promote farmers welfare and farmers' income. This resulted in low income of farmers. The persistent low level of farmer's income is causing harmful effect on the interest in farming and farm investments, due to which more and more cultivators, mainly of younger age group leave farming. This can result in adverse effect on the future of agriculture in India. Thus, to secure future of agriculture and to improve livelihood of farmers, research institutes should come with technological breakthroughs to improve the welfare of farmers and raise agricultural income through diversified options, including post-production management and value addition related activities.

It give me immense pleasure that ICAR - Central Institute of Post-Harvest Engineering and Technology (CIPHET) is organizing a summer school on "Emerging Post-Harvest Engineering and Technological Interventions for Enhancing Farmer's Income" during 04-24 September, 2018. I appreciate the timely initiative of the organizers and the theme of the summer school is most appropriate. I hope that this summer school would be a platform for interaction of participants with subject experts from different parts of the country and update themselves with the recent information and interventions in this field.

My best wishes to organizers and entire team associated with this summer school.

(Dr. R.K. Singh)

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We express our sincere gratitude to Dr. K. Alagusundaram, DDG (Ag. Engg), Dr. Kanchan K. Singh, ADG (Engg) and Dr. S. N. Jha ADG (PE) for their constant encouragement, guidance and motivation to conduct this programme.

We express our sincere thanks to Dr. R. K. Singh, Director (Acting), ICAR-CIPHET, Ludhiana for unending support, encouragement and valuable guidance to conduct this summer school. The moral support with constant monitoring and inventive ideas were crucial to pursue this summer school for planning and implementation of this programme.

We express our sincere thanks to all the scientists of ICAR-CIPHET from both Ludhiana and Abohar campus, Experts from different organizations for providing the lecture notes in time, and other facilities for smooth conducting of this summer school.

We are indebted to all technical, administrative and supporting staff of ICAR-CIPHET, Ludhiana and Abohar Campus for putting their sincere efforts for smooth organization of this summer school.

Finally, we would like to thank everybody and congratulate to all for successful organization of this summer school.

Sandeep Mann
Renu Balakrishnan
Yogesh Bhaskar Kalnar

ICAR Sponsored Summer School

Emerging Post-Harvest Engineering and Technological Interventions for Enhancing Farmer's Income

September 04-24, 2018

CONTENTS

Construction of Evaporative Cool Room for On Farm Storage of Horticultural Produce

S.N. Jha[1], Sandeep Mann[2] and K. Narsaiah[2]

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The quality and storage life of fruits and vegetables may be seriously compromised within a few hours of harvest unless the crop has been cooled promptly to control deterioration. The major problem during storage is the change in the quality parameters of the produce especially the physical characteristics such as; the color, texture and freshness in which the price sometimes depend on. In order to extend the shelf life, fruits and vegetables need to be properly stored. Proper storage means controlling both the temperature and relative humidity of the storage area. Although, refrigeration is very popular but it has been observed that several fruits and vegetables, for example banana, plantain, tomato etc. cannot be stored in the domestic refrigerator for a long period as they are susceptible to chilling injury. Apart from this, the epileptic power supply and low income of farmers in the rural communities' makes refrigeration expensive. Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. The efficiency of an evaporative cooling structure depends on the humidity of the surrounding air. Therefore, this article reviews the theory, advances, principles, methods of evaporative cooling, design considerations and also the optimum storage temperature, relative humidity and shelf life of fruits and vegetables. An Evaporative cooler reduces the storage temperature and also increases the relative humidity within the optimum level of the storage thereby keeping the fruits and vegetables fresh. It can be use for short term preservation after harvested. Thus, an evaporative cooling is a low cost technology for storage of fruits and vegetables. The Technology of evaporative cooling is cost effective and could be used to prolong the shelf-life of agricultural produce.

Introduction

The vegetables and fruits are important food items that are widely consumed because they form an essential part of a balanced diet. Fruits and vegetables are important sources of minerals and vitamins especially vitamin A and C. They also provide carbohydrates and protein, which are needed for normal healthy growth However, the quality and storage life of fruits and vegetables may be seriously compromised within a few hours of harvest unless the crop has been cooled promptly to control the deterioration. The major problem during storage is what happens to the quality parameters of these produce especially the physical characteristics such as; the color, texture and freshness in which the price sometimes depends on. In order to extend their shelf life, fruits need to be properly stored. Proper storage means controlling both the temperature and relative humidity of the storage area.

Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. The efficiency of an evaporative cooler depends on the humidity of the surrounding air. Very dry air can absorb a lot of moisture so greater cooling occurs. In the extreme case of air that is totally saturated with water, no evaporation can take place and no cooling occurs. Generally, an evaporative cooling structure is made of a porous material that is fed with water. Hot dry air is drawn over the material. The water evaporates into the air raising its humidity and at the same time reducing the temperature of the air. Aeration, temperature and relative humidity management, microorganisms control, sanitation and preventing moisture loss greatly improves the storability of produce by maintaining a cool and uniform environment throughout the storage period. Low temperature prolongs storage life by reducing respiration rate as well as reducing growth of spoilage microorganisms. Temperature, relative humidity and atmospheric composition during prestorage, storage and transit could control decay. For optimum decay control, two or more factors often are modified simultaneously and these are temperature and relative humidity. Proper management of temperature is so critical to post harvest disease control that all other treatments can be considered as supplements to refrigeration . However, temperatures as low as possible are desirable because they significantly slow growth and thus reduce decay.

Respiration is one of the basic physiological factors, which speeds up ripening of fresh commodities and is directly related to maturation, handling and ultimately to the shelf life. Generally, the loss of freshness of perishable commodities depends on the rate of respiration. A common acid found in fruit includes citric, malic and ascorbic acid. During ripening, organic acids are among the major cellular constituents undergoing changes. Studies have shown that there is a considerable decrease in organic acid during ripening of fruits. An aspect to consider when handling fruits and vegetables is the temperature and relative humidity of the storage environment. For fresh harvested produce any method of increasing the relative humidity of the storage environment (or decreasing the vapour pressure deficit (VPD) between the commodity and its environment) will slow the rate of water loss and other metabolic activities. This will slow both the respiratory processes and activities of micro-organisms (pathogens) which are the most destructive activity during storage of fruits and vegetables Although, refrigeration is very popular but it has been observed that several fruits and vegetables, for example banana, plantain, tomato etc. cannot be stored in the domestic refrigerator for a long period as they are susceptible to chilling injury. Apart from this, the epileptic power supply and low income of farmers in the rural communities' makes refrigeration expensive.

FAO (1983) advocated a low cost storage system based on the principle of evaporative cooling for storage of fruits and vegetables, which is simple and relatively efficient. The basic principle relies on cooling by evaporation. However, sometimes when evaporative cooling system is used in preservation, it is used with shade on top.

Advances in Evaporative Cooling Technology

Different designs of evaporative coolers have been reported in literature for the preservation of fruits and vegetables. The design ranges from straw packing house to some sophisticated design. FAO (1986) reported that the packing houses of typical evaporative coolers are made from natural materials that can be moistened with water. Wetting the walls and roof first thing in the morning which is tedious creates conditions for evaporative cooling of the packing house. The major problem of these structures is the constructing material which deteriorates quickly and is susceptible to rodent attack. An evaporative cooler for preservation of fruit and vegetable which complements natural air with forced air to cool small lots of produce. The report also showed some other evaporative cooler which he called drip coolers and can be constructed from simple material such as burlap and bamboo. They operate solely through the process of evaporation without the use of fan. These coolers are cumbersome and have the same problem of the packing house.

A cheap cool store in Kenya, with the help of local grass for storage of vegetables was developed. The roof and walls wet by dripping water from the top of the roof. Evaporative coolers, which rely on wind pressures to force air through wet pads, have also been designed and constructed, especially in some developing countries like India, China and Nigeria.

Construction of various evaporative systems was done by using available materials as absorbent (pads). Materials used include canvas, jute curtains and hourdis clay blocks. Also a mechanical fan was introduced to some of the coolers constructed.

The development of hexagonal wooden evaporative cooling systems and the system could be sub-divided into three parts head tank and pipe lines work ,the through and the frame work made of woods and its adjoints. The pipe line works at the top of the hexagonal frame supplied water constantly to wet the pad which is made of jute fibre. Wind pressure forced the air through the wetted jute pad. Limitation of this design is that the sufficiency of the evaporative cooler depends on wind velocity. An evaporative cooled structure for storage of fruits and vegetables with a double wall made of baked bricks and the top of the storage space covered with *khaskhas*/gunny cloth in a bamboo framed structure. Sanni, (1999) did a research on the development of evaporative cooling system on the storage of vegetable crops .The major development was implemented by adding a regulated fan speed, water flow rate and wetted-thickness .This was possible as a result of varying temperature and relative humidity within the facility. Dzivama, (2000) researched on the performance evaluation of an active cooling system using the principles of evaporative cooling for the storage of fruits and vegetables. He developed mathematical models for the evaporative process at the pad-end and the storage chamber and a stem variety of sponge was considered to be the best pad material from the local materials tested as pad material.

Olosunde, (2006) also did a research on the performance evaluation of absorbent, materials in evaporative cooling system for the storage of fruits and vegetables. Three materials were selected to be used as pad materials: jute, Hessian and cotton waste. The design implemented a centrifugal fan, high density polystyrene plastic, Plywood used as covering for the walls and basement and the top and the main body frame was made of thick wood. The performance criteria included the cooling efficiency, amount of heat load removed and the quality assessments of stored products. The result showed that the jute material had the overall advantage over the other materials. The cooling efficiency could be increased if two sides were padded. Sushmita et al., (2008) researched on Comparative Study on Storage of Fruits and Vegetables in Evaporative Cooling Chamber and in Ambient. An evaporative cool chamber was constructed with the help of baked bricks and riverbed sand. It was recorded that weight loss of fruits and vegetables kept inside the chamber was lower than those stored outside the chamber. The fruits and vegetables were fresh up to 3 to 5 days more inside the chamber than outside.

Acedo (1997) developed two simple evaporative coolers with jute bag and rice husk as the cooling pad in the Philippines for cooling and storage of vegetables. He prevented decay by washing the product first in the chlorinated water. Jain (2007) presented a two stage evaporative cooler for fruits and vegetable which incorporated a heat exchanger. This design is expensive but he could only achieve a storage life of 14 days for tomato. Anyanwu (2004) developed a porous wall (pot in pot) evaporative cooler for preservation of fruits and vegetables. He got a storage life of less than four days (93hours) on tomato. In this research work, an evaporative cooler with locally sourced materials for the construction was developed and evaluated. The evaporative cooler fabricated with mud (clay) directly excavated from the swamp is not electricity dependent will help farmers and marketers of fruits and vegetables to be able to store and preserve efficiently their products.

Factors Affecting the Shelf Life of Fruits and Vegetables

There are various factors that do affect the shelf life of fruits and vegetables which would lead to their spoilage. The various factors include:

i) Ambient Condition : The environmental condition has a great influence on the shelf life of fruits and vegetables and the factors can be sub-divided into temperature and relative humidity.

ii) Temperature : Temperature is defined as the degree of hotness or coldness of a material. Temperature has a great influence on the shelf life of agricultural products. FAO, (1998) found that all produce are subject to damage when exposed to extreme temperatures which will lead to increase in their level of respiration. Also, it was further disclosed that agricultural products vary in their temperature tolerance.

Gravani, (2008) observed that for every 18°F (-7.7°C) rise in temperature within the moderate temperature range (50°F-100°F)/(10°C-37.8°C) where most food is handled, the rate of chemical reactions is approximately doubled. As a result, excessive temperatures will increase the rate of natural food enzyme reactions and the reactions of other food constituents.

iii) Relative Humidity : This is the measurement of the amount of water vapour in the air as a percentage of the maximum quantity that the air is capable of holding at a specific temperature. It has a great effect on the deterioration of fruits and vegetables because it has a direct relationship with the moisture content in the atmosphere which determines whether the shelf life will not be exceeded. The relative humidity of storage unit directly influences water loss in produce.

iv) Variety and stage of ripening: Post-harvest operation does not stop the fruits and vegetables from respiring which if not controlled will lead to the over-ripening of the fruits which will lead to early deterioration. Depending on the stage the fruits are harvested, which in practice varies from mature green to fully ripened, the commodities have different storage conditions

Principles of Evaporative Cooling

Evaporative Cooling with Psychrometric Chart

Cooling through the evaporation of water is an ancient and effective way of cooling water. He further disclosed that this was the method being used by plants and animals to reduce body temperature. The conditions at which evaporative cooling would take place which are stated below:

(1) Temperatures are high

(2) Humidity is Low

(3) Water can be spared for its use

(4) Air movement is available (from wind to electric fan)

Also the change of liquid stage to vapour requires the addition of energy or heat. The energy that is added to water to change it to vapour comes from the environment, thus making the environment cooler.

Therefore, the use of the psychrometric chart is of great importance in order to discover whether evaporative cooling has taken place. Air conditions can be quickly characterized by using Properties on the chart include dry-bulb and wet-bulb temperatures, relative humidity, humidity ratio, specific volume, dew point temperature and enthalpy Beiler, (2009).

When considering water evaporating into air, the wet-bulb temperature, as compared to the air's dry-bulb temperature is a measure of the potential for evaporative cooling. The greater the difference between the two temperatures, the greater the evaporative cooling effect. When the temperatures are the same, no net evaporation of water in air occurs, thus there is no cooling effect (Wikipedia.com).

Therefore for optimum cooling efficiency using the evaporative cooling technique temperature and the relative humidity measurement is needed to be taken and the psychrometric chart defines these variables at various stages.

B. Factors Affecting Rate of Evaporation

Evaporative cooling results in reduction of temperature and increase in relative humidity (Olosunde, 2006).It is necessary to understand the factors that can limit the efficiency of the system from producing the intended results. There are four major factors that affect the rate of evaporation which was analysed. He later added that though they are discussed separately but it is important to keep in mind that they all interact with each other to influence the overall rate of evaporation, and therefore the rate of cooling. These factors discussed by including:

(1) Air Temperature

Evaporation occurs when water is absorbs sufficient energy to change from liquid to gas. Air with a relatively high temperature will be able to stimulate the evaporative process and also be capable of holding a great quantity of water vapour. Therefore, areas with high temperatures will have a high rate of evaporation and more cooling will occur. With lower temperature, less water vapour can be held and less evaporation and cooling will take place.

(2) Air Movement

Air movement velocity either natural (wind) or artificial (fan) is an important factor that influences the rate of evaporation. As water evaporates from wet surface, it raises the humidity of the air that is closest to the water surface (moist area). If the humid air remains in place, the rate of evaporation will start to slow down as the humidity rises. On the other hand if the humid air near the water surface is constantly being moved away and replaced with drier air, the rate of evaporation will either increase or remain constant.

(3) Surface Area

The area of the evaporating surface is another important factor that affects the rate of evaporation. The greater the surface area from which the water evaporates, the greater the rate of evaporation.

(4) Relative Humidity of the Air

This is the measurement of the amount of water vapour in the air as a percentage of the maximum quantity that the air is capable of holding at a specific temperature. When the relative humidity of the air is low, this means that only a portion of the total quantity of water which the air is capable of holding is being held. Under this condition, the air is capable of taking additional moisture, hence with all other conditions favourable, the rate of evaporation will be higher and thus the efficiency of the evaporative cooling system is expected to be higher.

Methods of Evaporative Cooling

Rusten, 1985 specified that there are two main methods of evaporative cooling namely:

(1) Direct evaporative cooling

(2) Indirect evaporative cooling

(1) Direct Evaporative Cooling

This is a method by which air is passed through a media that is flooded with water .The latent heat associated with the vaporizing of the water cools and humidifies the air streams which now allows the moist and cool air to move to its intended direction. (Sellers, 2004) Sanjeev, (2008) disclosed that direct evaporative cooling has the following major limitations:

i) The increase in humidity of air may be undesirable.

ii) The lowest temperature obtainable is the wet-bulb temperature of the outside air,

iii) The high concentration and precipitation of salts in water deposit on the pads and the other parts, which causes blockage, corrosion requires frequent cleaning, replacement and servicing.

(2) Indirect Evaporative cooling

A heat exchanger is combined with an evaporative cooler and the common approach used is the passes return/ exhaust air through an evaporative cooling process and then to an air-to air heat exchanger which in turn cools the air, another approach is the use of a cooling tower to evaporatively cool a water circuit through a coil to a cool air stream (Sellers, 2004) and Sanjeev, (2008) also said indirect cooling differs from direct cooling in the sense that in indirect cooling the process air cools by the evaporation of water but there is no direct contact of water with process air. Instead a secondary airstream is used for evaporation of water. So the moisture content of process air remains the same.

Forms of Direct Evaporative Cooling

Dzivama, (2000) did a study on the forms of evaporative cooling process and discovered that there are two forms in which the evaporative cooling principle can be applied. The difference is based on the means of providing the air movement across/through the moist materials .These is the passive and non-passive forms. The passive form of evaporative cooling relies on the natural wind velocity, to provide the means of air movement across/through the moist surface to effect evaporation. This form can be constructed on the farm, for short term on farm storage while the non- passive form uses a fan to provide air movement.

A. Passive-direct evaporative cooling system

Construction and design varies but the general principles are the same. The main components include:

i) The cabinets where the produce is stored.

ii) The absorbent material used to expose the water to the moving air

iii) An overhead tank/through which the water seeps down on to and wet the absorbent material. The absorbent material covering the cabinet absorbs water from the tank on top of the cabinets, the entire cloth that was used as cabinet is soaked in water and the air moves past the wet cloth and evaporation occurs. As long as evaporation takes place, the contents of the cabinet will kept at a temperature lower than that of the environment and the temperature reduction obtained in this type of cooler ranged from 5°C to 10°C. Different researches have been done by researcher: to designed various forms of coolers.

B. Non- passive direct evaporative cooling system

This uses a small fan, a water pump which is powered by electricity. The products are kept in storage cabins inside the coolers, Absorbent material which receives the water and expose it to evaporation with the help of the fan which draws air through the pad and a overhead tank which is constantly supplying water to the absorbent material. Materials used as the absorbent materials are hessian materials, cotton waste and celdek and the body frame is made of wood. The pad and the fan are directly opposite to each other.

Design construction and impact assessment of evaporative cooler

A charcoal evaporative milk cooler was designed and fabricated, with inner dimensions being 1.00 m long x 1.00 m wide x 0.75 m high (Figs. 1 and 2). Apilot study in the area indicated that the daily quantities of marketed milk by individual traders ranged from 40 to 160 litres (Wayua, unpublished data). The capacity of the cooler was, therefore, chosen in relation to the daily quantities of marketed camel milk in the region. The target was to cool approximately 200 litres of milk per producer/trader to temperatures less than 10°C, which is necessary to reduce microbial milk spoilage in the ASALs, characterised by high ambient temperatures (>25°C). The frame was constructed from 25 mm x 25 mm x 4 mm angle iron, reinforced with 3 mm thick steel wire mesh and chicken wire inside and out, leaving a 10 cm wide cavity which was filled with charcoal. The cooler was provided with a side door which opened outwards. The charcoal walls were on all four sides. Charcoal was selected as the pad material because it has a very porous structure that can hold water, is light, durable for repeated wetting and drying, is inexpensive and locally available in the study area, essential requirements for a good pad material water reservoir (white 50 litre plastic tank) linked to the cooler at the top through a perforated pipe (holes 3 mm diameter, 10 cm apart) maintained the charcoal walls uniformly wet by water being properly distributed along the upper edge of the walls through a drip system. The water flow rate from the reservoir was measured by a flow meter and its flow rate adjusted by a manual valve. Water seeps through the charcoal walls and evaporates at the wall outer surfaces, keeping the storage space temperature below ambient temperature consistently during the cooler operation. Any excess water dripping from the bottom was collected into a water reservoir and re-used. To prevent heat absorption from the ground, the base of the cooler was made of galvanised iron sheet with a layer of water-soaked charcoal underneath. Four caster wheels of 15 cm diameter were fixed at each corner of the framework to make the unit portable.

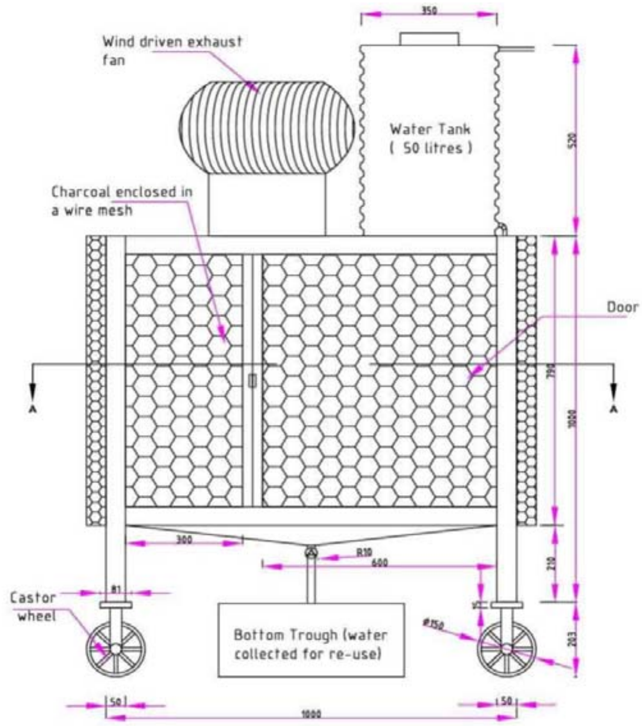

Fig. 1. Front view of the drip type charcoal evaporative cooler (all figures in mm)

The roof was made of galvanised iron sheet (painted white) over which was placed grass thatch to prevent overheating of the cooler interior by direct solar radiation. An opening of 0.30 m diameter was left at the centre of the roof to accommodate a wind-driven turbine) which enhanced air movement through the charcoal walls by sucking out air from the cooler. The ventilator consisted of a number of vertical curved vanes in a spherical dome (0.25 m in height) mounted on a frame. A shaft and bearings connected the top moving section to a base duct. The ventilator works on the principle that when wind blows on the aerofoil vanes the resulting lift and drag forces cause it to rotate.

This rotation produces a negative pressure inside which extracts warm air that has risen to the top of the cooler to the outside, therefore, drawing new cool air through the wet charcoal walls. In the absence of wind, the ventilator works on the principle of stack effects. The ventilators are inexpensive to run and can be used in remote locations without electricity supply.

Zero Energy Cool Chamber

It is a semi-underground chamber. Out of the total height of 67.5 cm, 30.0 cm is above the ground and the rest is underground. The sidewalls and the floor is cemented. The sidewalls are made of double layer of bricks leaving 7.5 cm space between the walls. The cavity between the walls is filled with riverbed sand. About 400 bricks are required to make a chamber of 165 cm x 115 cm x 67.5 cm dimension. The top of the storage area of the chamber is covered with gunny cloth over a bamboo frame. The bricks of the walls and floor, the sand used in the cavity and the top cover made of gunny cloth are saturated with water. The sand in the cavity is made saturated by fixing a drip system with plastic pipes connected to an overhead water source.

Shelf life of banana, khasi mandarin, tomato, pointed gourd, betelvine and *lai* (*Brssica rugosa*) were evaluated. The shelf life of these fruits/vegetables could be extended by 25, 21, 13, 31 and 9 days respectively, which was more or close to double compared under room condition. Temperature difference between the structures and the ambient has been observed to be about 8 degree C during summer months and about 3 degree C during winter months. It can accommodate about one quintal of fruits / vegetable at a time.

1. Current status of the technology

i.	Whether commercialized	: Demonstrated at farmers field
ii.	No. of licensees	: No
iii.	No. of units sold so far (till date)	: No
iv.	Profit from sale of single prototype/ process	: NA
v.	IP status (whether patented / patient application filed)	: No

2. Improvement over conventional practice

Advantage	Unit		
Output advantage/ Higher recovery	Kg/ hr. or q/ day	NA	
Reduction in PH losses	10 Kg/ q	0	
Labour cost reduction	Rs./ q	NA	
Energy saving	Rs./ q	NA	
Time saving (in terms of capacity)	Hr. /day or days/ yr	NA	
Improvement in storage life (extended period)	Days	Tomato	: 13
		Betelvine	: 11
		Pointed gourd	: 4
		Khasi mandarin	: 15
		Lai (*Brssica rugosa*)	: 9
Decrease in maintenance cost	Rs./ machine	NA	
Benefits in case of custom hiring	Rs./q	NA	
Value addition	NA		
Any other			

3. Cost involved : Rs.2940.00

4. Employment generation (mandays/ annum, no. of persons): NA

5. Anticipated Market demand for the equipment or product developed
Suitable for farmers.

6. Cost economics and benefits over conventional technology (Rs. /unit)

Sr. No.	Assumptions and cost/ benefits	Technology (equipment/ process developed)			Conventional technology (Bamboo *khasa*)			Remarks (if any)
A.	**Assumptions**							
i.	Capacity	1 q/batch			1 q/batch			
ii.	Cost	2940.00			150.00 x 10 = 1500.00			Buy 10 times at present cost to match life
iii.	Life or degeneracy period (in years)	5			0.5			
iv.	Annual use (Hours of hiring to be shown separately)	12 months			12 months			
v.	Salvage value	35 %			0			
vi.	Interest rate	12%			12%			
vii.	Labour charges (Rs./h or day)	x			x			
viii.	Cost of fuel (Rs./l)	x			x			
ix.	Cost of electricity (Rs./unit)	x			x			
B.	**Fixed cost**							
i.	Depreciation on all machinery	@15%: Rs.36.75			@20%: 25.00			Per month
ii.	Interest on fixed capital	@12%: Rs.29.40			@12%: 15.00			-do-
	Sub total (B)	56.00			40.00			
C.	**Variable cost**							
i.	Cost of raw material	x			x			
ii.	Repair and maintenance (Rs/year)	100.00			60.00			
iii.	Fuel and electricity charges (Rs.)	x			x			
iv.	Other expenses (Rs.)	x			x			
	Sub total C	100.00			60.00			
D.	**Total cost (B+C)**	156.00			100.00			
E.	**Returns**							
a.	Final product (main) recovery	Qty (Rs./unit)	Rate (Rs.)	Total	Qty	Rate (Rs./unit)	Total (Rs.)	
		90 kg	1800	1800	75 kg	1500	1500	
b.	By product	x	x	x	x	x	x	• Compared for Tomato.
c.	Custom hiring	x	x	x	x	x	x	
	Total returns (a+b+c)	1800.00	1500.00					• @Rs.20/kg
F.	**Profit (E-D)**	1644.00			1400.00			
G.	**Saving over conventional practice (Rs./unit)**	244.00						Av. per batch per month

Recommended minimum temperature to increase storage time

There is no ideal storage temperature for all fruits and vegetables, because their response to reduced temperatures varies widely. The importance of factors such as mould growth and chilling injuries must be taken into account, as well as the required length of storage (Wills et al., 1989). Storage temperature for fruits and vegetables can range from -1 to 13°C, depending on their perishability. Extremely perishable fruits such as apricots, berries, cherries, figs, watermelons can be stored at -1 to 4°C for 1-5 weeks; less perishable fruits such as mandarin, nectarine, ripe or green pineapple can be stored at 5-9°C for 2-5 weeks; bananas at 10°C for 1-2 weeks and green bananas at 13°C for 1-2 weeks. Highly perishable vegetables can be stored up to 4 weeks such as asparagus, beans, broccoli and Brussels sprouts at -1-4°C for 1-4 weeks; cauliflower at 5-9°C for 2-4 weeks. Green tomato is less perishable and can be stored at 10°C for 3-6 weeks and non-perishable vegetables such as carrots, onions, potatoes and parsnips can be stored at 5-9°C for 12-28 weeks. Similarly, sweet potatoes can be stored at 10°C for 16-24 weeks. The storage life of produce is highly variable and related to the respiration rate; there is an inverse relation between respiration rate and storage life in that produce with low respiration generally keeps longer. For example, the respiration rate of a very perishable fruit like ripe banana is 200 mL $CO2.kg^{-1}h^{-1}$ at 15°C, compared to a non-perishable fruit such as apple, which has a respiration rate of 25 mL $CO2.kg^{-1} h^{-1}$ at 15°C.

Exposure of fruits and vegetables to high temperatures during post-harvest reduces their storage or shelf life. This is because as living material, their metabolic rate is normally higher with higher temperatures. High temperature treatments are beneficial in curing root crops, drying bulb crops and controlling diseases and pests in some fruits. Many fruits are exposed to high temperatures in combination with ethylene (or another suitable gas) to initiate or improve ripening or skin colour.

Conclusion

When fruits and vegetables are exposed to high temperatures during post-harvest it reduces the storage or shelf life and as such, the shelf life of most fresh vegetables can be extended by prompt storage in an environment that maintains product quality. Although, refrigeration is very popular but it has been observed that several fruits and vegetables, for example banana, plantain, tomato etc. cannot be stored in the domestic refrigerator for a long period as they are susceptible to chilling injury. Apart from this, the epileptic power supply and low income of farmers in the rural communities' makes refrigeration expensive. Hence the need for an evaporative cooling structure for storage of fruits and vegetables.

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Role of Plasticulture Technologies in Agriculture Production and Post-Harvest Management

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India supports nearly 16% of world's population with 2.4% land resource and 4% water resource and lately the dwindling quality and the vagaries of the availability of these resources are raising serious questions on the sustainability of the agricultural practice. To counter the problem, efforts need to be redirected to improve the productivity of the land, efficiency of the supply chain while reducing the carbon footprint by efficient usage of fertilizers, as a result of agricultural practice. Plasticulture, which is use of plastic in agricultural practice, is an answer to this rallying cry. Plasticulture is a scientific way of carrying out agriculture, which not only improves the productivity, but optimizes the input resources as well, thereby reducing the cost. There has been significant progress in the adoption of Plasticulture techniques in the last decade, however the low penetration levels suggest it needs to grow at a rapid pace from now. On the demand side awareness of the available options and subsidies, its relevance and applicability could improve the adoption rate. From the supply side industry needs to take efforts to bring down the capital cost, work on creating an environment where Plasticulture culture is a norm than exception. Concentrated efforts in direction of demonstration, spreading word of mouth, and building credibility by performance & after-sales services could help shape the industry. Government policy intervention in creating the environment for investments in R&D, supporting farmers with initial subsidies as per the local conditions and improving the timelines for sanctions of subsidies would be important to shape the structure of the industry. There are enough cases of successful implementation of these measures elsewhere and subsequent value creation to all the stakeholders across the value chain. It is becoming increasingly clear that this technique remains, no more a choice but the only option, if we have to remain self-sustainable in our food security. We are at the cusp of changing paradigm in agriculture and it is an opportunity we have to tame efficiently and swiftly. A second phase of Green Revolution is in making. Use of plastic material in agricultural practices is referred to as Plasticulture. Plasticulture includes all kinds of plant or soil coverings ranging from mulch films, row coverings, poly-tunnels to greenhouses. The benefits of Plasticulture are reduced water loss, UV stabilization to cool soil and prevent insects & prevention of weed growth. Polyethylene plastic film is used majorly for Plasticulture, by growers, because of its flexibility, easy manufacturing and affordability.

Status

Compared to world average of polymer utilization in agriculture which stands at 8%, India has ploymer utilization of just 2%. Per capita consumption of plastic in India is 9.7 kg/person which is far below world average of 45 kg/person. The net sowed area in India stands at 141.3 million Ha and the net irrigated area is 63.2 million Ha (45%). There is also heavy pre and postharvest losses which further contribute to low availability of food grains and fruits and vegetables. All these factors make use of plastics in agriculture an interesting proposition, as there are substantial benefits of employing the Plasticulture techniques to improve the productivity while saving the water consumption and minimizing the post-harvest wastages. The greater use of plastic in agriculture can also help to a great extent to achieve up to fifty percent of the intended targets in Agriculture. The wider use of Plasticulture can reduce the loss of harvest and can increase the efficiency thus contributing more to the GDP. It is estimated that the agriculture output can be increased by ~INR 68,000 Cr by using proper Plasticulture applications like drip irrigation, mulching etc. Also, using innovative plastic packaging and handling techniques can promote proper harvest management which will in turn contribute towards the Agriculture-GDP.

Major plasticulture technologies applications areas are as follows:

Water management

1. Lining of canals, ponds & reservoirs with plastics film
2. Drip & Sprinkler Irrigation

3. PVC & HDPE pipes used for water conveyance
4. Sub-surface Drainage

Nursery Management:

1. Nursery bags, Pro-trays, Plastic plugs, Coco-pits, Hanging baskets, Trays etc
2. Surface cover cultivation :
3. Soil Solarisation
4. Plastics Mulching

Controlled environment agriculture:

1. Greenhouses
2. Shade net houses
3. Low tunnels
4. Plant Protection nets

Post-harvest Management:

1. Plastics crates, bins, boxes, leno bags, unit packaging products etc
2. Controlled Atmospheric Packaging(CAP) & Modified Atmospheric Packaging (MAP)

To harness or untap the potential of plastics in agriculture ICAR has started All India Coordinated Research Project on Plasticulture Engineering and Technologies (PET) become operational in 1988 during VII Plan period (known as AICRP on Application of Plastic in Agriculture). AICRP on PET takes research and extension activity pertaining to water management, protected farming, post-harvest produce management etc. In XII Plan period, the project became operative at fourteen Centres. The major thrust areas of the project are on surface covered cultivation and development of package of practices for better utilization of covered area, rainwater harvesting or water storage pond lining, efficient utilization techniques for stored water including pressurized irrigation, gravity fed micro-irrigation, farm machinery components using plastics as material for reducing weight and improving efficiency and intensive fish culture devices and strategies. It has made significant contributions during the course of its execution in the field mentioned above. It includes development of polyhouse cultivation strategies and its participatory evaluation, plastic film lined ponds, shade net / insect net house designs, plastic body winnower-cum-grader for hilly regions, packaging strategies for fruits and fish, plastic mango ripening chamber, gadgets for intensive fish culture, etc AICRP on PET developed several plasticulture technologies which plays important role in agriculture production and post harvest Management

Role of plasticulture technologies in agriculture production:

1. Polyhouse, Shade net structures low tunnel and mulching technology :

Improved Polyhouse, shade net structure design and mulching techniques developed in this scheme have direct and indirect impact on overall agricultural production due to following advantages

- Intensive cropping on small land area – higher productivity per unit of natural resources used (land and water)
- Less input requirement - more input use efficiency labour and soil solarization.
- Environment friendly - Excessive uses of inputs (fertilizers and pesticides) are avoided.
- High quality produce - free of pesticide residues for human consumption.
- Easy to relocate and dismantled in case of low tunnel with low cost of operation
- Higher yield and better quality produce due to creation of optimum conditions such as climatic control, balanced plant nutrition and plant protection, which can never be achieved in the open field conditions.
- Some of the low cost technologies and design of Polyhouse reduce the cost of production and also increased production of crops

- Shade nets cuts down the light intensity and reduce the temperatures to some extent, making the climate congenial to grow many off-season crops where conventional farming is too difficult.
- In case of mulching Soil moisture control, temperature control in root zone, weed control, reduce damage to produce (Strawberry protected from contact to soil)
- Enhances photosynthesis by light reflected back to leaves, insect pest management (act as repellant or attractor for some insects

Major application of controlled environment structures

1. Offseason cultivation of vegetables crops, flowers and high value crops
2. Nursery and seedling raising
3. In the area of aquaculture

Some of the studies carried out by AICRP on PET centres in the field of protected cultivation (greenhouse/ polyhouse and shade net structure) evident that use of plasticulture technologies have increased production of agriculture crops

Role of Polyhouse, shade net, low tunnel technology in agriculture production

Yield of cumin seeds was increased about 67 % under protected cultivation (low tunnel) over control. Watermelon is yielded 40 times more over control. i.e 40.45tn/ha. Onion yield achieved 8.64 ton per ha which is higher than the potential yield of the onion. Sunburn of fruit is reduced from 43% to 2% under protected cultivation (colored shadenet). Increase in production of vegetables (capsicum, tomato, cucumber, brinjal, chilli, biiterguard etc..) by 2- 3 times with 20%-30% early yield in protected cultivation (Polyhouse, nethouse) for e.g. Highest tomato yield of 116.3 t/ha and Capsicum 6.20 t/ha in 35% shading.. The highest yield of brinjal was 3.07 kg/m 2 was obtained at a spacing of 45x60cm, while in open field it was 2 to 2.5 kg/m^2 . Yield of broccoli 3.17 kg/m^2 at spacing of 30X30cm, while it was 2 kg/m^2 in open conditions. 3. Mulching with black film (ordinary and biodegradable) improved yield of okra by 57 to 66% over control. Yield of strawberry increased from 4.6 t/ha to 14.24 t/ha in protected cultivation. Round the year cultivation in polyhouse/ shade net house has B.C ratio in range of 2- 3. Following table illustrates the summarized findings of the work and impact of technology.

Table: Yield performance of different crops under protected cultivation:

Crop	Average yield in open (t/ha)	Expected yield in poly-net-house (t/ha)	Remarks
Tomato	45-60	70-100	About 1.5 times higher yield compared to open field and about 20-30 % will be early yield
Capsicum	18-20	40-55	About 2 - 2.5 times higher yield compared to open field and about 40 % will be early yield
Chilli	25-30	30-50	About 1.2 - 1.5 times higher yield compared to open field
Bittergoured	20-25	30-40	About 1.5 times higher yield compared to open field
Cucumber	20-25	40-75	About 2.25 times higher yield compared to open field

Micro irrigation, plastic lined pond and plastic based farm tools and equipments

Micro irrigation and polythene lined pond are plasticulture technologies have wide application in the area of water management. Water is important input for agriculture so its precise and judious management increased the yield of crops. Some of the major advantages of this technologies are: Maximum water use efficiency, Fertilizer/ nutrient loss is minimized, Low operational cost and soil erosion is not taken place, improved seed germination, not necessary to level the fields, harvesting water for multiple use, prevent loss of water etc. Almora centre (2011) designed Low density polyethylene lined small ponds were found quite effective in providing supplemental irrigation to horticultural/vegetable production in hilly areas. Water resources of 2417 m^3 capacity were developed at the farmers' field. Micro-irrigation in conjunction with LDPE lined pond constructed on higher elevated terrace and the system is operated by gravity was evaluated by Almora centre (2012). The garden pea and frenchbean were grown using the micro-irrigation system. Garden pea had yield 6.3% higher in micro-irrigation as compared to check basin. Role of plasticulture technologies contributed in improving animal husbandry production: Controlled environment provided by plasticulture technology help to enhance animal production which is evindent from this findings. ICAR-VPKAS Almora centre (2012) evaluated growth of the exotic carp; silver carp, in the polytanks that polyhouse covered tank. Growth of carp was better 129.0% from the cemented pond and 90.8% from the earthen open pond. Bhubaneshwar centre (2009) developed FRP carp hatchery found found suitable for production of spawn up to 0.55 million in one operation. Some useful gadgets like demand fish feeder and colored net are also in filed to enhance fish production in aquaculture sector

Role of plasticulture technologies in Post harvest management

Plasticulture technologies have major role in area of post harvest management.

Plastics properties described earlier made them best contender in post harvest management from filed to the consumer basket. Major areas of plasticulture technologies application in post harvest management are drying, short term storage and long term storage , material handling and transportation of agricultural produce.

Drying of agriculture produce

Drying unit operation is simple method of preservation of agricultural produce. The plasticulture technology such as polyhouse multitier drier makes good use of modified microclimatic condition for drying of fruits and vegetable crops. High drying rates reduce time of dying and good quality that open sun drying are some advantages of this plasticulture technology.

SKUAST-K Srinagar centre developed multitier solar tunnel drier for drying of vegetables results revealed that The percentage weight loss in palak, fenugreek and okra were around 88%, 86% & 54%.During the drying of the samples inside the greenhouse dryer, the max/min temperature varied between 39.9 to -7.1 ^{0}C The final moisture content of palak & fenugreek was around 3.5% while it was 5% for okra.

Storage and Packaging, transportation of agriculture produce

Plasticulture technology play important role in storage and transportation of agriculture produce. It helps in preservation of produce from short term storage to long term storage. Packaging provides produce itself microclimate which maintain its quality as well as extend the shelf life of produce. It offers several advantages such as ease in handling, flexibility in transport and storage with lower cost of operation. Reducing losses and maintain quality in storage of agriculture produce. Some of the popular plasticulture technologies are Plastics crates, bins, boxes, leno bags, unit packaging products, colored shade nets, Modified Atmospheric Packaging (MAP). Plastic packaging plays an important role in the fruit and vegetable distribution chain. According to Watkins and Nock (2012), it offers main function of packaging with ease: Containment. Containment is the basic requirement for movement of a product from one point to another. The package type and size will be a function of the product and market requirements. protection and preservation. Packages provide protection for the product against environmental factors such as dust and water, as well as impact and compression bruising and friction injuries that can occur during handling and transport. Convenience. Products are packaged in sizes convenient for handlers and for the consumer. Consumer packages are often contained within larger containers for transport because of economies of scale communication. In addition to advertising the type and source of the product, the package lists gross and net package weight, unit size of the product and any additional information required by government regulations.

Some silent research findings of AICRP on PET centres in reduction of losses in perishables : Shadenet Based farm storage structure (Junagadh centre, 2011) Shelf life of tomato increased up to 4 days and for spinach it was increased by 2 days in the net house (75%) with less weight loss and decay. Plastics in handling, packaging and transportation of custard apples (Udaipur, 2011) The study was undertaken in participatory mode with farmers with help of an NGO. Fruits packed in foam sheet have minimum loss in mass (0.67%) and loss in hardness (3.02 %) while colour was same in all the treatments studied. The data were 0.82% and 3.47%, respectively for packed in bubble plastic sheets. The maximum loss in mass (2.95%) and loss in hardness (7.88%) was obtained for the control sample. Junagadh centre (2011) studied transportation study of fruits found that the quality parameters significantly highest in (fiber plastic board carton) FPBC and losses observed minimum in FPBC. Transportation losses of sapota fruit was minimized about 12% and 3% in FPBC as compared to gunny bag and plastic crate, respectively. Bhubaneswar centre (2009) evaluated PE, PP and laminated PP packaging materials for enhancing the keeping qualities. Laminated PP packaging materials were found to be most suitable for both vacuum packaging and MAP of fish processed product. Keeping quality of the product was found unaltered even after 3 months in frozen storage. Study of shrink packaging by ICAR-CIPHET Abohar centre illustrate performance of shrink packaging plasticulture technology in improving shelf life of fruits.

Commodity	**Storage life**			
	Ambient		**Cold store**	
	Shrink wrapped	**Unwrapped**	**Shrink wrapped**	**Unwrapped**
Kinnow	27	13	70	41
Tomato	19	10	39	23
Capsicum	25	4	46	21

Conclusion

Plasticulture has been proved effective for enhancing Agricultural production all over the world. In India, it is gaining importance in area of for improving agriculture production and post harvest management in preventing transportation and storage loss. Still, the real benefits of the plasticulture are not being realized at farmer's level due to lack of information, standardized designs and package of practices, local level services, and availability of affordable technologies. AICRP on PET is striving to develop strategies for use, development and evaluation of efficient and economic plasticulture techniques for overall development of agriculture

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Value Addition of Horticultural Produce: A Tool to Double Farmer's Income

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Horticultural crops form a significant part of total agricultural produce in the country comprising of fruits, vegetables, root and tuber crops, flowers, ornamental plants, medicinal and aromatic plants, spices, condiments, plantation crops and mushrooms and have become key drivers for economic development in many of the states in the country. Most of these crops are of major importance, while a few are of minor importance. Though, India has witnessed a rapid growth in horticultural crop production in recent past but the increased production alone could not keep the horticultural produce in fresh condition for longer time. Thus value addition is necessary in order to preserve them for longer period. It is one of vital components of nutritional security because processing of fruits will not only reduce postharvest losses but also ensures sufficient food, both in quantity and in quality to every inhabitant in our planet. It provides convenience and safe food to consumers and promotes diversification and commercialization of horticultural processing sector by providing effective linkage between consumers and farmers. Thus, horticultural crops are right material in the present agricultural scenario for value addition because they are more profitable, has high degree of process ability and richness in health promoting compounds and higher potential for export. The various aspects of value addition to sustain and enhance the fruits and vegetables processing are discussed hereunder.

Production and export scenario of horticultural crops

India has made a good progress on the horticultural map of the world with a total annual production of horticultural crops touching over 286 million MT from an area of 24.5 million hectare. Horticultural crops cover about 11.25 per cent of the total area contributing about 28.0 per cent of the gross agricultural output in the country (Anonymous, 2014). Fruits and vegetables are the important category of horticultural crops grown in India. Our country is the second largest producer of fruits (90.2 million MT) and vegetables (169.1 million MT), contributing about 13 % and 15 % of the total world production of fruits and vegetables, respectively (NHB, 2016). Apart from fruits and vegetables, India also produces about 20 million tonnes of root and tuber crops. The country produces 41% of world mangoes, 27.8% banana, 35.3% papaya, 24% cashew nut (MOFPI, 2012) and presently (2016) India is the largest producer of banana (25.7%), papaya (43.6%) and mango including mangosteen (40.4%).

Among vegetables, India occupies the prime position in ginger and okra and ranks second in the production of potato, onion, cauliflower and third in cabbage in the world (NHB, 2016). The country produces 36% green peas, 30% cauliflower and 10% onion (MOFPI, 2009). Besides, it is also a well known fact that since centuries it has been the largest producer, consumer and exporter of spices. However, the productivity of fruits and vegetables grown in the country is low as compared to the developed countries. The overall productivity of the fruits is 11.8 tonnes per hectare and vegetables is 14.9 tonnes per hectare. The main fruits that enter the export market are mangoes, grapes, apples, citrus, bananas, sapota, litchi etc. Mango alone accounts for 40 per cent of the national fruit production and India is one of the leading exporters of fresh table grapes to the global market. However, export of vegetables is limited to Middle East, Europe, U.K and Singapore etc.

Value addition in horticulture sector

Value addition to the horticultural produce has assumed vital importance in our country due to diversity in socio-economic conditions, industrial growth, urbanization and globalization. Moreover, fruits and vegetables are highly perishable in nature and a large quantities of fruits and vegetables (6.0-18.0 %.) just perish due to inadequate storage, processing and marketing infrastructure (Nanda et al., 2012) This badly affects the availability of fruits and vegetables to the consumers and processing is the best way of utilizing surplus production for value addition during seasonal gluts. So far only 6 % of total fruit and vegetable produced in India are processed into different value added products indicating that there is a vast market yet to be tapped by the fruit and vegetable processing industry in the country. Post-harvest value addition includes primary, secondary, and tertiary processing which needs to be performed with following benefits.

Advantages of value addition

- Convert perishable fruits into durable product.
- Fruits, which are very difficult to eat out of hand can be processed in to a range of highly acceptable fruit product.
- Reduce post-harvest losses.
- Make off season availability of fruits.
- Provide safe and nutritional foods to the consumers.
- To emphasize primary and secondary processing.
- To reduce import and to meet export demands.
- To earn more foreign exchange.
- To encourage growth of subsidiary industries.
- To reduce the economic risk of marketing.
- To increase opportunities for smaller farms and companies through the development of markets.
- To diversify the economic base of rural communities.
- To improve the financial stability and profitability of farmers.
- To empower the farmers and other weaker sections of society especially women through gainful employment opportunities and revitalize rural communities.

Status of valued added products

Indian food processing activity is mainly confined to primary processing, which accounts for 80 per cent of the value addition whereas only 6 % of the total fruit and vegetables produced in India is being processed in different forms as a mean secondary processing. There has been a positive growth in ready to serve beverages, fruit juices and pulps, dehydrated and frozen fruits and vegetable products, preserved onions, cucumbers and gherkins, green pepper in brine, dehydrated garlic and ginger powder tomato products, pickles, convenience veg-spice pastes, processed mushrooms and curried vegetables over the last few years. This contribute the proportion of different products accounts for fruit juices and pulp (27%), ready to serve (RTS) beverages (13%), pickles (12%), jams and jellies (10%), synthetic syrup (8%), squashes (4%), tomato products (4%), canned products (4%) and other products (18%). There is considerable demand for some of these products in foreign markets e.g. mangoes both fresh and canned, fruit juices, salted cashew earn good foreign exchanges. Presently, mango, pineapple, citrus, grapes, tomatoes, peas, potato and cucumber are being processed on a large scale. Though product profile developed in India at present is limited to only few fruits and vegetables (Table 1) but there is a large potential for processing of papaya, sapota, banana, jackfruit, guava, aonla, carambola and other minor fruits through product diversification and quality enhancement. Similarly there is a greater scope for processing cauliflower, carrot, bitter-gourd, onion, garlic, watermelon, muskmelon etc.

Table 1. Profile of fruit and vegetable products developed in India

Horticultural produce	Product
Tomato	Pulp, Puree, Sauce/Ketchup
Apple	Juice/Concentrate
Citrus fruits	Squash/cordial
Fleshy fruits	Pulp, Juice, Nectar
Guava	Jelly
Onion	Powder/Paste
Potato	Chips
Garlic	Powder/Paste
Ginger/Turmeric	Powder
Mango	Powder (amchur)
Mango/Jackfruit/Guava	Fruit leather
Apple	Chips
Papaya/Pumpkin	Candy
Mango, citrus fruits, vegetables like carrots, Jackfruit, Cauliflower etc.	Pickles
Cabbage	Sauerkraut (by lactic acid fermentation)

Source: Maini and Anand (2006)

Choice for value addition

Fruits and vegetable can be processed in a number of products like fruit pulps and juices, concentrates, alcoholic and non-alcoholic beverages, canned fruits and vegetables, jams, squashes, pickles, chutneys and dehydrated vegetables. The new arrivals in this segment are minimally processed fruit, vegetable curries in retortable pouches, canned mushroom and mushroom products, fruit bar, dried fruits and vegetables and fruit juice concentrates. Some of these products may find market in the international trade but concentrated efforts are still required for the development of novel products for global market. This can be achieved by paying special attention to following parameter for deriving maximum benefit through value addition.

- **Uniqueness:** The developed product should be one of its own kinds. Indigenous fruit crop variability to our country can be gainfully exploited for this purpose.
- **Novelty:** The product should be new and unusual like blue or black rose so that no one can compete.
- **Export potential:** The product developed should have demand in international market for higher return and appreciation of benefit of global trade.
- **High value:** The product should have high value for low volume for ease of trading and distribution. The spices and herbal plants extracts from India can fulfil this requirement.
- **Availability:** Consistent availability of the product in required quantity should be ensured for stable market and faith.
- **Market:** Any product that is developed must have ready market available because market is the key for success of any product. The processed product can be classified into three different categories based on their market demand.

i) Products that have a high demand

- Fried products
- Dried fruits and vegetables
- Juices, squashes and cordials
- Sauces
- Wines

ii) Products that have a lower demand

- Chutneys
- Jams, jellies and marmalades
- Pickles and salted vegetables
- Pastes and purees

iii) Products that may have a future demand

- Canned fruits
- Crystallized fruits
- Fruit leathers
- Fruit cheese
- Minimally processed fruit and vegetables

Ways to add value to fruits and vegetables

Value addition is a process of increasing the economic value and consumer appeal of a commodity. In the past, the consumer's preferences were limited to taste and flavour and the horticultural produce was processed primarily into jams, jellies, chutneys, etc. But after 1950, the priorities have changed to safe and nutritious foods. Canning and dehydration were considered to be the most sophisticated methods of processing, prior to the discovery of rapid freezing (Abdullah, 2010). In 21st century, considerable emphasis has been given on functional, nutraceutical food products due to their great demand among the consumers. By products of fruit and vegetable processing could also be gainfully utilized for extraction of high value compound and novel product development. Besides, considerable volumes of unmarketable and physically damaged fruits and vegetables that are without infection can be converted into value added products by processing.

There are several methods for preserving fruits and vegetables. Selection of method will depend on the type of fruit or vegetable and the level of processed product. Some of the fruit properties for manufacturing different value added products are listed in Table 2. It is to be noted that no processing technique can transform poor quality raw materials into good one rather it can only extend the product's shelf life. In order to ensure that your product meets required high standards, following factors should be considered:

Table 2. Raw material properties required for various fruit products.

Processed Products	Sensory properties				Chemical composition		
	Shape	Texture	Flavour	Taste	Acidity	Sugars	Pectin
Dried Fruits	+ +	+ +		+ +		+ +	
Fruit Juices			+ +	+ +	+ +		
Marmalade			+ +	+ +			+ +
Jams	+ +	+ +	+ +	+ +			
Jellies	+ +	+ +	+ +	+ +			+ +
Fruit Paste				+ +		+ +	

Source: Puri and Sanghera (1987)

- Always use high quality raw ingredients
- Establish good processing techniques and follow them
- Maintain an appropriate product environment after processing.
- Ensure optimal use of fruits as a function of their properties

Value addition of guava

Guava is very popular as a fresh fruit because of its excellent taste, high vitamin content and 100% edibility. This fruit is equally important for the processing industry. A large number of processed products are manufactured from guava. Processed guava pulp is an excellent raw material for preparation of various other guava products such as nectars, beverages, jams, toffee, cheese, ice cream topping etc. Guava pulp can be preserved successfully in bulk either by application of heat (aseptic packaging) or addition of chemical preservation (SO_2). Because of presence of

rich amount of pectin, a high quality natural jelly is obtained from guava. Guava leather, dehydrated guavas, and guava powder are the other important products that have a great market potential. Further value addition in guava as new product development can be approached through following ways:

- A product entirely new in character.
- A product apparently similar in character in many respects to some existing brands but with distinguishing features.
- A product similar to one already in the market but new form of manufacture
- A product novel in kind, made by novel process or through novel ingredient.
- A product resulting from substantial modifications of the characters with change in nature/proportion of ingredients or processing methods or conditions or packing system.

Factors influencing the value addition of fruit and vegetable

Almost all fruits and vegetables can be processed in one or other forms. However, processing requires frequent handling, high temperature and pressure treatment and the choice of processing depends on the characteristics of individual fruit or vegetable. For instance, a particular variety of fruit or vegetable may be excellent for table purpose but may not necessarily be good for processing. Similarly, many ordinary table varieties of tomatoes are not suitable for making paste or other processed products. A particular mango or pineapple may be very tasty as fresh fruit but it may fail to withstand the processing requirements due to variations in their varietal characters such as fruit maturity, size and other quality parameters. Such varietal differences further extended to their suitability for different processing method such as canning, freezing, pickling or drying. A variety of peas that is suitable for canning may be quite unsatisfactory for freezing and varieties of potatoes that are preferred for freezing may be less satisfactory for drying or potato chip manufacture. Therefore, following factors determines whether the processing of the produce is worthwhile or not.

a. Demand for a particular fruit or vegetable in the processed form.
b. Quality of the raw material, i.e. whether it can withstand processing.
c. Regular supplies of the raw material. Because even when a variety is most suitable for processing, it is not always appropriate unless large and regular supplies are made available.

Export of processed products

India is the major producer of mango pulps and fruit juices (Table 3). Processed fruits and vegetables account for about 20% and 17% of the world horticultural trade, respectively. India's major exports are in fruit pulp, pickles, chutneys, canned fruits and vegetables, concentrated pulps and juices, dehydrated vegetables and frozen fruits and vegetables. Among the processed fruits, 41% trade is of fruit juices and 12% of dried fruits (APEDA, 2011). Similarly, among processed vegetables, the major items are mushrooms, gherkins and frozen pre-cut vegetables. Five commodities namely fresh onions, mango pulp, processed gherkins, fresh grapes and fresh mangoes together account for about half of the total horticultural exports. India is also a major exporter of mango pulp in the world and the country's export has increased to 1,28,866.01 MT of mango pulp worth of Rs. 796.17 crores during the year 2015-16. Fruit juices, fruit pulp and pickles are mainly imported by the USSR, Yemen, UK, UAE, Saudi Arabia, Kuwait, Germany, USA, Holland and Switzerland. Nearly half of India's processed fruit exports are mango based fruit juice, canned and bottled fruits.

Table 3. Quantity of processed fruit and vegetable products in India

Products	Production (,000 tonnes)
Mango pulp	737.10
Fruit juice	293.83
Fruit nectars	125.70
Dried fruits	84.8
Preserves and candies	73.7
Fruit Powder (flour)	15.4
Mixed fruit pulps	3.3
Total	1334.3

Source: FAO (2011)

Future strategies and action plan for promotion of value addition

- New market oriented technologies for secondary agriculture and value addition
- Cutting edge technology for value addition through minimal processing
- Large scale drying technology to preserve vegetables
- Bio-energy and solid waste utilization
- Effective transfer of technologies to the target groups
- Development of standards for product quality of fresh horticultural products
- Small scale processing sector is needed to be replaced slowly with large scale units, more cost effective and energy efficient technologies should be provided to the processors.

Summary

Value addition of horticultural produce plays an important role in conversion and better utilization of surplus produce into nutritionally rich processed products with wider acceptance. Preservation techniques like freezing, canning and drying all serve to transform perishable fruits and vegetables into products that can be consumed year round and transported safely to consumers all over the world. Minimally processed vegetables reduce the time of cooking with various health benefits. Similarly ready-to-eat fruit provide varied taste and convenience of time with extended shelf life. There are tremendous opportunities for the establishment of a vibrant and potentially profitable horti-processing sector. This will however require stronger, more meaningful linkages between the farming community, the agro-processing sector, Government and financial institutions. It is therefore, appropriate time for us to come out of primary processing and bulk exporting of processed products and get into newer product development and marketing of ready to consume product through value addition. Production of fruit juices, dehydrated products, fruit bar, fruit leather, fruit wines and semi-processed food, are some of the areas that can be envisaged to explore international market.

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Extrusion Technology for Increasing Farmer's Income

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Extrusion processing is a promising techniue to develop the healthy food products which are cholesterol free, low in fat, and rich in phytofactors. Extrusion can be defined as the process that combines the mixing, forming, texturizing and cooking of raw material to develop a new food product with special characteristics. It is a high-temperature short-time (HTST) process that reduces microbial contamination and inactivates enzymes. It has an important role in the food industry as efficient manufacturing processes. Extrusion cooking technologies are used for cereal and protein processing in the food and, closely related, pet foods and feeds sectors. The processing units have evolved from simple conveying devices to become very sophisticated in the last decade. Extrusion processing has been found to lower the level of antinutrients and enhanced the digestibility of proteins and starch (Bargale and Kulkarni, 2010; Singh et al., 2007).

Extrusion technology involves forcing of raw material or food materials or feed formulation through a hole (or die) to produce the products of desired shapes and size. High throughput with continuous operation, lower processing cost, higher quality of heat sensitive nutrients because of high temperature for short time and low moisture process result in environment friendly process, are some of the key attributes of extrusion technology. The thermal energy generated by viscous dissipation during extrusion cooking with combination of shearing effect cooks the raw mixture quickly so that the properties of the materials are modified by physico-chemical changes of the biopolymers. It results in gelatinization of starch, denaturation of proteins, inactivation of many native enzymes and antinutritional factors, reduction of microbial counts, and improvement in digestibility and biological value of nutrients. There are several different types and styles of extruders available in the market. This may cause a difficulty for food or feed manufacturers to select a proper extruder for specific type production. In general, extruders are divided into two major categories:

- ✓ Single-screw extruder
- ✓ Twin-screw extruder

Single screw extruders

Single-screw cooking extruders have compressive screws with decreasing channel depth turning at high speeds to increase shear and mechanical energy input for heating. Heating of a product is induced by the resulting friction. The barrel is jacketed for steam to allow additional contact heating in the metering section. To increase capacity and efficiency, it is common to preheat ingredients in a pre-conditioner by adding steam before they enter the extruder. Categories of single-screw extruders include (Harper, 1981):

a) ***Cold forming (Pasta-type) extruder***: Deep flight, smooth barrel, low shear speed.

b) ***Little or no cooking extruders***: Used for pasta, pastry dough, cookies, egg-rolls, ravioli, processed meat and certain candy.

c) ***High-pressure forming extruder***: Grooved barrels to prevent a slip at the wall and greater compression in the screw design. Used for pre-gelatinize cereal and fried snack foods.

d) ***Low-Shear cooking extruders***: Moderates shear machines with high compression machines and grooved barrels to enhance mixing. Soft-moist foods and meat like snacks such as simulated jerky.

e) ***Collet extruders***: High shear machines with grooved-barrels and screw with multiple shallow flights. Used for puffed snacks and expanded curls or collets.

Twin screw extruders

Twin screw consists of two parallel screws in a barrel with a figure-eight cross section. The use of twin-screw extruders for food processing started in the 1970s, with an expanding number of applications in the 1980s. Twin screw extruders are generally one and one-half times or more expensive than single a screw machine for the same capacity (Lusas and Riaz 1994). Yet the degree of quality control and processing flexibility they offer can make them attractive to food industries. Twin screws produce a more uniform flow of the product through the barrel due to the positive pumping action of the screw flights. Some other advantages of twin screw are:

- ✓ Handle viscous, oily, sticky or very wet material and some other products which will slip in single screw extruder, (it is possible to add up to 25% fat in a twin screw extruder)
- ✓ Less wear in smaller part of the machine than in single screw extruder.
- ✓ Wide range of particle size (from fine powder to grains) may be used, whereas single screw is limited to a specific range of particle size.
- ✓ Because of the self wiping characteristics clean up is very easy.

Extrusion technology plays an important role in the modern food industry especially for the production of ready-to-eat snack food products from various agri-produce. Market of ready-to-eat snack food is dominated by extruded snack products such as breakfast cereals, extruded cereal shapes etc. A series of products has been developed by extrusion cooking, using variety of cereal and legume ingredients as raw materials to produce nutritionally enriched products in such a way that their nutritive quality was substantially improved. The quality of the final products may vary and depends on extrusion parameters such as raw materials composition, feed moisture, barrel temperature, screw speed, type of extruder and screw configuration (Miller & Mulvaney, 2000). There are two forms of extrusion – cold extrusion which operates below 70°C and hot extrusion which operates above 70°C.

Extruded products can serve as an attractive delivery system for addressing nutritional deficiencies as they are generally consumed by targeted groups like children, teenagers with a high measure of acceptance. Also, due to their low-moisture content, extruded products are shelf-stable and are amenable to easy handling and extended storage at room temperatures, which is very advantageous, especially in developing countries where storage under controlled condition and handling systems are not adequate. Additionally, extrusion processing can utilize economic raw materials such as co-products of cereals and/or pulses milling industry like brokens, middlings, flour, or bran to produce nutritionally balanced products with required nutrients. Extrusion processing has a potential to increase the bioavailability of some nutrients, such as iron, phosphorus and protein, through the inactivation of anti-nutritional factors. However, the high-temperature, low moisture and high-shear conditions of conventional extrusion can destroy substantial quantities of heat-sensitive nutrients. Therefore, to overcome this disadvantage of extrusion processing newer interventions such as supercritical fluid extrusion and use of microencapsulated powders to protect heat-labile nutrients/colorings/flavorings are being researched and applied. The use of extruded snack foods on a regular basis can therefore not only treat but also prevent nutritional deficiencies in targeted population. Such kind of intervention through extrusion processing is cheap, simple, effective and safe and can be adopted in future nutritional programs.

Food materials for extrusion processing

Structure-forming materials

The structure of an extruded product is created by forming a melt fluid from biopolymers and blowing bubbles of water vapour into the fluid to produce foam. After expansion, the rapid fall in temperature caused by evaporation, and the rise in viscosity due to moisture loss, rigidifies the cellular structure. Starch polymers are very good at this function and well-expanded cellular structures can be made from any of the separated starches available from materials such as wheat, maize, rice or potato. Proteins may be used to form structures in extrudates at high concentrations. For example soya proteins may be used to produce an expanded structure in TVP, if their concentration in the recipe is > 40% w/w, at moisture levels of 30– Raw materials for extrusion cooking 7 40% w/w (Guy, 2001).

Dispersed-phase filling materials

Starch acts as a continuous phase and several dispersed phase lies within the continuous starch phase. The dispersed phase is most commonly formed by any proteins present and by fibrous materials such as cellulose or bran. The protein may be used in different forms such as animal proteins and plant proteins. The presence of the dispersed-phase materials affects the nature of the extrusion process in two ways. Their physical presence in the cell walls will reduce the potential for expansion of the starch film by disrupting the cell walls when their structures penetrate the walls of the film. The second effect caused by the presence of dispersed filler relates to the elastic recoil or die swell effect of the fluid as it leaves the die exit.

Plasticisers and lubricants

The addition of ingredients such as water serves to reduce interactions by plasticising the dry polymer forms, transforming them from solids to deformable plastic fluids. The levels of applied shear may be reduced by the presence of lubricants such as oils and fats. These materials lubricate both the interacting particles in the dough and the particles that are rubbing against the surfaces of screws and barrel.

Soluble solids

Sugars or salts, may be added to a recipe for flavouring or humectant properties, addition of these substances dilute the starch phase and in turn reduces the viscosity.

Nucleating substances

Substances that increase bubble nucleation have been found to increase the numbers of bubbles appearing in the hot melt fluid of an extruder. Two well known materials used as nucleating agents are- powdered calcium carbonate 'creta preparata' and talc (magnesium silicate).

Colouring and Flavouring substances

Colouring compounds may be added during extrusion and generally, heat stable colours are added. Flavour compounds may also be added in secondary operations post extrusion.

I. Effect of extrusion cooking on physical characteristics of products

Water Absorption and Water Solubility Index

Water Absorption index (WAI) has been generally attributed to the dispersion of starch in excess water. The dispersion is increased by the degree of starch damage due to gelatinization and extrusion–induced fragmentation, that is, molecular weight reduction of amylose and amylopectin molecules (Yagci and Gogus, 2008). Studies indicated that increasing feed moisture significantly decreased the WAI of extrudate; increasing the level of soybean flour tends to decrease the WAI, might be because of oil in soybean which interfered with water uptake.

Water Solubility Index (WSI) is often used as an indicator of degradation of molecular components (Yang et al., 2008), which measures the degree of starch conversion during extrusion which is the amount of soluble polysaccharide released from the starch component after extrusion process (Ding 2005). Mercier and Feillet (1975) reported increase in soluble starch with increasing extrusion temperature and decreasing feed moisture. Gelatinization, the conversion of raw starch to a cooked and digestible material by the application of water and heat, is one of the important effects that extrusion cooking has on the starch component of foods (Qing-Bo et al., 2005). Among functional properties, water holding capacity is important because of the hydrogen bonds formed between water and polar residues of protein molecules.

Viscosity

The viscosity of a paste depends on to a large extent on the degree of gelatinization of the starch granules and the rate of molecular breakdown. Viscosity generally depends on solubility and water holding capacity as well as the structure of components in a food system. Viscosity profile can be thought of as a reflection of the granular changes in the starch granule that occur during gelatinization (Thomas and Atwell, 1997). Extrusion can induce starch dextrinization resulting in reduction of viscosity in gruels and a concomitant increase in caloric and nutrient density (Jansen et al., 1981). Studies reported that increase in the amount of soybean flour and increase in feed moisture decreased the apparent viscosity of extrudate. In addition to the effect of extrusion, the reduction in viscosity may be attributed to the high level of oil from the soybean flour which consequently decreased the shear effect as a result of lubrication in the metering zone. Increase in moisture on the other hand, will further lubricate the dough leading to less shearing effect.

Expansion

Sectional expansion index (SEI) is a measure of the cross-sectional area expansion of extrudates. Hashimoto and Grossmann (2003) reported a decrease in expansion with increasing extrusion temperature for extrusion of cassava bran and cassava starch blends. It was found out that after a critical temperature, which depends both on the type of starch and moisture content, expansion decreases with temperature, most likely due to excessive softening and potential structural degradation of the starch melt which becomes unable to withstand the high vapour pressure and therefore collapse (Kokini et. al., 1992). Colonna et. al. (1989) also reported that the decrease in expansion at higher temperature has been attributed to increased dextrinization and weakening of structure.

Textural properties

Crispness is typically a textural attribute for ready to eat snack foods. Ryu and Walker (1995) observed that breaking strength and bulk density decreased over the temperature range of 140 to 160 ^{o}C in extrusion cooking of wheat flour. Ding et.al (2005) reported that increasing temperature would decrease melt visocosity, but it also increases the vapour pressure of water. This favour the bubble growth which is the driving force for expansion that produces low density products and thus decreasing hardness of extrudate. It is reported that progressive increase in temperature resulted in pores in the structure due to formation of air cells and the surface appeared flaky and porous and hence decreased hardness (Bhattacharya and Choudhary, 1994). Fiber content in feed material also affects the textural characteristics of extrudate. Fibre reduces the cell size, probably by causing premature rupture of gas cells, which reduces the overall expansion and results in less porous structure (Yanniotis et.al, 2007).

II. Effect of extrusion cooking on nutritional quality of food products

Macronutrients

Proteins

Extrusion cooking denatures proteins thus improves digestibility of proteins. Most proteins such as enzymes and enzyme inhibitors lose activity due to denaturation caused by the processing conditions such as heat and shear within the extruder barrel. High temperatures and low moisture promote Maillard reactions during extrusion cooking. Sucrose and reducing sugars, including those formed during shear of starch can react with lysine, thereby lowering the quality of protein. Lysine is the most limiting essential amino acid in cereals. Depletion of this essential amino acid during extrusion cooking can result in growth retardation in young children, if product is intended for them.

Carbohydrates

Starchy foods like food grains and tubers provide calories and satiation to the consumers. Extrusion cooking is a unique process because gelatinization occurs at much lower moisture content (12-22%) than is necessary in other food operations. Processing parameters like temperature, pressure and shear tend to increase the rate of gelatinization. Starch molecules can be physically broken into smaller and more digestible fragments during extrusion processing. Extrusion cooking may not result in complete gelatinization, but digestibility is often improved (Wang et al., 1993a). Incorporation of dietary fibre to starchy foods during extrusion can also affect the digestibility. Longer cellulose fibres reduced solubility (Chinnaswamy and Hanna, 1991), possibly due to transglycosidation. Flatulence causing oligosaccharides viz. raffinose and stachyose also decreased significantly during extrusion cooking of extruded high-starch fractions of pinto beans (Borejszo and Khan 1992) that may improve the consumer acceptability of legume based extruded products.

Dietary Fiber

Fiber is a term used to describe many food components. Dietary fiber includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and/ or blood cholesterol attenuation, and/ or blood glucose attenuation. Like starches, branched dietary fiber molecules are susceptible to shear during extrusion. These smaller molecules may be soluble in water. These smaller molecules could unite to form large insoluble complexes or Maillard compounds that may be analyzed as lignin.

Beans (*Phaseolus vulgaris* L) subjected to conditions making them hard-to-cook, and then treated beans were extruded under various conditions in order to make them more functional (Martin Cabrejas et al., 1999). The total fibre values were unaffected by extrusion but insoluble fibre decreased when extruded at 25% moisture content. Soluble fibre increases in those samples and especially in a sample processed at 30% moisture and at 180^{o} C.

Table 2. Nutritional quality of dietary fibre rich extruded foods

Food Source	Nutrition assay	Health effect	Reference
Extruded wheat, barley with husks, or oats with husks	Rat feeding study for 6 weeks	decreased Cholesterol in rats fed extruded grains versus raw grains or casein control	Wang and Klopfenstein, 1993
Extruded potato peels	*In vitro* bile acid binding	lower serum cholesterol	Camire et al., 1993
Extruded rice, oat, corn and wheat brans	Hamster feeding study	Extrusion did not affect cholesterol –lowering properties	Kahlon et al., 1998

Lipids

Extruded products are usually processed from grains which are low in fat content but fat is often added during post extrusion by frying or spraying of fats or oil (lipids) to hold flavouring compounds. Generally food materials containing less than ten percent fat are extruded because greater quantities of fat if present in feed material making extrusion difficult, particularly for expanded products. Lipids actually grease the internal parts of the extruder and increase the slippage within the extruder barrel.

Table 3. Antioxidant for extruded food products

Anioxidant treatment	Advantages	Limitations
Tocopherols	Varying vitamin E activity; natural appeal to final products	Unstable to heat; common forms are difficult to measure in feed material
Phenolic acids	Natural	Result in darker colour due to complex formation during extrusion; may give bitter or astringent flavour
Ascorbic acid	Natural; enhances iron bioavailability	Unstable, thermal degradation, higher levels impart acidic flavour
Nitrogen flush in packaging	No direct additives	Oxidation may take place due to trapping of some air in expanded foods, costlier than ordinary packaging

Vitamins

Vitamins are essential for metabolism of macronutrients. Since extruded foods are intended for consumption by children and other groups with high nutritional needs, their vitamin content is of great importance. Due to reduction of vitamins in extrusion cooking, some processors are prompt to apply vitamins post–extrusion as a spray. Marchetti et al., 1999 reported that fat–coated ascorbic acid, menadione, pyridoxide and folic acid were retained well than crystalline forms in extruded fish feed. Although fortification of extruded foods

Table 4: Loss of water soluble vitamins during extrusion cooking (Source: Camire ME. 2001)

Vitamins	Losses (%)
Vitamins B_1	5-100
Vitamins B_2	0-40
Vitamins B_6	4-44
Vitamins B_{12}	1-40
Niacin	0-40
Vitamins C	0-87

with micronutrients is a popular concept but little research has been oriented towards the interaction of extrusion cooking conditions and stability of vitamins.

Minerals

Minerals are unlikely to lose in the steam distillate at the die during extrusion cooking but entrapment or binding may take place during this process. Abrasive foods like brans rich in dietary fiber may abrade the interior of the extruder barrel and screws, resulting in increased mineral content particularly iron. Extruded corn, which has low dietary fiber, showed no change in total, elemental, or soluble iron after extrusion using twin screw extruder (Camire and Dougherty, 1998). Extrusion did not reduce iron and zinc absorption from wheat bran and flour in adult human volunteers (Fairweather-Tait et al., 1989). Mineral bio-availability may be affected in foods rich in dietary fiber and phytate. Extrusion reduced phytate levels in wheat flour (Fairweather–Tait et al., 1989). Inactivation of phytases during extrusion in these studies may be the possible reason of these findings. Fortification of extruded products with minerals has become a common practice particularly in ready-to-eat products. As certain iron salts react with phenolics and result in unpleasant dark colours. Kapanidis and Lee (1996) recommended the addition of ferrous sulfate heptahydrate in a simulated rice product for maintaining light colour. Addition of calcium hydroxide (0.15-0.35%) to cornmeal extrudates lowered expansion and increased lightness in color (Martinez-Bustos et al., 1998).

Advanced extrusion processing technologies in development of health foods

Supercritical fluid extrusion

Fig. 1. SCFX barrel and rice die configuration in processing puffed rice

Supercritical fluid extrusion (SCFX) process enables the formation of an expanded structure at lower temperature (<100°C). This process allows manipulation of in barrel pressure and temperature during processing with added opportunities for generation of microcellular, composite structures of different morphologies and mechanical properties. Supercritical fluid extrusion (SCFX) process uses supercritical carbon dioxide (SC-CO_2) as a low temperature-blowing agent and hence allows the use of heat labile food components such as flavorants, colorants and bioactives in the raw material formulation. In the SCFX process, the expansion of the melt is achieved by first solubilizing SC-CO_2 in the melt and then inducing nucleation due to pressure drop in the die, which is followed by cell growth caused by diffusion of CO_2 into the nucleated cell (Rizvi et al. 1995). Supercritical carbon dioxide extrusion offers several benefits over the conventional extrusion cooking processes. As SCFX extrusion is conducted at low temperature (60– 80°C) and low shear conditions compared with conventional steam-based extrusion, nutritional loss of heat-sensitive ingredients is minimized. The lower pH of the melt due to dissolved SC-CO_2 inhibits Maillard reaction, which otherwise would cause further loss of essential amino acids. Moreover, SC-CO_2-expanded extrudates show predominantly homogeneous closed cell structures and nonporous surface, which not only facilitate flavor encapsulation but also provide better textural control over steam-based products (Alavi et al. 1999). These advantages of SCFX process in turn can also be exploited to create a new generation of functional or health food products.

Use of encapsulated powders in the extrusion process

Addition of flavouring compounds post-extrusion is the most common method of flavouring. This process requires oil addition onto the surface of the extrudates as a fixative agent for the flavours which in turn can increase the chances of oxidative rancidity and hence lower down the shelf-life of the product. Incorporating flavours into feed materials prior to extrusion is more preferable as the flavour distributes more evenly and has a better stability against oxidation. But high temperature of extrusion cooking results in thermal destruction of flavouring compounds due to presence of volatiles. To overcome the disadvantages of traditional extrusion cooking, the use of encapsulated powders in the extrusion process to enhance the retention of heat sensitive flavor components has been explored. The use of encapsulated D-limonene in the extrusion cooking process has been reported, and a high retention for D-limonene was found due to the formation of inclusion complexes with starch that resulted in products with lesser components degradation (Yuliani et al. 2006).

Fortification using extrusion technology

Both cold extrusion and hot extrusion processes can be utilized for preparation of simulated rice used in fortification. Hot extrusion involves relatively high temperatures (above 70 °C) obtained by pre-conditioning and D or heat transfer through steam-heated barrel jackets. This process results in fully or partially pre-cooked simulated rice kernels. Commercially, this method is currently applied by Wuxi NutriRice Co. (DSMD Buhler) and China National Cereals, Oils and Foodstuffs Corporate (COFCO) in China and by Superlative Snacks Inc. in the Philippines. On the other hand, cold extrusion, does not utilize any additional thermal energy input other than the heat generated during the process itself and is primarily a low temperature (below 70 °C), forming process resulting in grains that are uncooked, opaque and easier to differentiate from regular rice kernels in terms of shape. This process is commercially used by Vigui (Italy) and PATH for the production of UltraRice (Alavi et al.,2008). UltraRice™ is already marketed in Brazil, Colombia, and India.

The basic steps for the preparation of rice analogues include formation of dough comprising the principal ingredients and the additives; feeding this dough into an extruder; extruding the dough for a time and at a temperature and pressure effective to substantially gelatinise the starch fraction of the rice flour and denature the protein (for hot extrusion) or simply passing the dough through the extruder at lower temperature to give it a proper shape (for cold extrusion); treating the freshly extruded rice analogues with binder setting or cross-linking agents so that they can retain their desired properties for a prolonged time; and finally drying these analogues to a desired moisture content.

Healthy food products developed by extrusion processing at ICAR-CIPHET

ICAR-CIPHET has developed considerable number of health food products such as high-fibre extrudates from groundnut hull fibre, multigrain high protein extrudates, composite fruit and vegetable fortified expanded snack foods, non-wheat composite pasta, pearl millet-whey protein composite extrudate, nutritionally rich functional pasta, antioxidant rich pasta from pseudocereals, vegetable incorporated composite pasta. Mridula et al. (2014) developed high protein rich extruded snack food utilizing sorghum and pearl millet with maize, legume and sesame seeds. This study indicated that 16% feed moisture, 120^{o}C barrel temperature, and 300rpm/s screw speed may be considered for development of multigrain based health food using extrusion technique with sensory acceptability score 8.64 at 9 point hedonic scale. This sample provided 382kcal calories, 2.03g crude fibre, 2.49mg iron, 206mg calcium in 100g sample and 19.27% protein with 67.02% in vitro protein digestibility. Sharma et al. (2015) optimized the extrusion variables for development of multigrain based expanded snacks with 20% sorghum. Based upon multiple response optimization in this study, optimized conditions were feed moisture 14 %; die head temperature 110 ^{o}C and screw speed 342.4 rpm (342) with maximum desirability (0.93). Protein, calcium and iron in the optimized sample were 15.5 %, 116.6 mg/100 g and, 4.3 mg/100 g, respectively.

There are enormous possibilities for development of nutritionally balanced ready to eat snack food products using extrusion technique and also required research efforts in the area of effect of extrusion cooking on physio-chemicals and healthful components of food viz. flavonoids, inulin, lycopene and related carotenoids, omega-3 fatty acids, tannins, caffeine and other stimulants, etc. Though commercial production of extruded products are being done and a significant number of products in different flavours and taste are available in the market however the nutritionally quality of the available products is poor in proportion to the amount being paid by the consumers. Hence, ICAR-CIPHET is continuously making efforts in this direction and the technology available with this institute can easily be adopted by self help groups and entrepreneurs for income generation and profitability.

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Mechanization of Indian Traditional Foods for Enhancing Income

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The capacity to preserve food is directly related to the level of technological development. The slow progress in upgrading traditional food processing and preservation techniques contributes to food and nutrition in security in the country. Simple, low-cost, traditional food processing techniques are the bed rock of small-scale food processing enterprises that are crucial to rural development. By generating employment opportunities in the rural areas, small scale food industries reduce rural-urban migration and the associated social problems. They are vital to reducing post-harvest food losses and increasing food availability. Regrettably, rapid growth and development of small-scale food industries hampered by adoption of inefficient and inappropriate technologies, limited machinery availability to process traditional food, poor management, inadequate working capital, limited access to banks and other financial institutions, high interest rate sand low profit margins. While a lot still needs to be done, some successes have been achieved in upgrading traditional food processing technologies including the mechanization of Dosa, Bundi, Laddo, Badundi and chapatti making machine. Present chapter elaborate the requirement of mechanization of traditional foods and their role in increasing the income.

Traditional Indian foods have been prepared for many years and preparation varies across the country. Traditional wisdom about processing of food, its preservation techniques and their therapeutic effects has been established for many generations in India. Food systems can deliver numerous biological functions through dietary components in the human body. Indian traditional foods are also recognized as functional foods because of the presence of functional components such as body-healing chemicals, antioxidants, dietary fibers and probiotics. These functional molecules help in weight management and blood sugar level balance and support immunity of the body. The functional properties of foods are further enhanced by processing techniques such as sprouting, malting, and fermentation. At different stages of life, the constitution of the human body changes and it requires unique eating habits to sustain normal physiological functions. As indicated by these diverse stages, our ancestors had different foods that were healthy and nutritionally dense. The attempts to change the traditional food habits have not been successful to the extent envisaged. As the value of time is increasing day by day, especially with the working women being the sign of times, the demand for the ready-to-eat traditional foods is also increasing. Though the basic kitchen technology for the production of these foods is known, considerable research and development efforts are required to translate these technologies to the level of large-scale production. This requires a lot of input from the food engineers and technologists. The variation in these foods is so vast that it is very difficult to treat them under a uniform class. The traditional food prepared and consumed in one region may not be known in another region. Till recently, the preparation of traditional foods was considered more an art than science and the mechanization has been thought of very recently.

For the process of mechanization, the successful operation of any machine depends largely on the kinematics of the machines. The motion of parts is largely of rectilinear and curvilinear type. Rectilinear type includes unidirectional, reciprocating motion while curvilinear type includes rotary, oscillatory and simple harmonic motions. Design is a process of prescribing the sizes, shapes, material composition and arrangements of parts so that the resulting machine will perform the prescribed task. The role of science in the design process is to provide tools, to be used by the designers as they practice their art. It is the process of evaluating the various interacting alternatives that designers need for a large collection of mathematical and scientific tools. These tools when applied properly can provide more accurate and reliable information for use in judging a design, than one can achieve through the process of iteration. Thus mathematical and scientific tools can be of tremendous help in deciding alternatives. However, scientific tools aid imagination and creative abilities of the designers to make faster decisions. The largest collection of scientific methods at the designer's disposal falls into the category of analysis. These are the techniques, which allow the designer to critically examine an already existing or proposed design in order to judge its suitability for the task. Thus analysis in itself is not a creative science but one of evaluation and rating things that are already conceived. Most of the effort is spent on analysis but the real goal is the synthesis, that is, the design of a machine or system. However, analysis is a vital tool, inevitably be used as one of the steps in the design process. Accordingly, the mechanization of the traditional foods has been considered in the light of the different design aspects.

The mechanization of the most common types of traditional foods has already started to occupy an important position and some of the mechanized traditional foods are described below:

1. **Chapathi machine**: The Chapathi machine comprises of two major sub-units, namely the Chapathi sheeting unit and the Chapathi-baking unit. Both these units are integrated into the Chapathi machine in order to produce Chapathi continuously in largescale automatically. The forming of circular Chapathi discs of required thickness and diameter is done using the sheeting unit and the discs are transferred to the Chapathi-baking unit for baking. The development of the Chapathi machine design includes series 9 of improvements and is presented as improved devices. The invention is covered by Indian patents.
2. **Dosa Machine**: Some traditional Indian foods such as Dosa and Idli are becoming more popular. Dosa, an Indian traditional food is consumed by a large section of population as a breakfast food. For the largescale production, a continuous automatic Dosa machine was designed and fabricated. The machine can handle different types of batter such as conventional batter as well as instant batter mix (powder). The consistency of the batter, the time–temperature for baking of the Dosa have been standardized. Predetermined quantity of the batter is dispensed, spread to uniform thickness on the hot plate of the machine and baked Dosa are scraped, rolled and discharged automatically.
3. **Boondi Machine**: The Boondi machine has two sub-units, namely, Boondi forming unit and Boondi frying unit and both are integrated for continuous operation. The forming machine has a die, for varying the diameter of the globules and the unit has the provision for changing the die plates having different sizes of holes. In order to form Boondi globules, the batter is made to flow through perforated die under mechanical vibration. As the batter passes through the holes/perforations of the die, it breaks into 10 globules, fall directly into the hot oil of the continuous circular fryer.
4. **Continuous Basundi Making Machine (CBM):** CBM machine was designed based on the principle of Scrap Surface Heat Exchanger (SSHE). It consists of concentration unit of three SSHEs and chilling units of two SSHEs with specially designed scrapers, Variable Frequency Drive (VFD) to facilitate variation of speed of scrapers, Resistance Temperature Detector (RTD) sensors and other controls to optimize processing parameters, which results in better quality product in terms of sensory and rheological attributes. Standardization of mechanized production of 'Basundi' in terms of manufacturing techniques, sensory profiles, and compositional and physico-chemical attributes is done for attaining a product of uniform standard and assured quality. The method of hi tech production of 'Basundi', using 'Standard Process' and 'Continuous Basundi Making Machine' offers several advantages over traditional method of Basundi making.
5. **Batch type Halwasan making Machine (BHM):** Standardization of mechanized production of 'Halwasan' in terms of manufacturing techniques, sensory profiles and compositional and physicochemical attributes is done for attaining a product of uniform standard and assured quality. Halwasan prepared by using Batch type of Halwasan making Machine (BHM), is very good in hygienic quality as well as rheological attributes, having average sensory score of 92/100 as compared to sensory score 88/100 of Halwasan made by traditional/ conventional method. The cost of processing in BHM is almost half than conventional method. The keeping quality at room temperature of Halwasan made by using BHM is 20-22 days compared to keeping quality of 8-10 days of Halwasan made by conventional method. The profit margin is around 90-100%.
6. **Integrated Plant for Traditional Indian Dairy Products Integrated Plant**: Traditional Indian Dairy Products (TIDP) was designed for mechanized production of TIDP, having capacity of handling 250 kg of milk per hour. The plant is consisting of three basic units (i) Plate Heat Exchanger (PHE), (ii) Twin Cylinder Thin Film Scraped Surface Heat Exchanger (Twin SSHE) and (iii) Batch type Steam Jacketed Kettle. Patent filing for the plant and standard process of mechanized production of Basundi, Halwasan, Kulfi mix and Sandesh using this integrated plant is in process. This integrated plant is suitable for mechanized production of value added Traditional Indian

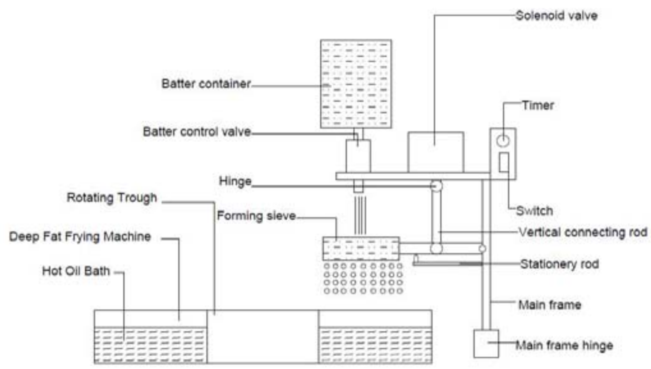
Dairy Products like Kulfi mix, Basundi, Kheer, Khoa, Peda, Thabdi, Burfi, Gajar Halwa, Dudhi Halwa, Halwasan etc. The mechanized production of TIDP has better control over the processing parameters to have hygienic production with better rheological quality of processed product. It also helps to overcome the limitation of traditional method of manufacture like inefficient use of energy, poor hygienic conditions, non-uniform product quality, intensive labour, small scale production etc. The processing cost of mechanized production of TIDP using this plant is almost half than the cost of processing of conventional method of production. The mechanized production of such TIDP, will help in commercialization and to promote small entrepreneurship through Public Private Partnership (PPP) to improve the socio-economical status of milk producing farmers. The technology develop with mechanization would benefit both the milk producer and consumers and will promote entrepreneurial development by fetching the higher price of value added products.

The design and development of equipment for the large scale hygienic production of traditional foods received considerable encouragement for environmental reasons as well. As a category, Indian traditional food industry is the largest, both in terms of tonnage and value. However, the production is done at different levels, mostly in unorganized sector, barring a few large industries. In order to improve the quality and shelf life of these products, the important need of the hour is automation of this traditional food industry irrespective of the scale. In addition to quality, for the conservation of material and energy, timely knowledge of physical, chemical, microbial and sensory attributes through offline or online are essential. The measurement of many of these attributes, which are not possible till recent past, is now possible due to rapid advancements in instrumentation and process control. Application of sophisticated technologies such as neural networks, fuzzy logic etc in process control is to be enhanced. Computer based control and monitoring of the process with the help of online sensors and analyzers is to be taken up as a challenge in the present food processing industry.

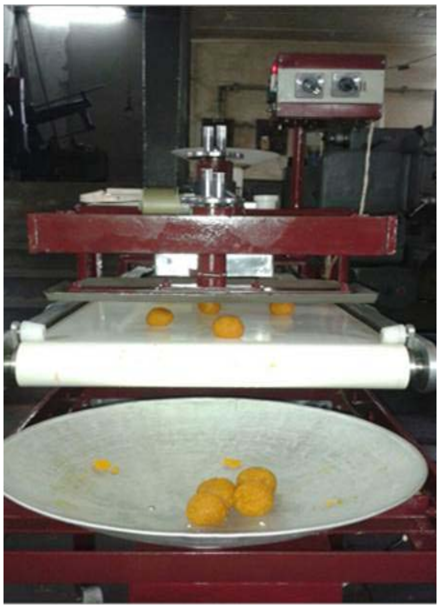
New Incorporations

Chapati making machine

Dosa making machine



Boondi machine



Automatic ladoo making machine

Basundi making machine

The machine has capacity to produce 200 ladoos per hour making the process totally hygienic.

The machine has output capacity of 20-40 litres of basundi per hour and having all parts made of SS-304. The machine is fitted with geared motor and stirrer with PTFE lined scraper.

Conclusions

Mechanization and automation is a technology that is capable of being the driver of the country's traditional food sector development. The use of this technology in food sector capable of producing a constant supply of high quality, consistency, reduce production costs, improve production rates and save the labour cost. The main thrust mechanization of traditional food is to provide solutions to issues that matters to the mechanization of small and medium industries (SMIs) food companies. High R&D projects that deem appropriate to the current demand of farmers and food industry SMIs, need to be addressed in the future in order to advance the country's agro-food sector. This effort need to be carried out to meet the increasing demand for food due to growing population of the future. The farming and food SMEs community should also gear up to face the ever growing demand of food supply and transformation of food industry by embracing relevant technologies that will bring them to the future.

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Processing and Value Addition of Groundnut for Increasing Farmers' Income

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Over last few years, decline in groundnut (*Arachis hypogea*) production in India has been recorded. Despite, India is one of the major producer with 5.11 mT annual production (2015-16).The major producing states are Gujarat, Andhra Pradesh, Tamilnadu and Karnataka which accounts about 75% of its total production. The groundnut contains about 25% good quality protein, 40% oil rich in essential fatty acids, 3% fibre and 2.5% minerals. It is also one of the richest source of Niacin (19.9 mg/100g) and Thiamine (0.90 mg/100g) apart from good source of bioactive phytochemicals (isoflavones and trans-resveratrol). Due to its nutritive value, it is called poor man's Almond. The quality characteristics and uses of groundnut vary among the developed and developing countries. In developed countries, it is used for the preparation of peanut butter and confectionary products also apart from oil extraction, whereas, in developing countries, it is mainly used for oil extraction and its by-product is utilized for animal feed. It has been estimated that about 80 percent of the total groundnut produced in India undergoes processing to utilize as oil or cake. Groundnut has potential to combat protein-energy malnutrition. It is therefore necessary to adequately research in to the possibility of groundnut processing into other useful and edible products. Preparation of milk like product and its utilization in the development of dairy analogues such as flavoured beverage, curd, yoghurt, *lassi*, probiotic yoghurt, paneer/tofu, non-dairy whitener, protein isolates/concentrates from de-oiled cake etc may be one potential area, which may provide sustainability to groundnut growers and contribute in reduction of malnutrition in the country.

Introduction

At present, for medical reasons, significant amount of consumers opt for plant based milk substitutes for various medical reasons or as a lifestyle choice. Medical reasons include lactose intolerance as well as milk protein allergies. Plant milk substitutes also serve as a more affordable option. Technologically, plant milk substitutes are suspensions of dissolved and disintegrated plant material in water, resembling cow's milk in appearance. They are manufactured by extracting the plant material in water, separating the liquid and formulating the final product. Homogenization and thermal treatments are necessary to improve the suspension and microbial stabilities of commercial products that can be consumed as such or be further processed into fermented dairy type products. Groundnut is one of the major raw materials used for preparation of plant based milk. The nutritional properties depend on the variety, processing and fortification. If formulated into palatable and nutritionally adequate products, it can offer a sustainable alternative to dairy products.

Plant milk substitutes are water extracts of legumes, oil seeds, cereals or pseudocereals that resemble cow's milk in appearance. There is a wide variety of traditional plant based beverages around the world, for example "tigernut milk" in Spain; Sikhye, a beverage made of cooked rice, malt extract and sugar in Korea; Boza, a fermented drink made of wheat, rye, millet and maize consumed in Bulgaria, Albania, Turkey and Romania; Bushera, a fermented sorghum or millet malt based beverage from Uganda, and traditional soy milk originating from China. The most widely consumed plant milk substitute is soy milk. The first commercially successful product was launched in Hong Kong in 1940 and the market grew rapidly during the seventies and early eighties in Asia after the development of technologies for large scale production of mild flavoured soy milk (Chen, 1989). The demand for soy milk in the Western world was initiated by consumers intolerant to cow's milk (Patisaul and Jefferson, 2010). Soy products are still dominating the market in the Western world, but the emerging of alternative products from other plant sources such as coconut, oat, peanut and almond have decreased its share. Overall, the dairy alternative market is still growing. According to an estimate, 15% of European consumers avoid dairy products for a variety of reasons, including medical reasons such as lactose intolerance (LI), cow's milk allergy (CMA), cholesterol issues and phenylketonuria, as well as lifestyle choices like a vegetarian/vegan diet or concerns about growth hormone or antibiotic residues in cow's milk (Jago, 2011). The main treatment for LI is the avoidance of lactose containing foods and replacing milk and dairy products with lactose free dairy or dairy free alternatives. Functional food market is dominated by dairy based probiotic products mainly yoghurt. There is need to develop dairy alternatives due to allergenic milk proteins, lactose and high cholesterol content (Bansal et al. 2016a, 2016b).

Total world production of groundnut in 2012-13 is about 37.2 mt. It is major oilseed crop in India accounting for 45% of oilseed area and 55% of oilseed production. India is rated as the second largest producer of groundnut in the world with annual production of over 5-6 MT. China, India, Nigeria, USA and Myanmar are the major groundnut growing countries. Groundnut contains on an average 40-45 per cent oil and 23-25 per cent protein and is a rich source of calcium, iron and vitamin B complex like thiamine, riboflavin, niacin and vitamin A. In developing countries, it is mainly used for oil extraction and its by product is utilized for animal feed purposes. Animal milk, in India at any rate, has a venerated place as a food for both children and adults. A milk-like beverage or a re-constitutable powder from which to generate it by adding water, represents an acceptable way of furnishing proteins and other nutrients to all age groups, often at reasonable cost. Plant milks may serve as a boon for the countries where the supply of milk is inadequate. Groundnut and soybean are two major raw materials used for preparation of milk like products.

Process

Plant milk substitutes are colloidal suspensions or emulsions consisting of dissolved and disintegrated plant material. They are prepared traditionally by grinding the raw material into a slurry and straining it to remove coarse particles. Although countless variations of the process exist, the general outline of a modern industrial scale process is essentially the same: the plant material is soaked and wet milled to extract the milk constituents, or alternatively the raw material is dry milled and the flour is extracted in water. The grinding waste is separated by filtering or decanting. Depending on the product, standardisation and/or addition of other ingredients such as sugar, oil, flavourings and stabilisers may take place, followed by homogenisation and pasteurisation/UHT treatment to improve suspension and microbial stabilities. These extracts can also be spray dried to produce powders (Diarra et al., 2005).

Pre-treatments

Raw material pre-treatments include dehulling, soaking and blanching (Debruyne, 2006). Blanching is required to inactivate trypsin inhibitors and lipoxygenase that would produce off-flavours in soy milk and peanut milk (Yadav et al. 2012; Giri and Mangaraj, 2012). Roasting of the raw material enhances the aroma and flavour of the final product, but heating decreases the protein solubility and extraction yield (Hinds et al., 1997a; Chauhan et al 2003).

Extraction

The extraction step has a profound effect on the composition of the resulting product. To increase the yield of the process, the efficiency of this step may be improved by increasing the pH with bicarbonate or NaOH, elevated temperatures or the use of enzymes. Alkaline pH during extraction increases the protein extractability. A higher extraction temperature increases the extractability of fat, but the denaturation of proteins decreases their solubility and yield. Papain and enzymes extracted from *Pestulotiopsis westerdijkii* increased the protein yield of peanut and soy milks (Rustom et al., 1993). In addition to proteolytic enzymes, a mixture of amyloglucosidase and a cellulase cocktail has been shown to increase the carbohydrate recovery of peanut milk (Rustom et al., 1993). Eriksen (1983) used a variety of enzymes in soy milk extraction and found out that the highest protein and total solids yield was attained using a neutral or alkaline proteinases at their optimum pH. In addition to increasing the extraction yield, proteolytic enzymes improve the suspension stability (Rustom et al., 1991). Also a cellulase treatment after homogenisation has been reported to decrease the particle size and yield a more stable suspension (Rosenthal et al., 2003).

Separation

After the extraction step coarse particles are removed from the slurry by filtration, decanting or centrifugation. When using raw materials high in fat, such as peanuts, the excess fat can be removed using a separator as in dairy processing.

Product formulation

Other ingredients can be added to the product base after the removal of coarse plant material. These include vitamins and minerals used for fortification as well as sweeteners, flavourings, salt, oils and stabilizers. As suspension stability is an issue in plant milk substitutes, hydrocolloids are often used to increase the viscosity of the continuous phase, and also emulsifiers have been proven to be beneficial in some beverages. Mono- and diglycerides, glyceryl monostearate, guar gum and carrageenan can be effectively used for stabilizing peanut and soymilk. The addition of nutrients in food substitutes may be necessary to ensure the nutritional quality of the product. The nutrients used must be bioavailable and sufficiently stable, and not cause excessive changes in product quality. The challenge in mineral enrichment is the reactivity of metal ions with other food components and the use of sequestrants such as citric acid may thus be necessary (Zhang et al., 2007a). Some mineral sources used in plant milk substitutes include ferric ammonium citrate and ferric pyrophosphate as iron sources and tricalcium phosphate and calcium carbonate as calcium sources (Zhang et al., 2007a; Zhao et al., 2005).

Stability

Plant milk substitutes contain insoluble particles such as protein, starch, fibre and other cellular material. These particles, being denser than water can sediment, making the product unstable. The suspension stability can be increased by decreasing the particle size, improving their solubility or by using hydrocolloids and emulsifiers (Durand et al., 2003). Many plant milk substitutes coagulate when heating. When proteins unfold as a result of heating, the nonpolar amino acid residues are exposed to water increasing the surface hydrophobicity. This enhances protein-protein interactions that can result in aggregation and sedimentation or gelling (Phillips et al., 1994). The heat stability of proteins depends on the pH, ionic strength and the presence of other compounds such as minerals and carbohydrates (McSweeney et al., 2004). Homogenisation improves the stability of plant milk substitutes by disrupting aggregates and lipid droplets and thus decreasing the particle size distribution (Malaki Nik et al., 2008). Homogenisation in the conventional dairy processing pressure range (20 MPa) increases the suspension stability sufficiently of soy and peanut milk. Ultra high pressure homogenisation (UHPH) of soy milk at 200-300 MPa reduces the particle sizes intensely and improves the stability compared to conventionally processed products. A higher homogenisation temperature has been reported to increase the stability of peanut milk (Hinds et al., 1997a). In soy milk, heat denaturation of proteins is required for suspension stability.

Shelf life

Commercial plant milk substitutes are pasteurised or UHT treated to extend the shelf life. Pasteurisation is carried out at temperatures below 100 °C, and it destroys enough micro-organisms to enable a shelf-life. Rustom et al. (1996) treated a peanut beverage for 4 and 20 s at 137°C. The longer treatment time decreased the suspension stability slightly, but led to higher taste and acceptability scores. Both treatments were effective in increasing the microbial shelf life. In commercial products, pulsed electric fields have been suggested to extend the microbial shelf life (Cortés et al., 2005). Also other non-thermal processes such as ultraviolet sterilisation, high pressure throttling, high pressure processing and ultra-high pressure homogenisation (UHPH) have been explored as methods of soy milk preservation (Bandla et al., 2011; Cruz et al., 2007; Smith et al., 2009; Sharma et al., 2009).

Fermented products

Fermentation with lactic acid bacteria improves the sensory and nutritional properties, and microbial shelf life of foods. Plant milk substitutes can be fermented to produce dairy free yoghurt type products while rendering the raw material into a more palatable form (Bansal et al 2016a, 2016b). The levels of hexanal responsible for the undesired nutty flavour in peanut milk can be efficiently reduced with fermentation (Yadav et al. 2010). Fermentation of soy milk reduced the amount of flatulence inducing oligosaccharides (Yadav at el. 2008). Some authors have used additives such as carboxymethyl cellulose, coagulants (calcium citrate), milk powder and gelatin to enhance the texture and reduce syneresis in the final product (Cheng et al., 2006; Yadav et al., 2010).

Nutritional quality

Plant milk substitutes are often perceived as healthy. In reality the nutritional properties vary greatly, as they depend strongly on the raw material, processing, fortification and the presence of other ingredients such as sweeteners and oil. Also milks produced of legumes other than soy, such as peanut and cowpea can have protein content as high as 4% (Tano-Debrah et al., 2005). Although plant milk substitutes are low in saturated fats and most products have caloric counts comparable to skim milk, some products contain as much energy as full milk, originating mostly from sugars and other carbohydrates. Plant proteins are generally of a lower nutritional quality compared to animal derived proteins due to limiting amino acids (lysine in cereals, methionine in legumes) and poor digestibility. The nutritional value of proteins depends mainly on the amino acid composition and their physiological utilisation and absorption that is in turn affected by processing. In addition to containing high value protein, milk and other dairy products provide 30–40% of dietary calcium, iodine, vitamin B12 and riboflavin and population groups with low milk intakes often have a poor status for these nutrients. To combat these shortcomings, some plant milk substitutes are fortified with calcium and vitamins, mainly B12, B2, D and E. However, consumer awareness is important as many of these products are not fortified.

Acceptability

Although the demand for plant milk substitutes is increasing, the unwillingness of the mainstream consumer to try unfamiliar foods that are perceived as unappealing may be a limiting factor. Many modern day soy and peanut milks and related products may have an improved sensory quality, but the product group carries a stigma because of early less appealing products on the market. Legume milks tend to possess "beany" and "painty" off-flavours originating from lipoxygenase activity (Chauhan et al 2003). The presence and intensity of the "beany" flavour depends on processing and storage conditions of soy milks and varieties with less lipoxygenase have less "beany" character (Chambers et al., 2006 and Yadav et al 2003) Another problem is a chalky mouthfeel some products have due to large insoluble particles (Durand et al., 2003). The acceptance of peanut milk has been shown to depend on the colour, mouthfeel, the absence of peanut flavour and similarity to cow's milk (Diarra et al. 2005, Jain et al. 2011) Information can increase the willingness to try novel foods. Taste is the most important purchase criteria of foods, and the information about a good and/or familiar taste increase the willingness to try an unfamiliar food most efficiently. Possible health benefits are also an important criteria and health information may increase both the willingness to try and the perceived liking of a food.

Future prospects

Plant based milk substitutes have a reputation of "health foods" but the products on the market vary remarkably in their nutritional profiles, some having very low protein and mineral contents. If these products are to be portrayed as substitutes for cow's milk, protein content and quality as well as fortification has to be considered by manufacturers. Attention should be brought to the possible ways of improving the nutritional properties by processing means e.g. the use of enzymes and the selection of raw materials based on their protein quality. Also a reconstitution approach may allow a more efficient extraction of protein from the material and the formulation of higher protein products. This would however increase the costs and also the environmental impact of the products. More knowledge is required to overcome the mineral fortification related stability issues.

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Strategies for Doubling Farmers Income through Agro-Processing

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[2]ICAR- NDRI, Karnal-132001, Haryana

Farmers' inclusive growth would require a shift from production-based agriculture to profit based farming. Small and marginal farmers, who constitute around 85 per cent of total farming population, are last to reap the benefits of agro-based enterprises; as they end up fighting distress sale and post-harvest losses. The farm harvest price i.e. average wholesale price at which the commodity is disposed off by the producer to the trader at the village site during the specified harvest period provides us a clear picture of farmers' condition. Since doubling of income will warrant high growth rate of production year after year, there would a need for robust post-production activities and hence' investment in storage and transportation' inducing cold chain logistics and food processing. It is hypothesized that with the establishment of processing centres/units,existing post-harvest losses, which occurred due to non-availability of processing and post-harvest infrastructure facilities, can be minimized upto 30 percent and farmers will also realize higher prices of their produce by 5 percent. Expected saving and/or income from this sector will be Rs. 634.94 crore per annum

India is agrarian country, however the remuneration received by farmers is not encouraging. Earlier the strategy was to increase production so that food security can be ensured to the people of country. This strategy involved (a) an increase in productivity through better technology and varieties and increased use of quality seed, fertiliser, irrigation and agro chemicals; (b) incentive structure in the form of remunerative prices for some crops and subsidies on farm inputs; (c) public investments in and for agriculture; and (d) facilitating institutions. India's food production multiplied 3.7 times while the population multiplied by 2.55 times since independence. The net result has been a 45 per cent increase in per person food production, which has made India not only food self-sufficient at aggregate level, but also a net food exporting country. It is true in some cases, growth in output brings similar increase in farmers' income but in many cases farmers' income did not grow much with increase in output. The net result has been that farmers' income remained low, which is evident from the incidence of poverty among farm households. Farmers' income also remained low in relation to income of those working in the non- farm sector. The low and highly fluctuating farm income is causing detrimental effect on the interest in farming and farm investments, and is also forcing more and more cultivators, particularly younger age group, to leave farming. This can cause serious adverse effect on the future of agriculture in the country. Itis apparent that income earned by a farmer from agriculture is crucial to address agrarian distress (Chand 2016) and promote farmers welfare. In this background, the goal set by the Prime Minister Sh. Narendra Modi to double farmers' income by 2022-23 is central to promote farmers' welfare, reduce agrarian distress and bring parity between income of farmers and those working in non-agricultural professions. Fundamentally there are three ways in which income of farmers may be enhanced, viz., increasing the gross income, reducing the costs, and stabilizing the income. Possible routes to achieving these objectives are showcased below (fig 1) and fourth one is unconventional which ICAR-CIPHET proposes i.e. through processing and marketing of their produce.

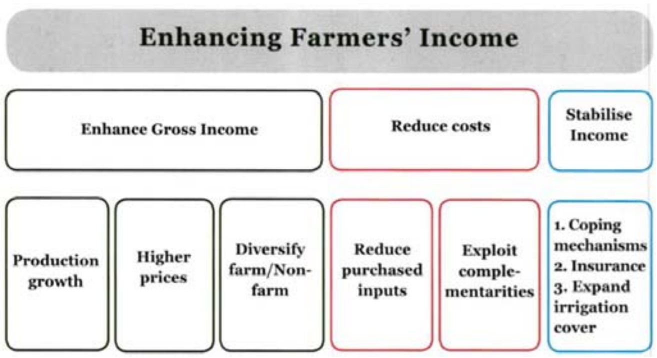

Fig. 1. Ways in which income of farmers may be enhanced

Diversification can be a major game changer. When we talk about diversification it is mostly about high value crops. It can be of three types, viz. product (high value enterprises), process (precision farming), and time diversification (delinking from seasonality). Bumper production of crops can lead to a sharp fall in prices. This can be prevented by changing seasonality. Not all the measures above can be implemented in all states and the pathway to doubling income will be different for each state. Under the assumption of current growth rates holding will be able to double incomes in 7 to 8 years.

Since doubling of income will warrant high growth rate of production year after year, there would a need for robust post-production activities and hence' investment in storage and transportation' inducing cold chain logistics and food processing. This will reduce post-harvest losses in high value crops such as fruits, vegetables, fish, etc. How to reduce post-harvest losses in high value crops is an important issue. Wastages in fruits, vegetables, fish, etc. need to be reduced by creating storage, cold chain, and market infrastructure. States need to be brought on board for addressing the above issues. Exercises similar to that of Madhya Pradesh, which has prepared a roadmap for doubling farmers' income, need to be taken up. The exercise should start at the block Level and then go up to the district and state level.

Enhancing Farmers income through processing and value addition of agricultural produce

Farmers' inclusive growth would require a shift from production-based agriculture to profit based farming. Small and marginal farmers, who constitute around 85 per cent of total farming population are last to reap the benefits of agro-based enterprises; as they end up fighting distress sale and post-harvest losses. The farm harvest price i.e. average wholesale price at which the commodity is disposed off by the producer to the trader at the village site during the specified harvest period provides us a clear picture of farmers' condition. The farm harvest price of major crops in Punjab, as indicated in Table 1 seems not remunerative.

Table 1. Farm Harvest Price of Major Crops in Punjab (2014-15)

Sl. No.	Crop	(Rs/Qtl)
1	Paddy	1400
2	Wheat	1410
3	Maize	1232
4	Gram	4434
5	Rapeseed and Mustard	2681
8	Sesamum	9000

(Source: Ministry of Agriculture and Farmers Welfare, 2017)

In Punjab for producing a quintal of wheat farmer has to invest Rs.1067.26 (Projected cost 2015-16, Ministry of Agriculture and Farmers Welfare) clearly shows that farmer is not getting remunerative price for their produce. Therefore, a strategy that must be adopted to double the farmers' income is value addition through processing at the production catchment itself.

What is Agro-processing

Agro processing is defined as set of techno-economic activities, applied to all the produces, originating from agricultural farm, livestock, aquacultural sources and forests for their conservation, handling and value-addition to make them usable as food, feed, fibre, fuel or industrial raw materials

Agro-processing centre (APC)

An agro-processing centre (APC) is an enterprise where the required facilities for primary and secondary processing, storage, handling and drying of cereals, pulses, oilseeds, fruits, vegetables and spices are made available on rental/ charge basis to rural people. Value added agro based products and processed food items are also prepared and marketed by the centre. This type of centre is managed by individuals/ co-operatives/ community / organizations / voluntary organization. Machines and equipment of small to medium capacity are used by these centres so that it will be easy to operate and handle. The centre meets the processing, preservation, handling and marketing needs of surplus produce available in a village or a cluster of villages. Thus, it is a means of providing income and employment to rural people through agro-processing activities of various produce. The activities of centre can be defined on the basis of available raw materials, processed products, market potential, etc. Such agro-processing centers may be established at cluster of 4-5villages or block level.

AICRP on PHET, PAU Ludhiana centre has established more than 50 APCs and as a result more APCs are coming up indicating and hence multiplier effect is clearly evident. Few examples of successful APC established under AICRP on PHET in Punjab (Table 2) shows that agripreneurs are earning a remunerative income.

Table 2. Economic benefits from APC in Punjab

APC	Lande Brar Agro Processing Complex (Moga)	Rode (Moga)	Konkekalan Grewal Flour Mill (Ludhiana)
Year of establishment	2003	2005	2006
Initial investment on machinery	5.80 lakh	6.75 lakh	6.45 lakh
Total cost (FC+VC)	6.83	14.25	21.35
Returns from processed products (Custom as well as profit basis) (in Rs. lakhs)			
Flour mill (30-35 q/day)	12.77	14.14	17.36
Mini rice mill (15 q /day)	3.37	3.54	3.38
Baby oil expeller (5 q/ day)	1.80	1.47	10.79
Masala grinder (2.75 q/day)	0.81	8.46	-
Animal feed mixer (20 q/day)	-	-	0.48
Annual Profit	11.92	13.36	10.66
Benefit cost ratio	2.75	1.93	1.50
Pay back period (years)	1.17	1.5	1.18
Break-even point (%)	54.01	59.95	54.16

Source: Nanda et. al, 2013

From above it is clear that one can earn an additional income of Rs. one lakh per month**.** Agro processing generates employment opportunities within sector and more opportunities in service sector. Agro processing centre (APC) in the production catchment has twin obvious advantages of enhanced income through value addition to the farm produce and reduction in post-harvest losses as a means to provide gainful rural employment. These APCs consist of two or more machines for processing at farm/village level. However, the requirement of machinery depends upon the crops to be processed, level of processing and scale of processing. Considering the specific requirements (marketable surplus and consumer demand) of Punjab state, various models have been provided.

Model-I: Agro-Processing Centre for Primary Processing of Food Grains, Oilseeds, Pulses and Spices

Table 3. Details of machines along with capacity and cost

Crop/ Commodity	Processed Products/ By-products	Components/ machines	Capacity	Total Cost (Rs.)
Paddy	Rice/Husk and bran	Mini rice mill with two polishers & elevators	250 kg/hr	1,80,000
Oilseeds	Filtered oil/Oil Cake	Baby oil expeller with filter press	60 kg/hr of oilseed	2,00,000
Wheat	Wheat Flour/Bran	Atta Chakki (with Scourer)	700 kg/hr	6,50,000
Wheat	Wheat Flour/Bran	Atta Chakki (Rajasthani)	150 kg/hr	50,000
Turmeric, Chilli	Turmeric and Chilli powder	Masala Grinder	50 kg/hr	70,000
Pulses	Graded pulses	Pulse cleaner-cum-grader	100 kg/hr	50,000
Mixture of by-products	Cattle feed	Cattle feed mill	9 qtls/hr	3,50,000
Electric motor with fitting	20-25 hp	1,50,000		
Total cost on machinery		17,00,000		

Additional Cost of packaging material approximately Rs. 150/- to Rs. 275/- per kg (depending upon the thickness) and printing charges = Rs. 0.50/package

Model-II: Mini Rice Mill, Extruded products

Sr. No.	Description	Nos	Rate	Total (Rs.)
1	Mini Rice Mill unit (with cleaner, sheller and polisher)	1	500000	500000
2	Grain cleaner/Grader	1	10000	10000
3	Extruder and its accessories	1	2500000	2500000
5	Bags and packing material		150000	150000
6	10 hp Electric motor	1	25000	25000
	Total			3185000

Model-III Agro-Processing Centre for Potato and Extruded products

Sr No.	Particulars	No	Price (Rs/Unit)	Total cost (Rs.)
1	Potato chips plant	1	1000000	1000000
2	Extruder and its accessories	1	2500000	2500000
3	Weighing balance,	1	25000	25000
4	Packaging materials			150000
5	Bagging, packing, sealing machines	1	35000	35000
6	10 hp Electric motor	2	25000	50000
	Total			**3760000**

Model APC-IV: Turmeric and Ginger Drying and Grinding

Sr. No.	Machinery and Equipment	Nos	Rate	Total (Rs.)
1	Working Tables	3	10000	30000
2	Work benches	3	1,000	3000
3	Stainless steel container	2	1,000	2000
4	Improved stoves/ LPG burner	3	2,000	6000
5	Washing Machine	1	30,000	30000
6	Basket Centrifuge	1	20000	20000
7	Slices	1	10,500	10500
8	Stainless steel knives	10	50	500
9	Tray dryer	2	250,000	500000
10	Pulverizer/Hammer mill	1	35000	35000
11	Packaging materials		10000	10000
12	packing, sealing machines	1	35000	35000
13	10 hp Electric motor	1	25000	25000
	Total			**707000**

Model APC-V: Minimal processing, Drying and powdering, Value added products.

Sr. No	Description	Nos	Rate	Rs.
1	Working Tables	3	10000	30000
2	Stainless steel container	5	500	2500
3	Improved stoves/ LPG burner	3	2000	6000
4	Washing Machine	1	35000	35000
5	Basket Centrifuge	1	20000	20000
6	Stainless steel knives	10	50	500
7	Pulp extractor	1	9500	9500
8	Wooden spoon	10	50	500
9	Rigid Plastic funnels, large bottom	10	10	100
10	Glass jars, various sizes	500	10	5000
11	Hand /electrical operated capping device (cappers)	1	5200	5200
12	Bottle brushes	10	50	500
13	Work benches	3	1000	3000
14	Multipurpose Slicer	1	55000	55000
15	Multipurpose Peeler	1	55000	55000
16	Tray dryer	1	125000	125000
17	Pulverizer/Hammer mill	1	35000	35000
18	Weighing balance, Packaging materials	1	25000	25000
19	Bagging, packing, sealing machines	1	35000	35000
20	10 hp Electric motor	1	25000	25000
21	Cold Storage facility	1	800000	800000
	Total			**1272800**

Model APC-VI: Sugarcane bottling plant and Jaggery Unit

Sr No.	Particulars	No	Price	Total (Rs.)
1	Sugar cane juice bottling plant (Crusher, filter, boiler, treatment unit, bottling, corking, sterilizer, crates storage etc)	1 set	500000	500000
2	Moulding frame, sieves, boiling pans, etc.			800000
3	Generator set (10 KVA)	1 set		250000
	Total			**1550000**

The machines are mini rice mill, baby oil expeller, small attachakkies and large attachakkies with scouring machine, masala grinder, penja, cleaner, dal mill and feed mill along with construction and installation costing approximate Rs. 25-30 lakhs and an amount of Rs 6.0-8.0 lakhs for construction of APC shed and installation of machinery (Table 12). It is expected from the state government to provide appropriate subsidy to encourage farmers to set up these units. A desired covered space of approx. 200-300 sq. yard is required for the installation of all these machines.

To motivate the youth towards agro processing, it is envisaged that at least 25% of the capital cost can be provided by govern as an assistance. If one APC of each type in each block then an amount of Rs. 50.62 crore (details given below in Table 13) is required as an incentive for the development of such agro-processing centers in the Punjab state.

Further, government initiative in the form of establishing five primary processing or collection centres and pack houses in the state will also contributes towards increasing the income of the farmers. The proposed Rs 140 crore multi-product mega food park in Ludhiana would be set up by Punjab Agro Industries on 100 acres of land at

Table 4. Estimated Government assistance for establishment of Model APC at block level in Punjab

Model APC for Punjab	Approx. Budget Required for development	Assistance from Govt.	Proposed No. block wise	Budget Required from Govt.
Model I Agro-Processing Centre for Primary Processing of Food Grains, Oilseeds, Pulses and Spices	20 Lakh	25% of actual cost@ 5.0 Lakh	150	750.0 Lakh
Model-II: Mini Rice Mill, Extruded products	30 Lakh	25% of actual cost@ 7.5 Lakh	150	1125.0 Lakh
Model-III Agro-Processing Centre for Potato and Extruded products	40 Lakh	25% of actual cost@ 10.0 Lakh	150	1500 Lakh
APC-IV: Turmeric and Ginger Drying and Grinding	15 Lakh	25% of actual cost@ 3.75 Lakh	150	562.5 Lakh
APC-V: Minimal processing, Drying and powdering, Value added products.	15 Lakh	25% of actual cost@ 3.75 Lakh	150	562.5 Lakh
APC-VI: Sugarcane bottling plant and Jaggery Unit	15 Lakh	25% of actual cost@ 3.75 Lakh	150	562.5 Lakh
Total	5062.5 Lakh			

Table 5. Expected additional income due to processing and postharvest management

Crops	Production (Thousand Metric Ton), 2014-15	Existing Losses* (%)	Value of existing losses	Expected saving/ increase in income (Rs crore)		
				Saving due to reduction of PHL @30%	Higher price realization/value addition @5%	Total
I	II	III	IV (II x III x current price)	V (V x 0.3)	VI (II x 0.05 of current price)	VII (V+VI)
Wheat	15088	3.95	595.98	840.33	106.37	358.47
Paddy	11259	3.12	351.28	491.79	78.81	226.35
Pulses	17	7.0	1.19	5.28	0.38	1.96
Oilseeds	60	4.60	2.76	7.40	0.80	3.02
Potato	2190	5.01	109.72	49.37	4.93	19.74
Kinnow	988	6.10	60.27	48.21	3.95	18.42
Guava	161	12.78	20.58	20.58	0.81	6.98
Total				**438.89**	**196.05**	**634.94**

* Figures are taken from the report of Jha et.al (2015)

Ladhowal. Five collection centres would be setup at village Muskabad (Samrala), Saholi (Nabha), Kangmai (Hoshiarpur), Lalgarh (Samana) and Babri (Gurdaspur). Besides, the state is going to identify five more such centres to develop world-class fruits and vegetables clusters.In this mega food park, 30-40 food processing units processing frozen fruits and vegetables, frozen French fries, milk, maize, bakery products, wheat pasta, tomato, chilies, snack foods, eggs, malt, honey, haldi etc. would be set up.It is worth mentioning that investments in food processing industries have multidimensional benefits, i.e., value addition and better price realization by the farmers, besides reducing the postharvest losses. These centres are expected to contribute through better price realization by the farmers.

Conclusions

1. It is hypothesized that with the establishment of processing centres/units,existing post-harvest losses, which occurred due to non- availability of processing and post-harvest infrastructure facilities, can be minimized upto

30 percent and farmers will also realize higher prices of their produce by 5 percent. Expected saving and/or income from this sector will be Rs. 634.94 crore per annum (Table 5). The above figure is for Punjab state only. The model may be different for different states and certainly enhance farmers income upto certain extent.

2. Small farmers needs to associate and form commodity groups/processor companies for better earning profits. Women can be given training in the area of processing and can go for value addition through mango pulp processing, guava products processing such as guava leather, guava nectar and various carbonated and fresh fruits beverages.

3. Development of integrated pack house are required for grading, sorting, packaging agricultural and horticultural produce. It will have mechanical grading and sorting line, pre-cooling chamber, cold storage, reefer van and pick up van.

4. Promoting Agro-Processing Centres (APC) at the production catchment. APC has facilities for primary and secondary processing, storage, handling and drying of cereals, pulses, oilseeds, fruits, vegetables and spices are made available on rental/ charge basis to rural people. This type of centre can be managed by individuals/ co-operatives/ community / organizations / voluntary organization. Machines and equipment of small to medium capacity are used by these centres so that it will be easy to operate and handle. The centre meets the processing, preservation, handling and marketing needs of surplus produce available in a village or a cluster of villages.

5. Skill Development Centre in horticultural crop processing and packaging. Trained manpower in the production, post-harvest & processing industries is required to cater to the demand for processed horticultural products for domestic trade and export purpose.

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Promoting Producer Organization among Farmers

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Indian agriculture is essentially small farm agriculture with 85 per cent of farmers owning less than 2 ha of land (Agricultural Census, 2010-11). Small holdings agriculture, which accounts for 44.6 per cent of total operated area is vital for increasing agricultural growth and enhancing food security in India. FAO (1990) have described small farmers as (i) seasonal producers; (ii) fragmented buyers and suppliers unable to exploit economies of scale; and (iii) dominated by household economics where functions such as consumption, investment, work and social activities are undifferentiated and unspecialized. Farmers with small holdings usually have limited resources and they focus mostly on the production side. They also have limited access to market and market information and sell their produce as soon as possible without any processing or value addition many a time's leading to distress sale. This poor marketing involves more and more intermediaries which leads to long marketing channel. This is to the extent that farmers' share in consumer's rupee varies between 56 to 89 per cent for paddy, 77 to 88 per cent for wheat, 72 to 86 per cent for coarse grains, and 79 to 86 per cent for pulses, 40 to 85 per cent in oil seeds and 32 to 68 per cent in case of horticultural crops (DAC, 2013).

The individual volume of production of the small farmers is low which averts them from reaping benefit of economics of scale. Small farmers can benefit from the economics of scale only through aggregation. Producer organizations are useful for mobilizing individual farmers' effort into collective action which will be helpful in improving the socio-economic condition of all the members of the group. Organizing farmers will aid in access to resources, information, specialization in commodities, processing and value addition, large-scale operations, market orientation and better bargaining power.

Producer Organization

Producer Organisation (PO) is a legal entity formed by primary producers with the aim to ensure better income for the members of the group. Producer organization can be Farmer's Interest Group (FIG), Commodity Interest Group (CIG), co-operatives, producer companies, federations, SHGs, farmers association or any other legal form which shares profits/benefits among the members. This is an organisation of the producers, by the producers and for the producers. FAO (2007) refers producer organizations as "independent, non-governmental, membership-based rural organizations of part or fulltime self-employed smallholders and family farmers, pastoralists, artisanal fishers, landless people, women, small entrepreneurs and indigenous peoples."

Features of a Producer Organization

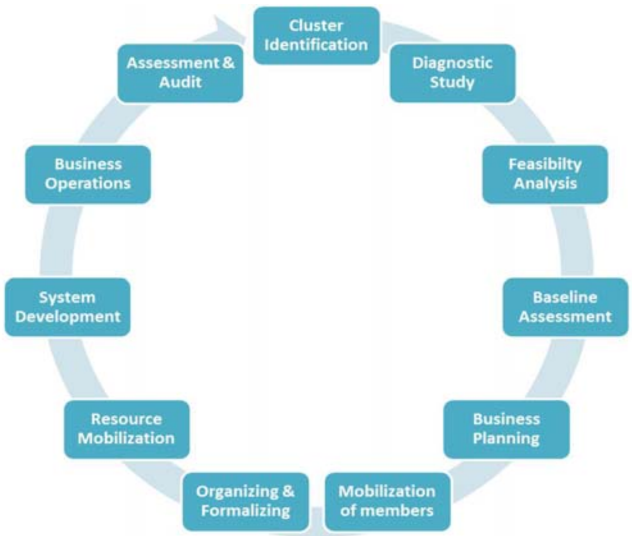
1. Registered body and a legal entity
2. Members will be primary producers for either farm or non-farm activities
3. Producers are shareholders in the organization
4. Works for the benefit of the members
5. Deals with business activities related to primary produce/product
6. A part of profit is shared among the members
7. Rest of the profit is added to PO's funds for business expansion

When the members of the producer organization are farmers, it is known as farmer producer organisation (FPO). FPO works on the values of self-help, self-responsibility, democracy, equity, equality and solidarity. FPO's are developed and promoted by resource institutions (RI)/ Producer Organization Promoting Institution (POPI) which are funded by Small Farmers' Agribusiness Consortium (SFAC) and NABARD.

Promotion and Development of FPO

The promotion and development process of FPO that has to be followed by RI/ POPI as directed by the Department of Agriculture and Cooperation in the Policy and Process Guidelines for Farmer Producer Organization is given below:

1. **Cluster identification:** Area where the FPO has to promoted should be identified. It should be ensured that identified cluster covers 8,000-10,000 farmers within one or two block
2. **Diagnostic study:** This is done to evaluate the preliminary situation of farmers, level of agriculture in the selected area based on which the potential interventions that is required in the area can be identified.
3. **Feasibility analysis:** This includes technical, social, financial, environmental, legal and political viability of the FPO in the selected area. This is done by RI/POPI which is later appraised by hired external experts.
4. **Baseline assessment:** This consists of collecting basic data from the farmers at the household level, based on which the outcome and impact of FPO can be measured in future. This will help in identifying the potential intervention and planning and developing business plan for the FPO in the selected area.
5. **Business planning:** Business plan gives a systematic collective visualization of the FPO with proper projections on several areas that need to be developed.
6. **Mobilizing farmers:** This can be done through awareness programmes, training, distribution of materials related to FPO, regular village meetings etc. The farmers who decide to join the FPO voluntarily after releasing the benefits of forming will become the promoter farmer member of the FPO.
7. **Organizing and formalizing:** The farmers of each village of the selected cluster will form FIG which will be later aggregated together to form FPOs. Usually, around 50-70 FIGs can be organized to form FPO. FPOs can be later registered under the Cooperative Societies Act or Producer Company provision under the Companies Act depending upon the interest of the members of FIG's. Sufficient time must be provided to the FIGs (18-24 month) to settle down before getting registered as the FPO.
8. **Resource mobilization:** All the resources (technical, financial, human, and physical) required by the FPO based on the business plan should be mobilized during this stage.
9. **Management systems development:** Guidelines should be developed for the proper functioning of the FPO's. It should address all the areas related to standard operating procedure, management of human resources, finance, procurement and quality management, stock and inventory, marketing, internal audit, conflict resolution and other important aspects. Resource institutions should facilitate the development of guidelines of the FPO.
10. **Business operations:** The commencement of operation includes procurement, production, processing, marketing of the commodities or products with which the FPO is dealing with. This also includes the financial management of the FPO. The governing and operational body of the FPO should be trained by RIs for the smooth functioning of the FPO.



(Source: DAC, 2013)

11. **Assessment and audit:** The performance of the FPO should be evaluated constantly and RIs should facilitate this. Transparency and accountability can be maintained by auditing the accounts of FPO regularly.

Registration of Producer Organization

Producer Organization can be registered under any of the following acts:

1. **Cooperative Societies Act/ Autonomous or Mutually Aided Cooperative Societies Act of the respective State:** Co-operative societies are mainly government promoted and usually established for the purpose of credit, production or distribution.
2. **Multi-State Cooperative Society Act, 2002:** Under this act the co-operative society can operate in more than one state. Co-operative societies registered under this act can be registered as Producer Company under section 581J of the Companies Act.
3. **Producer Company under Section 581 of Indian Companies Act, 1956, as amended in 2013:** This act combines the cooperative business with a governing structure similar to that of a private limited company. This organization is best suitable for agricultural commodities.
4. **Section 25 Company of Indian Companies Act, 1956, as amended as Section 8 in 2013:** For registration of PO's with limited liability for promoting commerce, art, science, religion, charity or any other useful object.
5. **Societies registered under Society Registration Act, 1860:** PO's focussed on charity or socially benefits can register under this section.
6. **Public Trusts registered under Indian Trusts Act, 1882:** PO's focussed on charity or socially benefits can register under this section.

Difference between Co-operative and Producer Company (NABARD, 2015)

Parameter	Cooperative Society	Producer Company
Registration	Cooperative Societies Act	Indian Companies Act
Objectives	Single object	Multi-object
Area of Operation	Restricted, discretionary	Entire country
Membership	Individuals and cooperatives	Any individual, group, association, producer of goods or services
Share	Non tradable	Not tradable but transferable; limited to members at par value
Profit sharing	Limited dividends on shares	Proportionate with volume of business
Voting rights	One member, one vote, but Government and Registrar of Cooperatives hold veto power	One member, one vote. Members not having transactions with the company cannot vote
Government control	Highly patronized to the extent of interference	Minimal, limited to statutory requirements
Extent of Autonomy	Limited in "real world scenario"	Fully autonomous, self-ruled within the provisions of Act
Reserves	Created if there are profits	Mandatory to create every year
Borrowing power	Restricted as per bye-law. Any amendment to bye-law needs to be approved by the Registrar and time consuming	Borrowing limit fixed by Special Resolution in general meeting. Companies have more freedom to raise borrowing power
Relationship with other corporate / business houses / NGOs	Transaction based	Producers and corporate entity can together float a producer company

FPO as Producer Company

Producer company is a hybrid which combines the goodness of a co-operative society and vitality and competency of a company. The clauses of Private Limited Company shall be applicable to the producer companies except the clauses specified in Producer Company Act from 581-A to 581-ZT, which make it different from a normal private or limited company. A producer company can carry out the following activities as mentioned in section 581 B of Companies Act 1956:

- Production, harvesting, procurement, grading, pooling, handling, marketing, selling, export of primary produce of the members or import goods for their benefit
- Processing including preserving, drying, distilling, brewing, venting, canning and packaging of produce of its members
- Manufacture, sale or supply of machinery, equipment or consumables mainly to its members
- Providing education on the mutual assistance principles to its members and others
- Rendering technical services, consultancy services, training, research and development and all other activities for the promotion of interest of its members
- Generation, transmission and distribution of power, revitalisation of land and water resources, their use, conservation and communications relatable to primary produce
- Insurance of producers or their primary produce
- Promoting techniques of mutuality and mutual assistance
- Welfare measures or facilities for the benefit of Members as may be decided by the Board
- Any other activity, ancillary or incidental to any of the activities referred to in above clauses which may promote the principles of mutuality and mutual assistance amongst the members in any other manner
- Financing of procurement, processing, marketing or other activities specified in above clauses which include extending credit facilities or any other financial services to its members

Features of a Producer Company

- Only primary producer or producer organization can become members
- Limited liability : liability is limited to the share capital held by the members
- Members' equity cannot be traded, however can be transferred but with the approval of Board of Directors
- Minimum authorized capital at the time of incorporation of PC should be Rs.5 lakh

Structure of Producer Company

Producer company is governed by its members, Board of Directors and Office bearers

1. Members

Only primary producers or producer organization can become members of a producer company. There should be at least 10 members or 2 or more registered producer institution (FIG/CIG/SHG) or a combination of these can form producer company. There is no maximum limit for the number of shareholders. Primary producer can become members by the purchase of the shares in the company. Members form the company and performance of the company depends on its members.

Members exert their authority mainly through general meetings. The rights of members include transfer one's shares, vote on resolutions at meetings of the company, can demand an extraordinary general meeting of the company, can attend and speak in a general meeting, can move amendments to resolutions proposed at meetings, in case the member is a corporate body, to appoint a representative to attend and vote at general meetings on its behalf and to require the company to circulate its resolutions.

2. Board of Directors

Board of Directors are elected by members. Usually the first Board of Directors will be selected from the promoter farmers. Every producer company is to have at least five and not more than 15 directors. The Directors will be selected on annual general meeting and their tenure varies between minimum 1 year and maximum 5 years. If any director resigns then election to his post shall be conducted within 90 days from the date of resignation. Every director is eligible for reappointment. The Board may co-opt one or more expert directors or additional directors not exceeding one fifth of the total number of directors. Expert director is any person who has expertise in running a producer company, but will not have right to vote in the election of chairman. The duties that the Board of Directors have to execute include:

- Formulation of the organisational policies and objectives including long term and annual objectives
- Formulation of corporate strategies and financial plans
- Determination of the dividend payable
- Determination of the quantum of withheld price and recommendation of patronage bonus
- Admission of new members
- Appointment of officers including Chief Executive, Company Secretary and exercise of superintendence
- Direction and control over Chief Executive and other officers appointed
- Ensure the maintenance of books of accounts
- Preparation of annual accounts to be placed before the annual general meeting with the auditor’s report and the replies on qualifications, if any, made by the auditors
- Acquisition or disposal of property in the ordinary course of business of Producer Company
- Investment of the funds in the ordinary course of business
- Sanction any loan or advance to any Member not being a director or his relative
- Such other measures as may be required in the discharge of functions or exercise of powers

3. Chief Executive Officer (CEO)

CEO is the ex-officio director of the producer company and is accountable to both the Board of Directors and members. CEO is a full time employee of the company and shall not retire by rotation. The qualifications, experience and terms and conditions of the service of CEO is determined by the Board according the requirement given in Article of Association (AoA).The functions of CEO include:

- Do administrative acts of routine nature including managing the day-to-day affairs of the company
- Operate bank accounts or authorize any person, subject to the general or special approval of the Board
- Make arrangements for safe custody of cash and other assets of the company
- Sign business related documents as may be ‘authorized by the Board’ for and on behalf of the Producer Company
- Maintain proper books of account, prepare annual accounts, place the audited accounts before the Board and in the Annual General Meeting of the Members
- Furnish the members with periodic information to appraise them of the operation and functions of the company
- Make appointments to posts in accordance with the powers delegated to him by the Board
- Assist the Board in the formation of goals, objectives, strategies, plans and policies
- Advise the Board with respect to legal and regulatory matters concerning the proposed and ongoing activities and take necessary action in respect thereof
- Exercise the powers as may be necessary in the ordinary course of business
- Discharge such other functions, and exercise such other powers, as may be delegated by the Board
- Provide timely information to the Members and Board of Directors for scheduled company meetings or emergency or short notice meetings.

4. Company Secretary

Producer company having an average annual turnover of more than five crore rupees in each of three consecutive financial year should have a company secretary.

Transforming FPO into a Producer Company

When the primary producers are ready to form a Producer company and prepared to contribute to the share capital then

1. Identify Promoter Directors
2. Prepare a draft Articles of Association (AoA)
3. Prepare a draft Memorandum of Association (MoA)
4. Call first informal meeting of the shareholders to approve AoA, MoA, selection of promoter and authorized capital and cost of each share
5. Collect the capital and savings also if possible.

Registration of FPO as Producer Company

The procedure to be followed for registering an FPO into a producer company is given below:

1. Digital Signature Certificate (DSC)

Digital Signature of at least one Director or Chairman is mandatory prior to enter the formal registration process in order to make the document submitted online secure and authentic. All filings done by the companies are to be filed using of digital signatures. Therefore, the company has to authorize a person's signature who will sign the documents. The prescribed application form for DSC is available in the website of Ministry of Corporate Affairs in which the required information can be filled and submitted online to the 'Certification Agencies'. DSCs are valid for one to two years which can be renewed for fee of Rs.1800. Certification Agencies (NIC, TCS, Safescript, MTNL etc.) also charge a service fee which vary from agency to agency.

2. Director Identification Number (DIN)

DIN number can be obtained online only from the company affairs cell at Noida, UP without any fees by providing identification proof number (Only PAN Card, Voter Identity card, passport or driving license number is accepted). The prescribed form is available in the website of Ministry of Corporate Affairs and the application can be submitted online.

3. Naming of a Producer Company

Producer Company should be named using the suffix "…..Producer Company Limited". Select, in order of preference, at least one suitable name up to a maximum of five names, related to the main product of the company. Check the availability of the name on the portal *http://www.mca.gov.in* and make certain that it does not resemble the name of any other already registered company. The application for the name can be filled in Form INC-1 with DIN/PAN number of the directors and submitted to Registrar of Companies (RoC). Once the name is applied the entire procedure should be completed within 60 days.

4. Memorandum & Articles of Association

After registering the name of the producer company, a MoA and AoA has to be prepared. An Article of Association (AoA) is a document that specifies the rules for company's operations. Memorandum of Association (MoA) is a document that indicates what activities the company can undertake. Both the documents should be printed, duly stamped, signed by the promoters in his/her own hand, his/her father's name, occupation, address and the number of shares subscribed for. Make sure that the Memorandum and Article is dated on a date after the date of stamping.

5. Documents to be submitted to the Registrar of Companies for the Incorporation of Producer Company

The following documents along with fees payable with the Registrar of Companies of the state has to be submitted where the Registered Office of the company is to be situated. The documents include copy of the letter of RoC confirming the availability of name of the company; MoA and AoA duly stamped and signed; Form INC-22 regarding of Registered Office of company (full address); Form DIR-22 (in duplicate) regarding particulars of directors; Form 1NC-7 (on a stamp paper) declaring compliance of all and incidental matters regarding formation of companies; Form DIR – 12 regarding consent of each director; An affidavit has to be submitted by subscribers that MoA is fully understood; if the MoA is submitted in Hindi by subscribers claiming the understanding of same; and Power of Attorney to the agent dealing with RoC to make necessary corrections in MoA and AoA if required. All the forms can be filled online in website of Ministry of Corporate Affairs (*http://www.mca.gov.in)*.

6. Certificate of Incorporation

The RoC, on being satisfied with all the documents submitted will issue a 'certificate of incorporation' within thirty days, which is a proof of the formation of producer company. On incorporation, a company becomes a person in the eyes of law.

7. Tasks to be completed immediately after incorporation of company

Open a bank account with minimum two officially nominated signatories in the name of the company¸ procure PAN number from the Income Tax and TIN number from the Commercial Tax Department to carry out business.

Cost Estimated for the Incorporation of a Producer Company

Particular	Heads	Amount (Rs)
Application for name of PC	Fees	500.00
Digital Signature	Fees	2600.00
Stamp duty	Memorandum of Association and Articles of Association	1500.00
Registration/Filing fees	MoA, AoA, Form-1, Form-18, Form-32	17200.00
Fees of Chartered Accountant or Company Secretary	Consultancy charges	10000.00
Stamps cancellation		300.00
Affidavit expenses	Fees of Notary	500.00
Share transfer fees and processing		5000.00
Miscellaneous expenses		2000.00
Total		**39600.00**

Case Study of Producer Company

1. SUBICSHA

Subicsha, is an innovative Coconut based Farmer Producer Organisation in Kerala which played an instrumental role in helping coconut farmers to get remunerative price for their produce. This organisation is a federation of self-help groups (SHGs) registered under the Producer Companies Act which makes it a Farmer Producer Company. They started with the production of coconut oil and now they are producing about 24 value added products including virgin coconut oil, coir, soap, pickle etc. They also followed different marketing strategies by opening outlet at the project area (Calicut), marketing through dealers at other districts, door to door sale by SHG members, participating in fairs and sales festivals. The marketing strategies adopted and quality of the produce led to the success of Subicsha.

2. Indian Organic Farmers Producer Company Limited (IOFPCL)

The Indian Organic Farmers Producer Company Limited (IOFPCL) founded in 2004 in Aluva, Kerala is one of the largest organic producer company in India. The company is owned and managed by the farmers themselves. The company was formed overcome to the challenges faced by the farmers in the production, marketing and certification of organic produce. Now the company is marketing certified organic produce like spices, coffee, coconut oil, virgin coconut oil, desiccated coconut powder, cashew nut etc. and is exporting their produce to Europe and Canada.

Conclusion

Farmer producer organisation is the organisation of the farmers, by the farmers and for the farmers, financially facilitated by the government. Producer company is one of the best forms of farmer producer organization in which farmers can focus on farming and on-farm activities while the marketing and other management activities of the organisation will be done by the professional staffs of the organisation. Even if the registration of a producer company is time consuming and difficult, the association can ensure better price for the produce of its members. This organisation can also establish better forward and backward market linkages.

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Conversion of Agro Biomass to Wealth for Additional Income

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Agro biomass is one of the renewable resources that are found in nature in abundant quantity. Utilization of agricultural waste is very important concern especially seeing world scenario of energy demand gap (Harshwardhan and Upadhayay, 2017). In India, agriculture delivers 54 % employment in rural as well as urban sectors. India is the world's second largest producer of fruits (74.9 million tonnes) and vegetables (146.5 MMt), each contributing 10.0 per cent and 13.3 per cent respectively, to the total world production (Bhat et al., 2011). An ample amount of solid residue is generated post retrieval of the main agricultural product. The amount of agro residues available in India is estimated to be nearly 620 million tons (Pandey et al., 2009). Approximately 50% of it is used as roofing material, animal feed, fuel and packing material while the other half is disposed of by burning in the field (Singh and Nain, 2014). Worldwide, it is common practice to dump residue as garbage to be decomposed by microbial activity or burning for energy generation; both endangering environmental health. Burning of paddy residue on agricultural field has been a common practice throughout north India posing poor air quality index particularly during the onset of winter. The lethal smoke produced during open burning leads to respiratory diseases, allergies and eye irritation. Rice, wheat, sugarcane, soybean, corn, banana, pineapple, citrus, mango and bamboo are a handful of crops that generate considerable residues. About 50 % of the total residues generated are produced by just three crops *viz.* rice, wheat and oilseed (Singh and Nain, 2014). Crop residues embrace all agricultural and horticultural wastes such as straw, stem, stalk, leaves, husk, stone, fiber, shell, peel, pulp, stubble, etc. which come from cereals (rice, wheat, maize or corn, sorghum, barley, millet), cotton, groundnut, jute, legumes, coffee, tea and fruits (banana, mango, citrus, guava, cashew). Agricultural and horticultural residues are highly important sources of biomass fuels for both the domestic and industrial sectors. These are rich in non-wood ligno-cellulosic and fibrous (soluble as well as insoluble) materials, annually renewable and a low cost source for natural fibers and other high value compounds. The term agricultural residue embraces all the organic materials which are produced as by-products from harvesting and processing of agricultural crops and can be further categorized into two categories.

Primary residues: Agricultural residues, which are generated in the field at the time of harvest, are defined as primary or field residues. Examples include: wheat/paddy straw, banana pseudo-stem (and leaves), sugarcane top, mustard/guar straw, cotton sticks, maize stalks, coconut empty bunches etc.

Secondary residue: The residues produced during processing are termed as secondary residues or processing byproducts. Examples include: paddy husk, bagasse, maize cob, coconut shell/husk, saw dust, palm oil shell, fiber and empty bunches, wastewater etc.

In the current eon, there is a rapid increase in volume and types of waste biomass. According to an estimate, roughly one-third of food produced for human consumption is lost or wasted globally throughout the supply chain, from initial agricultural production down to final household consumption (Gustavsson et al., 2011). Meager level of processing (6-8%) and a sizeable post-harvest loss (6-18%) are responsible for a monetary loss of Rs 31,500/- crores annually in case of fruits and vegetables alone (Nanda et al., 2012, Jha et al., 2015) while total post-harvest losses toll nearly 92,000/- crores. Legitimate utilization of nature and reduction of post-harvest losses are impetus to sustenance of flora and fauna including human being on this earth, in this universe. Utilization of waste residue is at nascent stage and a handful of waste is being recycled. This inappropriate management of waste biomass has resulted in climate change, water and soil contamination, and air pollution (Kaur et al., 2013). The waste biomass may become a potential source of high value compounds, chemicals, renewable and sustainable energy and other valuable materials. By-product recovery from agro residues can improve the overall economics of processing units in addition to solving the problem of environmental pollution considerably. The agro-residue and processing byproducts, being considered as waste can become wealth. They can be harnessed to produce a myriad of high value compounds as is evident from following instances:

1. **Biofuel/bioethanol**: Ever increasing population and industrialization have necessitated increasing demand of energy. Agro-biomass currently offers the only renewable source of energy that can substitute for petroleum fuels as well as reduce CO_2 emissions. The cellulosic material is the most abundant biomass and agro-residues on the earth and can be an attractive feedstock for bioethanol production. Bioethanol from agro-residues could be a promising technology that involves four processes: pre-treatment, enzymatic hydrolysis, fermentation and distillation (Gupta and Verma, 2015). The celluloses, lignans and other polysaccharides of agricultural residues have the potential to be converted in to fermentable sugars by mechanical and enzymatic ways which can be further fermented to produce ethanol. The ethanol can be used to run automobiles. Petroleum consumption for road transportation is currently the largest source of CO_2 emissions and accounts for 23% of CO_2 emissions worldwide. World total transport energy use and CO_2 emissions are projected to be 80% higher by 2030 than the current levels. Cassava, rice, maize, straws, stalks and bagasse can be used for biofuel production. Fermentation is an enzymatic controlled anaerobic process. Before fermentation, raw biomass is pre-treated and hydrolysed to increase surface area of the biomass, decrease crystalline structure of cellulose, separate hemicellulose and lignin. Enzymatically the cellulosic biomass is converted into glucose which is then fermented into ethanol by selected microorganisms. Brazil has developed a successful bioethanol program based on fermentation of sugar in sugarcane feedstock to ethanol (Ben-Iwo et al., 2016). In India, Institute of Chemical Technology (Mumbai) with the support of DBT has developed a technology to convert agro-residue into alcohol. The Kashipur plant made as public-private-partnership (PPP model run by India Glycols Limited) is actually a series of big bioreactors. The plant is utilising wheat and bagasse agro waste as raw material. The dry waste is fed into the plant is rapidly converted into slurry by using chemicals. The slurry is treated with specialized cellulase enzymes that convert the organic cellulose component of bio-waste into sugars. The plant produces 300 litres of alcohol for every 1000 kg of agro-waste. The cost per litre of 2G ethanol is Rs 25 per litre (Bagla, 2016).

2. **Anaerobic digestion for biogas and fertilizer production**: Anaerobic digestion is a multi-faceted technology suitable for energy production from agricultural residues and other biodegradable wastes. Here high moisture content (85–90%) biomass is first converted with the help of microorganisms in the absence of oxygen to produce a mixture of carbon dioxide, methane rich gas (biogas) and traces of other gases such as hydrogen sulphide. The by-product or nutrient rich digestate left after anaerobic digestion can serve as fertilizer for agriculture.

3. **Packaging material**: Sugarcane baggase, a processing residue is washed and treated with a combination of heating and chemical treatments to convert it into a fibrous matrix. The resulting pulp is bleached and mixed with other ingredients to convert it into sheets/rolls. These sheets/rolls can be used as paper, packaging material or can be moulded to produce biodegradable plates and cups. These can be an alternative to thermocol and plastics which are otherwise non-biodegradable and major environmental concern (https://www.thebetterindia.com/63696/biodegradable-tableware-sugarcane-fibre/).

4. **Compost:** On an average, agro-residues contain about 0.5% N, 0.2% P_2O_5 and 1.5% K_2O (NPK). Assuming that 50% of crop residues are utilized as cattle feed and fuel, the nutrient potential of the remaining residue is 6.5 million tonnes of NPK per annum, which accounts for 30% of total NPK consumption in India. Hence, the recycling of these wastes is an essence (Singh and Nain, 2014). The decomposition of organic matter by microorganisms in warm, moist, aerobic and anaerobic environment referred to as composting. It takes around 3-6 months depending upon agro-residue, moisture, temperature and oxygen conditions. Type of micro-organismal consortia also plays a pivotal role in compost development. Government of India is stressing upon development of compost manure to reduce chemical load on mother earth. The organic matter left after extraction of high value compounds is biodegradable and can be routed for the production of compost manure. The composted manure, if applied in arable land, improves soil texture and augments micronutrient deficiencies. It also increases moisture-holding capacity of the soil and helps in maintaining soil health at less capital investments. In vermi-composting, decomposition of organic waste is accomplished by earthworms and their nutrients rich excreta get mixed with manure (Asnani, 2006).

5. **Pyrolysis**: Pyrolysis involves the thermal decomposition of biomass at temperatures of about 350–550°C, under pressure and without or scanty oxygen. It yields liquid fraction (bio-oil), solid (predominantly ash) and gaseous fractions. The fast pyrolysis process yields liquid up to 75% by weight which can be used in engines, turbines and refineries or as energy carriers.

6. **Gasification**: It is the partial oxidation of biomass into a combustible gas mixture at temperatures of 800–900 °C. The gas produced, known as synthesis gas (syngas) consists of a mixture of carbon monoxide (18 to 20%), hydrogen (18–20%), carbon dioxide (8–10%), methane (2–3%) and steam. These gases can be burnt directly or used as a fuel for gas engines and gas turbines in generating electricity (Ben-Iwo et al., 2016).

7. **Charcoal making**: Briquette charcoal is a smokeless fuel. Instead of burning agricultural wastes in the fields, charcoal is produced by partial burning of waste under low oxygen. Charcoal is viewed as an advanced fuel because of its clean-burning nature and the fact that it can be stored for long periods of time without degradation (Bogale, 2009).

8. **Coconut coir**: Coconut is abundantly grown across Tamilnadu, Kerala and around the tropical areas in the globe. The coconut fiber is termed as coir. India and Srilanka are major exporters of coir in the world. Color of coir or coconut fibers may be brown or white type. Coir fibers are extracted from the husks surrounding coconut followed by retting with water and finally removing fiber. When coconut fiber is extracted from matured coconut, they are brown, strong and thick with good abrasion to resistance whereas when it is extracted from immature coconuts, they are white, smooth and soft. Dark brown coir is used in making brushes, floor mats and upholstery padding while white coir comes from the husks of coconuts harvested shortly before they ripen, is usually spun into yarn. The later may be woven into mats or twisted into twine or rope. Coir is the only natural fiber resistant to salt water and used to make nets for shellfish harvesting and ropes for marine applications (Kavitha, 2015; https://medium.com/@dinmj/coconut-fiber-types-process-of-making-coconut-fibre-10455f0e2c8).

9. **Pectin:** Pectin is widely used in the food industry as a thickener, emulsifier, texturizer and stabilizer in bakery, dairy, confectionary and beverage industry. It is usually added in jams and jellies as a gelling agent and being used as a fat substitute in spreads, ice-cream and salad dressings. Pectin has been shown to lower blood cholesterol levels and low-density lipoprotein cholesterol fractions, which is beneficial for human health (Shaha et al., 2013). Pectin is the methylated ester of polygalacturonic acid that contains 1, 4-linked á-D-galacturonic acid residues. Golgi apparatus of plant cells is the place where pectins are synthesized in the plant and form a matrix in which the hemicellulose polysaccharides of the plant cells are embedded. Pectin is a major component of the middle lamella; helps to bind cells together and also is a part of primary cell walls. The amount, structure and chemical composition of pectin differs among plants, within a plant over time, and in various parts of a plant. Commercial pectins are primarily extracted from citrus peels and apple pomace using an acid extraction method with yields of about 25 and 12% pectin, respectively (Yeoh et al., 2008). The estimated annual worldwide production of pectin is 7,250 metric tons, approximately 60% of which is produced from citrus fruits. California produces approximately 30% of the world supply (Chakraborty and Ray, 2011). India largely imports its required pectin from Brazil and China and the annual requirements are to the tune of 1200-1500 tonnes. Citrus pectin is usually sold in a finely powdered form; however, pectin is available commercially in both liquid and powdered form. Pectin polysaccharides consist of 300-1000 chains of galacturonic acid units. Lemons, oranges and grapefruits are pectin rich fruits that may help decrease cancer tumor formation.

10. **Electricity/energy generation**: Stalks, husks, cobs and other biomass of crops such as corn, wheat and rice unsuitable as direct human food or to livestock generally account for about half of the total biomass. Scientific advances allow producers to turn agricultural residues to generate electricity. Agricultural residues are usually not suitable for direct burning: they are processed into pellets or other forms before being used to produce power, a very requirement in India for paddy husk (www.ucsusa.org/agriculturalresidue). Sweden is the first country of the world whose 40% of the energy requirements are met by burning residues. The process employs sorting of residues and then burning under controlled conditions in furnaces to generate steam/energy to run turbines which

ultimately lead to electricity production transmitted on grid. Sweden is even importing waste from UK, Ireland and Italy to run its waste to energy successful technology program.

11. **Starch:** Starches are generally being isolated of potato, maize, rice and wheat and used for various food and non-food applications. However, specialized starches can be obtained of mango and litchi kernels. Both mango and litchi have 30-35% of their weight in the form of seeds. After industrial processing, considerable amounts of mango and litchi kernels (seeds) are discarded as waste which creates problem for both industry and environment. Isolation of starch can minimize industrial waste and adds to profit (Thori and Sandhu, 2017). Garg and Tandon reported 58% starch in mango kernels.

12. **Edible cutlery**: Plastic made cutlery/tableware are sure shot problem to human health and to environment. Non-recycled waste is engrossing our landfills and contaminating the earth and its wildlife populations. Plastic items used in our kitchen consist of polystyrene which discharges a chemical known as styrene that could increase the risk of lymphoma and leukemia (types of cancer). The average time for one plastic bottle to decompose is 450 years. In spite, the edible cutlery is a bio-degradable option that has a shelf life of three years and decomposes within four-five days (https://www.forbes.com/sites/micakelmachter/2016/03/30/indias-edible-cutlery-paves-the-way-for-asia-to-dream-of-zero-waste/#650643d11ef9). The base material for cutlery includes rice, ajwain, wheat, jowar flour, black pepper etc. which are then baked dry and made in different shapes and sizes. The spoon doesn't get soggy even in hot food and water. Narayan Peesapaty, the founder and Managing Director of *Bakey's Food Private Limited* from Hyderabad, has invented and introduced edible cutlery to India. It's available in 3 flavours sweet (little sugar), plain and spicy (with rock salt, black pepper, cumin seed and ajwain) (http://www.deccanchronicle.com/lifestyle/food-and-recipes/210316/hyderabad-man-invents-edible-cutlery.html).

13. **Specialized oil:** The stones of some fruits (e.g., mango, apricot, and peach) comprise substantial quantities of oil or fat and used for culinary, perfumery or toiletry applications. Palm kernel oil is used as cooking and industrial oil. Seeds of some fruits seeds (e.g., grape, papaya and passion fruit) contain oil with a specialized market. The process involves grinding the seeds and nuts to release the oil at quite low temperatures. Nuts and kernels are broken, minced using powered hammer mill which is followed by oil expression using a press or solvent extraction (Monspart-Senyi, 2006).

14. **Animal feed**: Straw/husk of wheat, guar and mustard are used in chopped form or in cake form for animal feed since these agro-residues contain mainly cellulose and other polysaccharides along with minerals. Other green residues of vegetables, fruits (processing waste) can also be fed to animals.

15. **Candied peel:** Boiling of slices or shreds of peel in 20%-sugar syrup for 15–20 min and then increasing the sugar concentration in the syrup to 65–70^{o}B makes citrus (orange, lemon, and grapefruit) peel as sweet candies or shreds. Soaking is done for 4-5 days followed by drying. Candied peel can be used in baked goods and snack food while shreds in marmalades (Monspart-Senyi, 2006).

16. In addition, rice bran oil, protein, fiber etc. are also extracted of agro-wastes.

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Processing and Value Addition of Horticultural Crops for Doubling the Income of Farmers

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The horticultural sector has established its credibility for improving land use, generating employment and nutritional security. To save glut wastage of agri-produce and create circumstances for higher economic returns to the growers and realize Govt's Program to Double the Income of Farmers, Govt. of India has undertaken several initiatives in the recent past in terms of implementation of ease of doing business, creating an enabling policy framework and development of infrastructure facilities to make it easy for organizations in the farming, agriculture and food processing sectors to set up and do business in the country.

Through the use of improved varieties and advanced agricultural technologies, India has achieved self-sufficiency in agriculture. India leads the World in production of milk, bananas, guavas, mangoes, cashew nuts and buffalo meat while it is second in rice, wheat, groundnuts, sugarcane, peas and onions.

However, at the ground level, the farmer is not progressing at the same rate. Farmers are not getting enough income from their produce. In face of lack of other alternatives, they have to rely on middlemen and money lenders. Income from the farm is no longer assured as agriculture is itself facing huge challenges from the fluctuating climate and the falling soil productivity. Due to lack of income from farming activities, farmers are under the pressure of huge debts and resort to suicides. A large proportion of the farmers' produce gets wasted due to lack of price availability and distant markets. The post harvest losses of agricultural produce at national level were estimated to be Rs. 92,651 crores (MOFPI, 2017). These losses amount to 4.65-5.99 % for cereals, 4.58-15.88% for fruits and vegetables, 6.36-8.41% for pulses, 3.08-9.96% for oilseeds and 6.74% for poultry.

Farm scale processing of the produce by the farmer or groups of farmers involving other family members of the farmers such as farm women and unemployed youth can help generate income. Hence there is need to develop farm-scale or farm-ready technologies at the universities and institutes. Further it is necessary that these research findings should be extended to the farmers. This necessitates the provision of trainings and other technical know-how to the farming community. The processing activity will also help to increase demand of their crop produce and lead to its value addition. This will help in encouraging farmers to become small-scale entrepreneurs.

India is the second largest producer of fruits and vegetables in the world. India produced 86.602 million metric tonnes of fruits and 169.478 million metric tonnes of vegetables. The area under cultivation of fruits stood at 6.110 million hectares while vegetables were cultivated at 9.542 million hectares. Punjab produces around 16.4 lakh tons of fruits with Kinnow being the largest produce of the State and 42.4 lakh tons of vegetables with potato making more than 50% of the vegetable production. Eighteen per cent of India's fruit and vegetable production - valued at Rs 13,300 crore - is wasted annually, according to data from the Central Institute of Post-Harvest Engineering and Technology. Currently, India has 6,300 cold storage facilities unevenly spread across the country, with an installed capacity of 30.11 million metric tonnes. Studies have shown this is half the amount of cold storage facilities that India actually needs. Cold storage capacity for all food products in the country should be more than 61 million metric tonnes. In order to reach that target, the report says an investment of more than Rs 55,000 crore is needed by 2015-2016 just to keep up with growing fruit and vegetable production levels.

In India only 2.2% fruits and vegetable produced are processed against 65% in US, 70% in Brazil, 78% in Philippines, 80% in South Africa and 83% in Malaysia. The annual wastage of fruits and vegetables in India is estimated at Rs. 25,000 crores .The value addition is only 7% in India as against 23% in China and 188% in UK.

The vast production base offers India tremendous opportunities for export. During 2015-16, India exported fruits and vegetables worth Rs. 8,391.41 crores which comprised of fruits worth Rs. 3,524.50 crores and vegetables worth Rs. 4,866.91 crores. India's exports of Processed Food was Rs. 26,067.64 Crores in 2015-16, which includes the share of products like Mango Pulp (Rs. 796.17Crores), Dried and Preserved Vegetable (Rs. 914.21 Crores), Other Processed Fruit and Vegetable (Rs. 2,900.33 Crores), Pulses (Rs. 1,603.22 Crores), Groundnuts (Rs. 4,046.05 Crores), Guargum (Rs. 3,233.87 Crores), Jaggery & Confectionary (Rs. 1,289.26 Crores), Cocoa Products (Rs. 1,266.99 Crores), Cereal Preparations (Rs. 3,341.31 Crores), Alcoholic and Non-Alcoholic Beverages (Rs. 2,005.13 Crores) and Miscelleneous Preparations (Rs. 2,593.49 Crores).

The Indian food processing industry is basically export oriented. India's geographical situation gives it the unique advantage of connectivity to Europe, Middle East, Japan, Singapore, Thailand, Malaysia and Korea. According to the data provided by the Department of Industrial Policies and Promotion (DIPP), the food processing sector in India has received around US$ 7.47 billion worth of Foreign Direct Investment (FDI) during the period April 2000-December 2016. The Confederation of Indian Industry (CII) estimates that the food processing sectors have the potential to attract as much as US$ 33 billion of investment over the next 10 years and also to generate employment of nine million person-days. Food Processing Industry - Scheme for Technology Upgradation/ Establishment/ Modernization for Food Processing Industries.This Scheme covers the following activities: Setting up/expansion/ modernization of food processing industries covering all segments viz fruits & vegetable, milk product, meat, poultry, fishery, oil seeds and such other agri-horticultural sectors leading to value addition and shelf life enhancement including food flavours and colours, oleoresins, spices, coconut, mushroom, hops. The assistance is in the form of grant subject to 25% of the plant & machinery and technical civil work subject to a maximum of Rs. 50 lakh in General Areas and 33.33% upto Rs. 75 lakh in difficult areas.

Food Industry Business Incubation Centre (FIC) under the Department of Food Science and Technology was established by Punjab Agricultural University with technical guidance from the Ohio State University, USA in June, 2015

The primary objectives of Food Industry Business Incubation Centre are:-

- To provide incubation facilities to the food industry, young entrepreneurs and farmers.
- To develop linkages between PAU, farmer and food industry for the development of food processing industry in the region.
- To develop and upscale technologies for processing and value addition of agricultural produce.
- To conduct short courses and trainings for the development of entrepreneurship skills in rural youth, farm women, budding entrepreneurs, NGOs, Self Help Groups and to increase the efficiency and effectiveness of Food Industry operations.

Technologies set up in the Food Industry Centre: Minimal processing techniques, Heat preservation techniques, Cold Preservation, Drying and dehydration, Juices and beverages, Canning, Packaging and Soy milk processing.

Important technologies developed by the department include sarson ka Saag, integrated processing technologies for tomato, potato, mushroom, carrot, baby corn, pear, kinnow, guava, grapes, jamun, peach, plum products, juices and beverages, flat bread technology, high protein, low calorie, high fiber and low or no sugar baked products ,instant dalia and sooji, multigrain 'dalia', 'atta', instant porridge and snacks, variety extruded snack foods, vegetable impregnated paneer, functional cereal/fruit and vegetable/meat/dairy products. More than seventeen technologies developed and up scaled at Food Industry Business Incubation Centre under Department Food Science and Technology has been transferred to different stakeholders for commercialization.

Food Industry Business Incubation Centre also conducts research as desired by various organizations and provide business incubation facilities to big. Medium, micro and small enterprises/growers to scale up the technologies developed by Punjab Agricultural University. Various growers of tomato, guava, plum, turmeric, lime, sugarcane and onion have prepared their products in the Food Industry Business Incubation Centre for commercial purposes. Centre covers entire range of food processing with special emphasis on fruits, vegetables and grain based products.

Food Processing Training cum Business Incubation Centre Bathinda, Punjab was established on 7th July,2015 by the combined efforts of Mrs Harsimrat Kaur Badal, Honorable Union Minister, Ministry of Food Processing Industries

& Former Punjab Chief Minister S. Prakash Singh Badal and the technical guidance from Department of Food science and Technology, Punjab Agricultural University and IICPT, Thanjuvar. Center was made with well furnished Infrastructure facilities and processing lines i.e. Fruit and vegetable products processing lines; (Juice Bottling line, drying and dehydration, canning, pulping and cold chambers.), Cereals, coarse grains, pulses, nuts and oilseeds products processing line (Bakery, Spices and condiments) were set in the incubation center. In the center, 1day, 2-4 days & 6 weeks hands-on skill development and entrepreneurship development training programmes in food processing are given. Incubation facilities and consultancy services are provided to start new food industries in the state, for expansion and for modernization of existing food industries. A Food Testing Laboratory is also being set up at Regional Research Station , Bathinda with grant in aid from MOFPI. Followoing are certain challenges observed in this sector.

In recent times, considerable emphasis has been placed on the handling of fresh fruits and vegetables. Methods such as aseptic packaging, cryogenic freezing, deep freezing, accelerated freeze drying, controlled and modified atmosphere storage, shrink wrapping etc. have been increasingly used in extending the shelf life of fruits and vegetables. These technologies must be adopted if India is to keep a pace with the rest of the World.

The selection of suitable varieties is, therefore, essential. Linking production to postharvest operations is essential to optimizing results. Pre-harvest parameters such as selection of proper planting material, crop management, and disease and pest control must be geared toward producing high quality produce. Once the crop is ready for harvest, attention must be paid to the harvesting technique/procedure. Poor harvesting

practices can lead to irreparable damage to horticultural produce. It is therefore necessary to standardize maturity indices and harvesting techniques for each and every fruit and vegetable in order to minimize damage at the time of harvest.

The adoption of **cold chain systems** has been pivotal to trade in fruits and vegetables in developed countries. The maintenance of low temperatures at different stages of handling helps in reducing losses and in retaining the quality of fruits and vegetable. High cost and the lack of abundant uninterrupted power supplies, make it impossible to develop cold chain systems in India. Consideration should, however, be given to the development of alternative cooling systems based on evaporative cooling techniques. Systems of this type would at least reduce postharvest deterioration and extend the shelf life of fresh fruits and vegetables.

Following are the technologies and methods of preservation involved in value addition of fruits and vegetables. :

Control Atmosphere/Modified Atmosphere Storage (CAP/MAP) : Controlled/ modified atmosphere storage and packaging has emerged as most significant food preservation technology as there are no additives and least or nil processing is involved.

Active packaging: This is an innovative approach of food preservation .This is a group of technologies in which the package is actively involved with food products or interacts with internal atmosphere to extend the shelf life while maintaining quality and safety. This is next generation packaging technology for preservation of fruits and vegetables by delaying ripening and preventing microbial growth.

Technology for fresh cut fruit and vegetable produce: Fresh cut processing involves adding value to a raw agricultural commodity (fruits and vegetables) by preparing (cleaning, cutting and packaging) them for consumer use. Consumers of such products are retail consumers, as well as food service establishments (restaurants, hotels and hospitals). Fresh cut products are attractive to consumers because they offer uniform price, size, convenience, reduced preparation time and 100% useable product. Adopting this technology at farm gate not only minimizes city sewage disposal problems but also will provide employment for the rural folk.

Frozen fruits and vegetables: Freezing has been a major factor in bringing convenience foods to the home, restaurant and institutional feeding establishments, because it preserves food without causing major changes in their size, shape, texture, colour and flavour. Freezing permits much of the work in preparing a food item or an entire meal to be done prior to the freezing step. This transfers operations that formerly had to be done in the home or restaurant to the food processor. The wide array of available frozen food products, many sold in their final serving dishes, represent a major revolution in the food industry and reflects gross changes in eating habits.

Dehydrated Fruits and vegetables: The process of dehydration involves removal of water from the food under controlled conditions. Food may be dehydrated to decrease weight and bulk. Various dehydrated products i.e. potato chips, potato powder , green leafy vegetables, tomato halves and powder, mushroom powder have been prepared by several basic drying methods i.e. cabinet drier, fludized bed drier, spray driers, freeze dehydration, solar and sun drying depending upon the type of food to be dried and the quality level that must be achieved and the cost than can be justified. In these products removal of all water leaves one-eighth the weight. These reductions can result in lower transportation and container cost.

Fabricated Foods: Food fabrication is the concern of food technologists for increasing the quantity and variety of food available to man and to meet the need of metabolically handicapped. Fabricated foods results in development of more economical, substitutes or analogs eg texturised vegetable protein based meat analogues, soyabean wari etc. This involves putting together of various nutrients in the desired proportion and imparting them organoleptic qualities through the use of additives and suitable processing.

Aseptic Packaging: A new technology for aseptic packaging i.e. processing of fruit juice/ concentrate that entered India is Bag- in-Box filling method wherein a sterile product is filled in sterile pack under sterile conditions with better quality and reduced energy cost. About 15 years back, aseptic processing was introduced in India and there are about 25 plants in India. In about 10 plants concentration is being taken up. Fruit juices, nectars, tomato puree, coconut water etc. are available. Much needs to be done for aseptic packaging fruit cubes and vegetable slices in there own juice and syrup, called particulate food which have good export demand.

Retort Pouch Processing: The advent of retort pouch processing technology has made the availability of shelf stable , ready-to-eat foods a reality in the Indian market having very high value addition since they offer the convenience of eating .These products do not contain any chemical preservatives and remain shelf stable without refrigeration for at least 1 year.

Extruded snack foods and breakfast cereals: Dried vegetable powder, antioxidants, dried fiber can be used as a source of nutrition and to add variety to the extruded snack foods. These can also add the natural colour to these foods giving them better acceptability.

Pickle and Sauerkraut: Sauerkraut or cucumber pickles are prepared by a natural lactic acid fermentation in the presence of small amounts of salt. They are also preserved in vinegar and salt. There are large variety of pickles which are mainly made from mango, lime, Indian gooseberry (amla), chilli, vegetables such as egg plants, carrots, cauliflower, tomato, bitter gourd, ginger, garlic, onion etc. Mango pickle in summers and carrot, turnip and cauliflour pickle in winter are two very common pickles eaten in all Indian houses. Gherkins are being exported from Indian market.

Chutney & Sauces : Lot of fruits and vegetables are made into delicious chutneys and sauces like mango chutney, apple chutney, vegetable sauce, apricot sauce and chutney. Our country is exporting some of the chutneys also.

Tomato products : Tomato being the richest source of an anti-oxidant “Lycopene” is processed into paste, puree, juice, soup, ketchup and tomato salsa.

Juices and beverages: Fruits and vegetables are the fastest growing segment of food industry in India. The country grows a large variety of fruits and vegetables due to its versatile environment. There is a great potential for manufacturing of juices and beverages by blending strong coloured and flavoured fruits and vegetables like grapes, jamun, beet root, purple carrots, tomatoes, beetroot, mango, pineapple guava, peach etc. These fruits and vegetables are ready-made power houses of quality that are important building blocks for a healthy body.

Suger Preseved products: Suger Preseved products based on fruits and vegetables like jam, jellies, marmalades, conserves, preserves and candies have become very popular in India. Some of these have great export potential.

Department of Food Science and technology has developed jams , preserves and candies from aonla, pear, peach, guava, kinnow, fig and carrot.

Potato chips: Various varieties of potatoes are found suitable for making chips and French fries i.e. Kufri jowar, K jyoti, Chipsona I and Chipsona III . Indigenous dehydrated potato slices and flour is prepared and used in various food preparations and extruded products. Various traditional potato products/ snacks like papad, wari, sevian are prepared from medium and high sugar potato varieties.

Utilization of Industrial Waste

Considerable volumes of unmarketable and physically damaged fruits and vegetables that are without infection can be converted into value added products by processing.

Biocolours: Bio colours are extracted from different plant origins and industrial waste like carotenoids (extruded from carrots) flavone (from citrus peel/ pulp), oleoresin (extruded from red capsicum) , chlorophylls (from green leafy vegetables) anthocyanins (from red, purple fruits and vegetables), lycopene (from tomatoes) and betanin (from beet root). Some of them have been used in preparation of ice-creams, snack foods, breakfast cereals, breads, biscuits and cakes.

Conclusion

Proper post-harvest handling and management through primary and secondary processing of the perishables is the only solution to manage the situation of glut and heavy postharvest losses of perishables. A number of deficiencies currently exist in the postharvest management and processing of fruits and vegetables in India. The establishment of infrastructural facilities for postharvest operations is a one time capital investment which must be undertaken and compensated for by the annual savings from reducing postharvest losses. Proper infrastructure, logistics and management and human resources are essential to improve postharvest management and marketing of fruits and vegetables.

In the past, fruits and vegetables were processed primarily into jams, jellies, chutneys, etc. Canning and dehydration were considered to be the most sophisticated methods of processing, prior to the discovery of rapid freezing. Cold storage has considered the only method suited to extending the shelf life of fruits and vegetables, until the development of modified and controlled atmosphere storage. Relatively little emphasis was placed on the handling of fresh fruits and vegetables.

In recent times, considerable emphasis has been placed on the handling of fresh fruits and vegetables. Canning has become practically obsolete and methods such as aseptic packaging, cryogenic freezing, deep freezing accelerated freeze drying, controlled and modified atmosphere storage, shrink wrapping etc. have been increasingly used in extending the shelf life of fruits and vegetables. These technologies must be adopted if India is to keep a pace with the rest of the World.

In order to promote quality and safety consciousness, emphasis should be given in particular to assure the use of water of appropriate quality in pre and post-harvest operations, as well as the appropriate use of pesticides, herbicides fungicides and fertilizers during the production of fruits and vegetables. The implementation of regulatory frameworks which govern food safety and quality, laboratories and quality assurance services is required in many countries across the region. Stringent quality management systems such as Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Point (HACCP) as well as proper packaging and temperature management are, therefore, required to assure food safety and freshness.

Entrepreneurship Development through Apiculture/ Honey Processing

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Honey processing plays a vital role in maintaining the quality of honey which depends on the type of honey as well as the machinery used for its processing. Generally, there are two types of honey-forest and apiary honey. The forest honey is produced by wild bees viz; *Apis dorsata* (rock bee) and *A. florae* (Little honey bee) and is collected by traditional honey hunters and tribals by squeezing the combs. Normally this honey has more moisture and extraneous matter likely to be at higher risk of spoilage. The apiary honey, on the other hand is produced by *A. cerana* (Indian honey bee) and *A. mellifera* (European honey bee) apiaries and collected by modern extraction methods. In order to maintain the natural quality and to prevent spoilage, it is necessary to process the honey before marketing. Honey is processed in order to destroy yeast cells, reduce the moisture content, delay granulation and to remove the extraneous matter like pollen, bees wax, dirt, air bubbles and other solid particles. Entrepreneurship in honey processing has become a remunerative business in punjab due to its high demand worldwide.

Honey is high viscosity product of characteristic flavor and aroma, colour and texture. The principal characteristics and behaviour of honey are due to its sugars, but the minor constituents such as flavouring materials, colour, pigments, acids and minerals are largely responsible for the differences among individual honeys. Honey is a good source of carbohydrate, minerals, amino acid, protein and vitamins thus considering itself as a complete diet. Honey is typically composed of Fructose (38.2%) ,Glucose (31.3%), Sucrose (1.3%), Maltose(7.1%),Water(17.2%), Higher sugars (1.5%), Ash (0.2%) and Other/undetermined (3.2%). Honey has a density of about 1.36 kilograms per liter (36% denser than water). Honey is classified by its floral source, and there are also divisions according to the packaging and processing used. There are also regional honeys. Honey is also graded on its color and optical density by USDA standards, graded on a scale called the Pfund scale, which ranges from 0 for “water white” honey to more than 114 for “dark amber” honey.

Classification of honey by Floral Source

Generally, honey is classified by the floral source of the nectar from which it was made. Honeys can be from specific types of flower nectars, from indeterminate origin, or can be blended after collection.

Blended: Most commercially available honey is blended, meaning that it is a mixture of two or more honeys differing in floral source, color, flavor, density or geographic origin.

Polyfloral: Polyfloral honey, also known as wildflower honey, is derived from the nectar of many types of flowers. The taste may vary from year to year, and the aroma and the flavor can be more or less intense, depending on which bloomings are prevalent.

Monofloral: Monofloral honey is made primarily from the nectar of one type of flower. Different monofloral honeys have a distinctive flavor and color because of differences between their principal nectar sources. In order to produce monofloral honey beekeepers keep beehives in an area where the bees have access to only one type of flower. In practice, because of the difficulties in containing bees, a small proportion of any honey will be from additional nectar from other flower types. Typical examples of North American monofloral honeys are clover, orange blossom, sage, tupelo, buckwheat, and sourwood. Some typical European examples include thyme, thistle, heather, acacia, dandelion, sunflower, honeysuckle, and varieties from lime and chestnut trees. In North Africa, such as Egypt, examples include clover, cotton and citrus, mainly orange blossoms.

Honeydew honey: Instead of taking nectar, bees can take honeydew, the sweet secretions of aphids or other plant sap-sucking insects. Honeydew honey is very dark brown in color, with a rich fragrance of stewed fruit or fig jam and is not sweet like nectar honeys. Germany’s Black Forest is a well known source of honeydew-based honeys, as well as some regions in Bulgaria. In Greece, pine honey (a type of honeydew honey) constitutes 60-65% of the annual honey production. Honeydew honey is popular in some areas, but in other areas beekeepers have difficulty selling the stronger flavored product.

The production of honeydew honey has some complications and dangers. The honey has a much larger proportion of indigestibles than light floral honeys, which can cause dysentery to the bees, resulting in the death of colonies in areas with cold winters. Good beekeeping management requires the removal of honeydew prior to winter in colder areas. Bees collecting this resource also have to be fed protein supplements, as honeydew lacks the protein-rich pollen accompaniment gathered from flowers.

Bastard Honey: Bastard honey is honey whose floral origins are unknown. Compared to monofloral honey, honey from one type of plant, or polyfloral honey, honey that has been mixed, bastard honey's origins are either unknown, undisclosed, or something else of the sort. The idea of bastard honey comes from the idea of illegitimate honey, whose ancestry is unknown.

Classification by packaging and processing

Generally, honey is bottled in its familiar liquid form. However, honey is sold in other forms, and can be subjected to a variety of processing methods.

- **Comb honey** is honey meant to be consumed still in the honeybees' wax comb. Comb honey traditionally is collected by using standard wooden frames in honey supers. The frames are collected and the comb cut out in chunks before packaging. As an alternative to this labor intensive method, plastic rings or cartridges can be used that do not require manual cutting of the comb and speed packaging. Comb honey harvested in the traditional manner is also referred to as "Cut-Comb honey".
- **Chunk honey** is honey packed in wide mouth containers consisting of one or more pieces of comb honey immersed in extracted liquid honey.

Organic

Organic honey and honey combs are those produced, processed and packaged in accordance with the principles of organic farming. Often organic honey is certified as meeting organic standards by some government agency or an independent organic farming certification organization. In the United Kingdom, the standard covers not only the origin of bees, but also the sitting of the apiaries. These must be on land that is certified as organic, and within a radius of four miles from the apiary site, nectar and pollen sources must consist essentially of organic crops or uncultivated areas.

Varieties of processing

- **Crystallized honey** is honey in which some of the glucose content has spontaneously crystallized from solution as the monohydrate. Also called "granulated honey."
- **Pasteurized honey** is honey that has been heated in a pasteurization process. Pasteurization in honey reduces the moisture level, destroys yeast cells and liquefies crystals in the honey. While this process sterilizes the honey and improves shelf-life, it has some disadvantages. Excessive heat-exposure also results in product deterioration, as it increases the level of hydroxymethylfurfural (HMF) and reduces enzyme (e.g. diastase) activity. The heat also affects appearance, taste, and fragrance. Heat processing can also darken the natural honey color (browning).
- **Raw honey** is honey as it exists in the beehive or as obtained by extraction, settling or straining without adding heat (although some honey that has been "minimally processed" is often labeled as raw honey). Raw honey contains some pollen and may contain small particles of wax.
- **Strained honey** is honey which has been passed through a mesh material to remove particulate material (pieces of wax, propolis, other defects) without removing pollen, minerals or valuable enzymes.
- **Ultra-filtered honey** is honey processed by very fine filtration under high pressure to remove all extraneous solids and pollen grains. The process typically heats honey to 150–170 °F (approx 65-77 °C) to more easily pass through the fine filter. Ultra-filtered honey is very clear and has a longer shelf life, because it crystallizes more

slowly because of the high temperatures breaking down any sugar seed crystals, making it preferred by the supermarket trade. The heating process degrades certain qualities of the honey similar to the aforementioned pasteurization process.

- **Ultrasonicated honey** is honey that has been processed by ultrasonication, a non-thermal processing alternative for honey. When honey is exposed to ultrasonication, most of the yeast cells are destroyed. Yeast cells that survive sonication generally lose their ability to grow. This reduces the rate of honey fermentation substantially. Ultrasonication also eliminates existing crystals and inhibits further crystallization in honey. Ultrasonically aided liquefaction can work at substantially lower temperatures of approximately 35 °C (95 °F) and can reduce liquefaction time to less than 30 seconds.
- **Whipped honey** also called creamed honey, spun honey, churned honey, candied honey and honey fondant is honey that has been processed to control crystallization. Whipped honey contains a large number of small crystals in the honey. The small crystals prevent the formation of larger crystals that can occur in unprocessed honey. The processing also produces a honey with a smooth spreadable consistency.
- **Dried honey** has the moisture extracted from liquid honey to create a completely solid, non-sticky honey. This process may or may not include the use of drying and anti-binding agents. Dried honey is commonly used to garnish desserts.

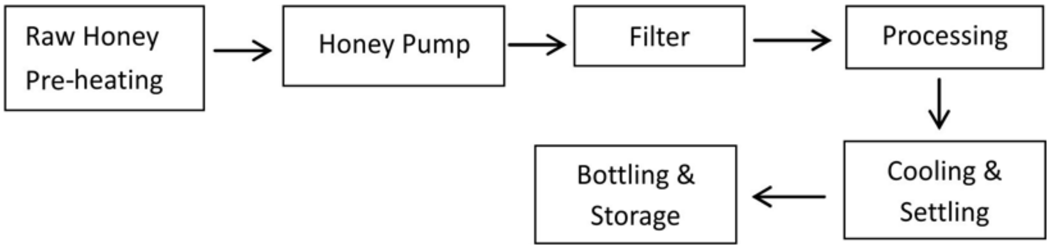
Post-Harvest Handling

Honey Heating: Honey is heated to increase its flowability for ease in its filtration, prevent granulation problem and for bottling the honey (packaging). This heating is mostly done in a very crude manner either directly or indirectly without any consideration to the temperature and exposure period. Such higher temperatures are known to result in discoloration, loss of characteristic flavour, aroma, vitamins, enzymes and even break down of sugars resulting in increase of hydroxymethyl furfural (HMF) content moreover, direct heating may even result in caramelization of honey. Sometimes, the beekeepers deliberately do it to darken the honey so that it is more acceptable to consumers. Actually consumers have more appeal for darker honey. The colour of honey depends on source flora, darker the colour higher will be the mineral content. The honey is also heated to delay granulation thus there is always a need to properly regulate the temperature during heating. For ease in filtering, the viscosity of honey has to be brought down appreciably. If this is the only objective, then heating the honey up to 40°C will suffice because further increase in temperature would not significantly bring down viscosity any further. The filtering process can even be speeded up by the use of some gear pump or vacuum pump. In the former, haziness may be produced because of air trapping in the form of some air bubbles. However, on settling it becomes crystal clear. The filtering at this temperature may separate out wax, the melting temperature of which is 62-65°C. Even while heating, there should be provision of continuous stirring of honey since otherwise the honey on the periphery may be exposed to higher temperatures than that at the centre. This is particularly true in the case of granulated honey since its thermal conductivity is very low and known to be about one tenth of that of liquid honey. During heating process, the honey should never be exposed to outer environment i.e. the heating should be carried in an enclosed container to preserve its flavour, aroma as it would not let the constituents with high vapour pressure to go off i.e. volatile substances should not escape.

Granulation in itself is not a problem. Every honey has its tendency to granulate sooner or later. The granulated honeys in our country do not find consumer acceptability as these are considered as adulterated honeys. The granulation depends upon dextrose water (D: W) ratio of honey, the storage temperature and presence of pollen grains and impurities. The honeys with D: W ratio of more than 2:1 granulate quickly and those with less than 1.8 do not granulate. The storage temperature around 14°C favors the crystallization of dextrose. This is all because honey is a supersaturated solution of sugars and on exposure to low temperature, the dextrose separates out as crystals. This crystallization is enhanced by the presence of material such as pollen grains and other fine impurities. While heating for avoiding granulation, every effort should be made not to exceed recommended temperatures i.e. the honey should be heated up to 77°C for only 5 min and then immediately be brought to 57°C and then stored.

Processing: The thumb rule is that the least processed honey is the best honey. However, the processing has become a necessary evil. Honey processing is termed as the indirect heating of honey at controlled temperatures and durations to facilitate its filtering, destroying all the yeast cells thereby preventing fermentation and delay granulation besides retaining its natural flavour, colour, aroma and other constituents.

The flow chart of the honey processing plant (HPP), unit-operation wise, has been shown as under:



Even though it is fact that the least processed honey is the best honey, yet in India honey processing is highly stressed upon since it is never pondered upon as to what the honey processing is and if there is any need for so called honey processing. The exhaustive unit operations which may be required depending upon the above two factors are pre-heating, pumping, filtration, pasteurization, anti-granulation treatment, moisture reduction, settling and packaging.

Packaging**:** Honey packaging technology is lacking in India. The packaging/ bottling of honey in itself is problematic because of honey being too viscous. If the bottling temperature is higher, it creates numerous air bubbles but these bubbles are smaller in size and readily rise up to the surface and may result into froth. But if the temperature is low, the bubbles produced are only a few but these are larger in size and do not readily rise to the surface. So while bottling, the tip of funnel should touch the bottle and should remain submerged in honey to check the air trapping or the funnel tip should touch the side wall of bottle. The vacuum packing technology may, however, totally avoid the problem of air trapping. While purchasing honey, it must be stressed upon that the honey does not have froth at its surface as it enhances its fermentation thereby reducing its shelf life.

Storage: There is an orthodox that the older the honey, the better it would be. Scientifically, however, it is not true. Honey quality deteriorates during storage with time which is actually governed by the storage temperature, moisture content of honey, storage structure and ambient relative humidity. Honey becomes darker in colour during storage, more rapidly so at higher temperatures. Contamination with metals also darkens honey. Sugars such as glucose, sucrose and fructose also decrease during storage. The breakdown of various sugars results into increase in hydroxymethyl furfural (HMF) which is a very sensitive indicator of honey quality. Higher HMF is also an indication of heated honey. In India where temperatures are generally higher, HMF is likely to cross the limits if stored at room temperature. So, there is a strong need for appropriate storage conditions if our honey has to find market outside India. According to our common Indian Standards (AGMARK), only fiehe test is prescribed, but it is only qualitative and does not depict the degree of deterioration.

The honey stored under refrigerated conditions does not spoil and shelf life remains quite long. However, during storage, the air-tightness of container must be ensured and the pack should immediately be closed after its use. It is so because honey being hygroscopic, may absorb moisture from environment which may trigger off some fermentation and spoilage may occur.

Unit Operations involved in a Modern Honey Processing Plant:

Liquification: Raw and granulated honey is liquefied in a liquefier at 40°C for 30 minutes in order to reduce the viscosity and increase the flowability of honey through the system.

Preheating and Straining: In the stainless steel preheating tank provided with coarse filter mesh (50-80 mesh size) to exclude coarse particles and a stirrer for uniform heating, the liquefied raw honey is heated and maintained at 45°C by circulating hot water through hot water jacket using centrifugal pump. At 45°C bees wax does not melt.

Micro-filtration: Through gear pump, honey is pumped to special polyurethane cartridge type filter to remove suspended solids of upto 40 microns which removes practically all dust, bee particles, foreign particles and pollen grains. In place of such filters, long type cloth filters or stainless steel filters or simple filters are also being used.

Pasteurization: Honey is then passed through helical coil heat exchanger maintained at a temperature of 60-70°C under vacuum for 15 minutes to inactivate the yeast cells. Honey is then taken to intermediate feeding tank at the same temperature of 60-70°C.

Moisture Reduction: Honey is then fed to falling film type heat exchanger where temperature is maintained at 60-65°C. The falling film not only evaporates the water from a thin film of honey (up to 8-10% max.) but also pasteurizes the honey. The vapours are cooled down and collected separately. Both moisture reduction and pasteurization is carried out under vacuum so that heating time could be reduced. Reduction in heating time also considerably reduces the quantity of Hydroxy Methyl Furfural (HMF) production. The temperature and total time in heat exchangers is controlled and monitored critically not exceed 60-65°C and 25 minutes respectively, thus avoiding any loss of natural quality attributes of honey.

Cooling and Settling of Honey: The processed and moisture reduced honey is immediately cooled by cold water circulations when honey passes through heat exchanger. Honey collected at the bottom of heat exchanger is pumped through a special pump under vacuum to air tight storage-cum-setting tanks.

While all bubbles and foam settle at the top, pure clean honey is taken for bottling with the help of filling machine preventing any human and atmospheric contamination.

Machinery of Commercial honey processing Plant

The investment on different capacity honey processing plant is presented in table 1.

Table 1. Investment on different capacity honey processing plant

Honey Processing Plant	Capacity (Kg/day)	Working Hours/day	Total investment (Rs)
Large Scale	400	8	10, 50, 000
Medium Scale	300	8	8, 55, 000
Medium Scale	200	8	5, 50,000
Small Scale	50/100	8	2, 50,000

Machinery involved

- Preheat tank with mechanical agitator, electric heaters, PT 100 sensor
- Pre-filter with 100 mesh screen
- Pump, gear Pump with motor 1 rpm @ 10 kg. Pr
- Filter: Sparkler type plate filter having PP cloth filter discs of 20 Micron size
- Evaporator: Falling film type with electric heaters and sensors
- Coolers, Settling Tanks with level indicators
- Control Panel all weatherproof with main switch, contractors with various motors, digital temperature indicators and controllers
- Vacuum Pump: dry type vacuum pump with electric motor developing 26 inches of vacuum
- Vacuum lines, electrical wiring etc.

Accessories required:

- Honey liquefier
- Raw honey storage tanks
- Honey processing unit (H.P.U.)
- Processed honey storage tanks
- Bottle filling machine

- Bottle cap sealing machine
- Bottle washing tray
- Bottle dryer

Quality Check and Norms of Honey

Some scientists even advocate the addition of water into honey to avoid granulation problem. But it has been laid out that nothing is to be added or subtracted from honey and it has to be sold in natural form. Such recommendations may make the consumers more cautions and suspicious about adulteration. Moreover, the addition of water not only affects the AGMARK grade status of honey but also make honey more vulnerable to fermentations.

Table 2. Standard Quality Specifications for Honey

Sr. No.	Characteristics	PFA	BIS (IS 4941 : 1994)			AGMARK (1984)			European Code (1969)	Codex Internat-onal (1987)
			Special	A	Standard	Special	A	Standard		
1.	Specific Gravity at 27° C (min.)	—	1.41	1.39	1.37	1.40	1.35	1.35	-	-
2.	Moisture (max.) %	25	20	22	25	20	22	25	21	21
3.	Reducing Sugars (min.)%	65	70	65	60	65	65	65	65	65
4.	Sucrose (max.) %	5	5	5	5	5	5	5	5	5
5.	Ratio L/D (min.)	0.95	1	1	1	1	0.95	0.95	-	-
6.	Ash (max.) %	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	-
7.	Acidity % (as formic acid) ml eq.	0.2	0.2	0.2	0.2	—	0.2	0.2	40 ml eq/ kg	40 ml eq / kg
8.	Fiehe's Test	—	-ve	-ve	-ve	-ve	-ve	-ve	—	—
9.	Aniline Chloride Test	—	—	—	—	-ve	-ve	-ve	—	—
10.	Total count of pollen and plant element / g of honey (max.)	—	50,000	50,000	50,000	—	—	—	—	—
11.	HMF (max.) ppm	—	80	80	80	—	—	—	40	80
12.	Optical Density (max.) at 660 nm	—	0.3	0.3	0.3	—	—	—	—	—
13.	Diastase No. (min.)	—	—	—	—	—	—	—	8	3
14.	Water Insoluble Matters (max.) % of pressed honey	—	—	—	—	—	—	—	—	0.1

Besides various tests prescribed by AGMARK, they have even provision for HMF testing of honey as per International Standards. Various organization such as (PFA, 1974), BIS (IS 4941 :1 974 ; IS 8964 : 1977 ; IS 4941, 1994), AGMARK (1984) and European code (1969) have set various standards (Table 2) for honey based on specific gravity, moisture, quantity or reducing sugars, sucrose, L/ D ratio, ash content, acidity. Fiehe's test, aniline chloride test, HMF and enzymatic (Diastase) activity. On the basis of the above parameters, both BIS and AGMARK have devised three grades of honey *vis.* Special grade, A grade and standard grade. In India, it is the AGMARK standards which are most commonly being followed.

Recent Technological Intervention for Meat and Egg Industry for Entrepreneurship Development

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Food-processing is considered to be a sunrise sector throughout the world, because of its large potential for growth and socio economic impact. It not only leads to income generation but also helps in reduction of wastage, value addition, and foreign exchange earnings and enhancing manufacturing competitiveness. In today's global market, quality and food safety have become competitive edge for the enterprises producing foods and providing services. With proper investment in food processing, technical innovation and infrastructure for agriculture sector, India could well become the food basket of the world. Presently, Indian food processing industry is ranked fifth in terms of production, consumption, export and expected growth. A strong and dynamic food processing sector plays a significant role in diversification of agricultural activities and employment opportunities. Food processing accounts for about 14% of manufacturing GDP, i.e. Rs. 2,80,000 crore, and employs about 13 million people directly and 35 million people indirectly. With the investment of every 1 million rupees, 18 direct jobs and 64 indirect jobs are created in organized food processing industry.

Livestock Industry especially meat and poultry products is most unorganized sector. As per BAHS, 2016 estimates 7.2 MT meats and 82.9 billion egg production with a per capita availability of 5.5 kg meat and 66 eggs per annum. India is one of the biggest exporter of deboned frozen buffalo meat and earns appx Rs 30,000 crores of foreign exchange (APEDA 2016), however, the processing of meat is limited to 2% only.

In many occasions, farmers and producers face uncertainty in marketing various livestock produce from their farms leading to unassured profit due to perishable nature, improper handling and storage. Therefore, these raw materials should be further processed into various ready-to-cook and ready-to-eat meat/egg/poultry/fish products having longer shelf life by the application of various processing technologies and novel preservation methods. The changing lifestyle, urbanization and awareness of consumers lead to the demand of health-oriented livestock products such as low-fat, low-cholesterol, low-calorie, low-sodium, fiber enriched, omega-3 enriched, fortified with micro nutrients. All the processing techniques open up new opportunities for the entrepreneurs. Various new techniques has evolved during the years for mechanization of meat industry, development of extended shelf life products, improvement of quality characteristics and packaging of meat and poultry products.

Recent Techniques

Robotics: The meat industry is also experiencing an uptick in the adoption of automation solutions; however the adoption rate is slow due to intensive capital investments and realization of lower margins. Further, the raw materials (i.e. animal carcasses) have a high degree of variability, which makes developing effective automated solutions a challenge. However, the automation leads to expected increase in efficiency, quality and safety. Different sectors of the food processing industry have adopted robotics at different paces. However, the meat processing sector has been slower to adopt robotics. There are several reasons for this, most notably, sanitation. Robotic components aren't always compatible with the sanitation requirements for surfaces that come into contact with food. However, the FDA recently approved wash-down robots and end-of-arm-tooling (EOAT) for use in direct food contact, which has spurred interest and investment in robotics. In particular, these approvals have helped move robotics into the meat processing industry, where they improve food safety and sanitation by eliminating human contact with the food product. Machines will become more compact and smarter.

High Application of high pressure processing (HPP): High pressure processing can be effectively utilized for tenderization of tough meats, improving the safety and shelf life of processed products. High pressure processing (HPP) allows the decontamination of foods with minimal impact on their nutritional and sensory features. In HPP technology, products are submerged in fluid in a pressure vessel and pressure is generated by pumping fluid into the closed vessel. The HPP technology tenderizes meat with constant pressure exerted over an extended duration and at temperature as high as 40°C. Unlike in canning/retort pouch packaging, HPP technology utilizes high pressure and low temperature for processing, hence the integrity, freshness, taste, nutritive value of products will be maintained. Once the influence of HPP on the muscle proteome is assessed optimum processing conditions will be established and HPP will be applied to meat pieces and sauces.

Pulsed electric field processing: PEF processing involves the application of very short, high-voltage electrical pulses released from two electrodes to a food. Usually, some pulses of 20 -1000 ìs duration with several thousand electric field strength (kV/cm) between some specialized electrodes are required for an effective PEF treatment. PEF efficiency is directly proportional to Electric field, Pulse duration (pulse width x pulse number) and larger cells easily damaged. PEF act as non-thermal hurdle for the growth of spoilage and pathogenic microbes, so help in the production of safe, stable products with the maintenance of desired organoleptic characteristics. PEF is also been applied for pre-treatment of fruits and vegetables prior to extraction of juice or drying. It also helps in treatment of waste and processing water of meat plants.

Innovative cooking technology : In order to limit or prevent the formation of mutagenic compounds during the food cooking, particularly muscle food cooking, it is required to control Maillard reactions by reducing the cooking temperature and limiting water loss experienced by food during cooking. There is therefore a need for the Food Industry to have novel methods for cooking which preserve organoleptic properties of food made of meat or fish, and significantly reduce the new formation of polycyclic or heterocyclic mutagenic compounds. The use of an atmosphere mainly composed of CO_2 during the cooking of a piece of meat in an oven heated to high temperatures allows to significantly reduce the new formation of the majority of the heterocyclic volatile compounds coming from the Maillard reactions, as well as the majority of volatile compounds coming from oxidation reactions (aldehydes, alkyl furans), compared to a conventional cooking performed with air.

Sous vide Cooking: Sous-vide (French word for “under vacuum”) is a method of cooking of food placed in a plastic pouch or a glass jar and cooked in a water bath or steam environment for longer than normal cooking times (usually 1 to 7 hours, up to 48 or more in some cases) at an accurately regulated temperature. The temperature is much lower than normally used for cooking, typically around 55 to 60 °C (131 to 140 °F) for meat, higher for vegetables. The intent is to cook the item evenly, ensuring that the inside is properly cooked without overcooking the outside, and to retain moisture. Sealing the food in sturdy plastic bags retains juices and aroma that otherwise would be lost in the process. The maintenance of temperature in a water bath prevents overcooking. In conventional high-heat cooking, such as oven roasting or grilling, the food is exposed to heat levels that are much higher than the desired internal cooking temperature leading to overcooking or undercooking, if not monitored closely. However, in this the precise temperature control of the water bath results in very precise control of cooking. Moreover, the temperature, and cooking can be even throughout the muscle food including irregularly-shaped and very thick meat cuts. The use of lower temperatures than conventional cooking results in much higher succulence at these lower temperatures, as cell walls in the food do not burst. Tough collagen in connective tissue get hydrolysed into gelatin reduces the toughness and improves juiciness. The exclusion of oxygen from food reduces the problem of oxidation of fat and proteins. It also improves the transfer of heat between the water bath and food, without the thermal insulating properties of any trapped air in the bag.

Enrobing: Enrobing/coating of meat products with edible materials viz. flours, whole eggs liquid and other additives enhance the acceptability of meat products. Enrobing imparts the products a crispy texture and increase the pleasure of eating with more desirable colour. Products will be juicer as natural juice is retained. Edible coating improves texture, flavour, nutritive value, juiciness and tenderness. Coating material act as sealing agent to prevent excess oil absorption. Meat pieces can be enrobed using whole egg liquid, curd, flours, corn flakes and bread crumbs which give crispy taste. Goat meat croquettes, goat meat samosa and goat meat cutlets were standardized at GADVASU.

Product innovation and diversification: Consumers always have internal perceptions, ideas or expectations of the sensorial attributes for a specific food commodity. These perceptions vary with region, community and cooking habits of the people. Any deviations from these expectations could be directly related to differences in quality. For instance, the surimi based products are known for its chewiness and gumminess in texture. The natural taste and color of the product are also very important concerns. The overall characteristic profile of the product may be designed based on consumer's preferences. Consequently, a golden brown color formation in smoked milk fish product may be directly associated to an efficient processing performance. Therefore, innovative idea can be implemented or marketed, if there is improvement in product attributes, process optimization and cost reduction. Marketing serves as the key player in any technological innovations. To develop the marketing strategies, thorough technical knowledge of the product attributes and process is essential for the efficient delivery of the new innovations into the market chains. Evidently, a close coordination between the R& D and marketing is crucial in ensuring a successful innovation and diversification of products.

Innovative packaging: The selection and designing of appropriate packaging technologies for value added products becomes an important segment in product innovations. The processors are looking for the packaging with cooking/ heating convenience, improved product protection and environment safety. Further, it should be designed that the consumer needn't touch the product before putting it in the oven and clean up is easy and mess free. Consumers may need to remove the primary package from a sleeve, detach a label or poke a hole in the pack before popping it in the oven, but no culinary expertise is required to cook the product.

Retorting: Thermal processing of meat destroys microorganisms and enzymes responsible for food spoilage. Thermal processing of foods refers to application of heat to improve digestibility, texture, flavour and destruction of enzymes and microbial population there by increasing the storage life. Thermal processing or application heat can be broadly categorised in below 100 ^{0}C and above 100^{0}Ctemperature.Meat and meat products are cooked by any one or a combination of three methods dry heat, moist heat and microwave cooking. Thermal processing in metal cans or retort pouches increases shelf life of products and decreases 50% processing time.

Least cost formulations: The meat and egg products should be developed/formulated in a manner to improve the nutritive and sensory quality with a reduction in the cost of production, so that the nutritive animal protein should be available to the masses at affordable prices. Incorporation of seasonal vegetables such as cabbage, cauliflower, carrot, bottle guard, pumpkin, etc.in meat products would be advantageous to reduce cost of meat products, to provide fiber and flavonoids in meat products, to facilitate consumption of vegetables and to provide balanced and healthful diet meat products. Meat products added with vegetables may find wide popularity among Indian consumers. It will improve the functionality of the product.

Restructured meat products: Restructured meat products are becoming an important component of the meat industry due to benefits like convenience in preparation, less demanded meat trimmings, different shapes product with improved tenderness, juiciness and flavour characteristics at economic cost. Moreover, restructured meat products can be formulated as per the requirement of a specific group of consumers seeking low fat, low salt, high dietary fibre and antioxidants in meat products. Various extenders and binders are used to improve the functionality, acceptability and economic viability of these products. The limitations of restructured meat products are rapid lipid oxidation during storage which deteriorates its colour and flavour. Moreover, low value cuts when incorporated also affect tenderness and colour of restructured meat products. Restructuring implies binding or holding of small meat pieces together using natural proteins to form a meat product with the properties of steak and roast meat. These products are called, reformed, flaked and formed, chopped and shaped and chunked and formed depending on large extent by the size of the constituent pieces. Sometimes they are also referred as intermediate value products. This type of product is preferred by the consumer and marketed as intermediate in value between traditional burgers and intact muscle steak. Restructured products have sensory characteristics somewhere between ground meat and intact muscle steaks. The purpose of producing restructured products is to effectively market low value carcasses of spent or aged animals with poor conformation and carcass components. Several methods like tumbling and massaging and blade tenderization facilitate production of high quality restructured products.

Value added Egg Products:

Various processed egg products were developed at GADVASU, whose patent technologies are transferred to entrepreneurs for their commercial exploitation. These products are now available Pan-India. Many varieties (mango, pine apple, plain) of egg jam were developed which has protein content in the range of 14-16% in comparison to regular fruit jams which has protein content of <1% (Chatli et al, 2014 published patent). Sugar-free egg jam was also developed, which has calories content reduced by almost 50%. Egg based chutney was also developed which has tangy flavour and sweet and salty in taste, it has protein content of 15.63 to 17.42 % and fat 4-6% (Chatli et al, 2014 published patent). Fiber enriched egg nuggets, cutlets, koftas were also developed whose technical know-how has already been transferred to the industry on exclusive basis. Nutritive egg drink concentrate of various varieties has also been developed by GADVASU and technologies have been transferred to the stakeholders.

Strategies to implement new technologies for entrepreneurship development

- Awareness about application and benefits of modern processing techniques over conventional techniques
- Provision of capital investments or subsidised loans
- Provision of logistic support
- Policy development, if required at government level
- Quality Assurance or Harmonization to all domestic and international standards
- Setting up of incubation centres
- Creation of database
- Well trained techno graphs and skilled human resources

GADVASU Interventions: Various processing technologies has been developed at Department of livestock Products Technology, GADVASU can be utilized to exploit the potential of profitable use of eggs, meat, poultry and fish. There is an urgent need to generate and implement technical know-how in respect of post-harvest handling, processing and value addition, health oriented meat/fish/egg product, new product development, preservation, packaging and marketing of the various meat and meat products (meat block, patties, balls, nuggets, sausages, loaves, hams, pickles, cutlets, spreads, snack meat foods etc.), egg (egg jam, egg chutney, egg sauce, egg drink, egg pickle, scrambled eggs etc.) and fish products (cutlets, nuggets, sausages, curries etc.) safely to consumer table. In addition, there is an urgent need to develop the technologies for cut-up-parts, product development for emu and fish. This will increase in profitability of the Punjab farmers and reduce the cost of animal protein so that meat/egg/fish products will come in the reach of people of lower income group also. Thus, it will provide the nutritional security to the people of Punjab. GADVASU has already transferred the developed technologies to 19 different entrepreneurs.

Department of Livestock Products Technology, GADVASU has started Poultry Processing Plant under Public Private Partnership Mode for the industrial exposure to our Undergraduate & Post Graduate students as well as for the training of the farmers. This project has been initiated as Revenue Generation Model for training of the farmers/ students for quality harvesting of poultry meat and processing of these products for value addition. The unit will act as sustainable Model for the scaling up of the institute developed novel technologies and can be replicated by entrepreneurs.

Conclusions

Entrepreneurs are key persons of any country for promoting economic growth. Development of entrepreneurship is directly related to the socio-economic development of the society. The growth and development of scientific technologies lead to industrialization and provided greater opportunities for productive employment and social change. The socio-economic development of the country is attained only when the society create a large number of entrepreneurs from strata of popularization. The present scenario of job prospects in our country reveals that it is not possible for our Govt. to provide wage employment to everyone. At this juncture, it becomes essential to divert the attention of youth toward self-employment and other entrepreneurial activities irrespective of their family background. It is widely accepted that the food processing sector is the most appropriate sector for creating jobs for rural poor, and thus reduce the burden on agricultural sector for creation of their livelihood. This is due to their familiarity with the agricultural sector which would make it easier to train and place them in food processing enterprises. The multiplier effect of investment in food processing industry on employment generation is also higher than any other sector. Therefore, for the overall progress of economy it is important that the farmers and backward communities working in rural food-processing units are treated at the top of the growth process. Rapid and sustained poverty reduction requires economic growth which is inclusive and the one that allows people to contribute to and benefit from it.

Agro Processing Centres: An Overview

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Green revolution was not a sudden development rather a culmination of socio economic processes which started in 1950s. Human element, land reforms, consolidation of holdings, connectivity, rural electrification, mechanization in agriculture high yielding varieties and technical support were instrumental in making the green revolution possible. This transformed India from a food deficient country to a self sufficient nation from 1950's to 1980's. In 1980's, an exponential increase in the production was recorded due to high yielding varieties, availability of water and technical support. This raised the need for the post harvest management of durables. The scholars advocated the development of agro based industries as a possible solution to the situation.It is not recent or post-independence that agro based industry was given importance rather its need dates from pre-independence when Mahatma Gandhi emphasized on the village based agro industry during India's independence movement.

Food Processing

Food Processing is considered as a sunrise sector with socio economic impact having large potential for growth, employment generation for rural poor and reducing the burden on agricultural sector. Since, the farmers are well acquainted with the agricultural operations and quality indices of the produce they can be easily trained and transformed from producers to processors.

Food processing involves the transformation of raw ingredients into food or other formsfor economic gain. It is broadly classified into 3 categories.

1. Primary Processing
2. Secondary Processing
3. Tertiary Processing

Primary processing involves removal of unwanted material and converting the raw material into commodity e.g. unbranded oil, milled rice, flour, spices, pulses etc. While secondary & tertiary processing involves conversion of commodity into edible form e.g. processed fruits and vegetables (jams, pickles,curries, gravies etc.), cereals(breakfast cereals, breads, cakes etc.), and processed dairy(flavored milk, cheese, ghee, butter etc.). In 1980's an effort to promote agro industry in India with emphasis on market demand, up-to-date technology and efficient management of the supply chain was emphasized. Establishment of rural entrepreneurship through suitable agro processing models/ complexes have the potential to increase the farmer's income, reduce the post-harvest losses, provide employment thereby causing a reduction in urban pull. Other than these, nutritional security, quality assurance and crop diversification are added attractions of this initiative.

India's economy is dependent mainly upon the agriculture. Even though 70-80% of our rural population is engaged in it, yet the contribution of agriculture based industries in generation of employment in the villages is very less. Appropriate post-harvest technologies and agro based industries have become an important tool in boosting rural economy through scientific conservation of food, feed and fibre material. Efficient and appropriate use of agricultural wastes and by products, development of the rural agro- processing industries is enabling the farmers to sell their value added products for the economic gain. Appropriate location specific, low cost, post-harvest technologies are indeed powerful instruments for bringing around a socio-economic upliftment of rural masses. Establishment of Agro Processing Complexes (APC) at rural level seems to be a suitable solution as it involves the producer at the grass root level, leading to nutritional security and their economic gain. APC is a place where more than one crop is processed and has required facilities for handling, processing and storage of agricultural produce at the village level.Due to wide variation in the terrain and climatic condition different agro processing models capable of processing two or more locally produced/ available crops seems to be an appropriate solution.

Regular surveys and feed backs from the agrarian community enabled, to short list the machines which would prove economically beneficial for the community. The selection of the machine capacityis affected by the market demand and consumption pattern of an area.The data of pre-existing units also affects the selection and establishment.

Novelty

These models were explicit to the community needs of the region, capable of processing the seasonal produce, which implies that they are operational the entire year. Since all the units do not run simultaneously, a single prime mover is installed from which the power is taken through the counter shafts for different units. The lay out of the machinery is planned in such a way that the units on both sides are balanced and do not hinder each other's operation. The details of the lay out have are explained later.

A number of factors play a key role in the establishment of APC from availability of raw material to sales and marketing of the finished product. An outline of different operations involved along with its execution is necessary for the smooth installation and operation of the unit. Before proceeding to the final execution it is important that the project idea should be completely explored weighing the pros and cons of the project. A brief outline of the plan should be thoroughly investigated and at any point if the project is economically not viable it should be abandoned (Fig 1).

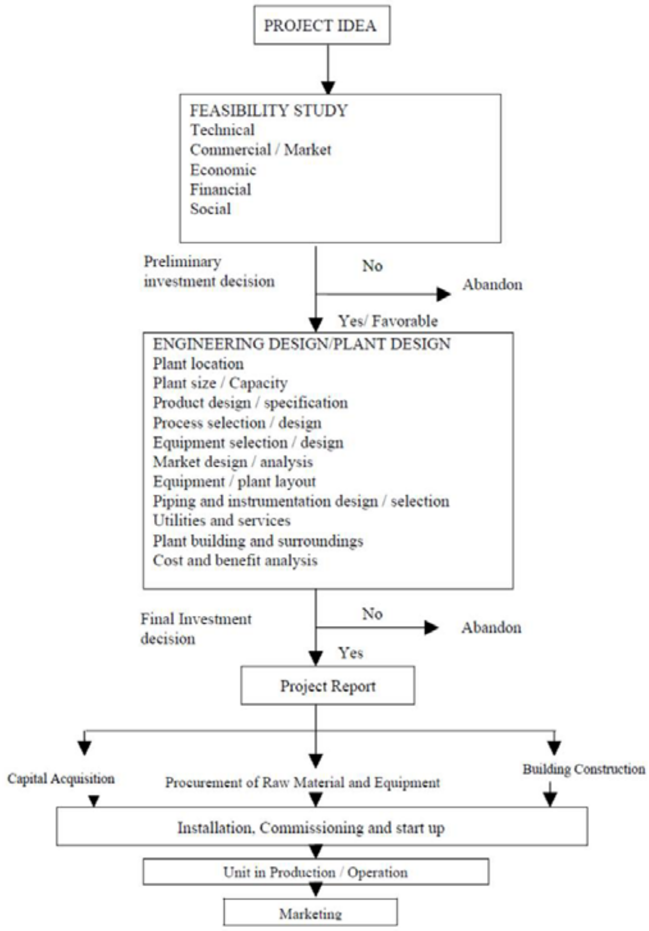

Fig. 1. Preliminary steps to be evaluated before establishing the Agro Processing Complex

The outline can be broadly divided into two parts.

- Planning
- Execution

The planning should be very precise and no detail should be missed. A lag or delay in planning can hamper the execution. Execution is directly dependent upon planning. When the planning is good, minimum issues and problems are faced during execution. Planning starts from the inception of project idea to the decision of final investment is the latter part is execution (Fig 1).

The Establishment of an Agro Processing Complex

A number of steps need to be followed in sequence for the establishment of APC.these are briefly outlined in the flow diagram (Fig 2).

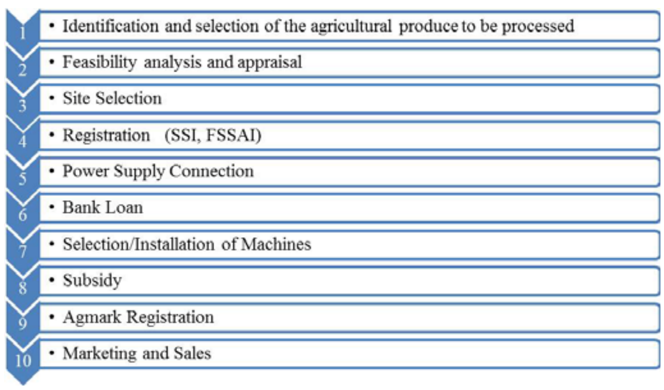

Fig. 2. Flow diagram of the steps involved in establishment of Agro Processing Unit

1. **Identification /Selection of Agricultural produce:**The crop production/cropping pattern of an area/neighbor hood are instrumental in determining the suitability of the raw material for processing. There should not be any compromise in the quality .Good products get better returns with their demand increases with time.The quality indices of the produce *viz.*moisture content, foreignmatter, grain infestation

etc. should be considered at the time of procurement. The volume of production helps to determine the type/ capacity of the machines. Space requirement for the storage of produce and processed products is important and is dependent upon the physical properties of the produce.

2. **Feasibility Report:**The feasibility report is prepared by taking into account all the parameters responsible for the economics. *viz.* the capital requirement, revenue, expenses, loan, interest, depreciation, bank installments etc. This financial report determines feasibility of the business plan. The major costs are tabulated in Table 1 under different heads i.e fixed cost, fixed investment, labor, material cost and return.The project should only be pursued if it is profitable.

Table1: Draft of the Feasibility Report

Sr. No.	Components/machines to be installed	Capacity	Cost (Rs.)
1	Mini rice mill	250 Kg/hr	3,00,000/-
	Baby oil expeller	60 kg/hr	3,50,000/-
	Atta Chakki (with Scourer)	300 kg/hr	6,70,000/-
	Atta Chakki (Rajasthani)(2 in no.)	150 kg/hr	50,000/-
	Masala grinder		70,000/-
	Pulses cleaner cum grader	100kg/hr	60,000/-
	Cattle feed mill	9qtl/hr	3,50,000/-
	Electric motor with fitting	20-25hp	1,50,000/-
	Construction and installation		6,00,000/-
	Total Investment		**26,00,000/-**
2	Fixed Cost (Annual)Interest (10%), Depreciation (10%),Repair and maintenance (5%)		A
3	Labour @ Rs.8,000/-p.m.(2 supervisors)		B
	@ Rs.6,000/-p.m.(4 labours)		
	Energy (Electricity)@35,000/- p.m.		
	Miscellaneous		
	Total		
	Raw material cost (for self processing)		C
	500 Qtl of wheat @Rs. 1400/- per Qtl		
	50 Qtl of oilseed @ Rs. 3500/- per Qtl		
4	Total cost per year		**A+B+C**
5	Returns from processed products & services		
	Paddy Processing (350 Qtl)		
	Quantity milled @Rs. 200/ Qtl.		D
	Sale of husk (20%) @ Rs. 325 / Qtl.		
	Sale of bran (4%) @ Rs. 1400/ Qtl.		
	Oilseed Processing (1450 Qtls)		E
	Milling charges @ Rs.300/Qtl of oilseed		
	Self processing		
	Oil produced 15Qtl @Rs. 9000/- per Qtl		F
	Deoiled cake 35Qtl @Rs. 2000/- per Qtl		
	Wheat (8,000 Qtls)		
	6500 Qtls @ Rs.200/Qtl		
	1500 Qtls @ Rs.150/Qtl		
	By product @ 2Kg/Qtl i.e. 160 Qtl		
	& @ Rs.1500/Qtl		
	Self processing		
	Flour produced 485Qtl @Rs. 1800/- per Qtl		
	By product 10Qtl @Rs. 1500/- per Qtl		
	Total:		**D+E+F**

Total profit Annual=(D+E+F)-(A+B+C)
*The tables includes the price of all the agro processing machines and construction,the fixed cost will vary depending upon the selection of machines(as per the requirement).

The price of land is not accounted, since it is assumed that the farmer has land on which the Agro processing complex can be established. The feasibility reports predicts the viability of the project. When the returns are generated i.e. outcome is positive (profit) the plan should be executed otherwise it should be abandoned.

3. **Site Selection:** Site selection involves assessing the needs of a new project against the merits of potential location, raw material, proximity to place etc. It is an essential componentin the success or failure of an APC.A number of factors natural, manmade, social and economical must be examined.These can be divided into five key factors.

    1. Local geography (topography, government regulations, drainage). The area should be elevated in comparison to the adjoining areas with good drainage facility.
    2. Daily operation (Raw material delivery, finished product distribution, internal material movement) Accessibility via road should be there for supply of raw material , delivery of finished products along with the convenience of the customers and staff.
    3. Utilities (Ensure enough water, electricity and energy resources are available)
    4. Environmental conditions (Examine the neighborhood and the environmental factors). There selected site should be clean and there should not be any garbage dump in the neighborhood.

4. **Registration(SSI):** Registration is an act of recording the name of the firm/company/enterprise or information on the official list with the Small scale industries (SSI). SSI is classified broadly into three segments (based on the investment).

    - Micro Enterprise (The investment should not exceed 25 lakhs)
    - Small Enterprise (The investment varies from 25 lakh to 5 crore)
    - Medium Enterprise (greater than 5crore)

    Establishment of APC"s falls under Micro enterprise with investment less than twenty five lakh. The name of the company can be registered with the Small Scale Industries(SSI) by submitting "Entrepreneur Memorandum for setting up of Micro, Small and Medium Enterprise" to the department. The details of the company, its ownership (owner/tenant), address proof and type of deed(proprietorship/partnership) are required. Submission of the form can be done both in person and online @http://msme.gov.in. Complete information regarding registration,schemes, benefits and procedure is available on website. There are no charges for the MSME registration and is completely optional under MSME Act. Registration provides the entrepreneur complete information regarding the hosts of benefits such as interest rate concessions, tax benefits and access to range of subsidies and schemes aimed at MSMEs. The information regarding MSME can be explored @https://msme.gov.in/schemes/pm-employment-generation-program-and-other-credit-support-schemes.

5. **Power supply connection:** Three phase (440V) AC electrical motors are used to run the machines. The load for the APC can be calculated as per the load requirement of the motors attached to the machines.The application for an electricity connection should be submitted to the nearest sub-station. Along with the application, an affidavit, security fee, advance charges and meter security charges are submitted to the electricity power distribution department/ company. These charges should be confirmed with the electricity department before depositing.

6. **Bank Loan:** Monetary assistance is needed at the time of establishing any project/enterprise. The monetary assistance can be availed from the bank at a predetermined rate of interest. To avail the loan a detailed project report prepared by the Chartered Accountant should be submitted to the bank.It is important to note that the bank accepts only the statement prepared by the Chartered Accountant. The statement details the particulars of the land, machines to be installed, all expenses, working capital, profit etc.Along with this a detailed outline of the loan pay back, SSI registration, approval of electricity connection, layout of the premises is also submitted to the bank.

7. **Installation of machine:** These models were explicit to the community needs of the region, capable of processing the seasonal produce, which implies that they are operational the entire year. Since all the units do not run

simultaneously, a single prime mover is installed from which the power is taken through the counter shafts for different units. The lay out of the machinery is planned in such a way that the units on both sides are balanced and do not hinder each other's operation. The details of the lay out have are explained later. During the installation of the machines special attention should be given to the masonry work. A skilled mason should be hired so that the needful can be accomplished.

8. **Subsidy:** The economic assistance provided by the government in the form of rebate/concession/financial aid to support a desirable activity responsible for the uplifting/improving the status of the society in terms of employment or economic gain. The subsidy can be routed through various departments.

MOFPI(Ministry of food Processing Industry):The Government of India realized the need of encouraging the food processing industry. It came up with different schemes to encourage the investment in the sector. A detail of different schemes launched by the government and its subsidies can be found on http://mofpi.nic.in/Schemes/related-schemes-other-agencies

KVIC (Khadi and Village Industries Commission): The scheme is implemented by KVIC functioning as the nodal agency at the national level. At the state level, the scheme is implemented through State KVIC Directorates, State Khadi and Village Industries Boards (KVIBs), District Industries Centres (DICs) and banks. In such cases KVIC routes government subsidy through designated banks for eventual disbursal to the beneficiaries / entrepreneurs directly into their bank accounts.

Table 2: Provision of subsidy for different categories under KVIC.

S. No.	Category	Subsidy
1.	General (Urban)	15%
2.	General (Rural)	25%
3.	Rural(SC/ST/OBC/Minorities/Women/Ex Service man/Physically handicapped/ NER / Hill and Border areas	35%

The balance amount of total project is provided by the banks in form of term loan and working capital.

9. **Agmark Registration: AGMARK** is a certification mark employed on agricultural products in India, confirming the standards of a commodity or product as per the guidelines approved by the Directorate of Marketing and Inspection (Government agency). These laboratories perform the chemical chemical analysis, microbiological analysis, pesticide residue, and aflatoxin analysis. Government of India. The term Agmark was coined by joining the words '**Ag**' to mean agriculture and '**mark**' for a certification mark. This term was introduced originally in the bill presented in the parliament of India for the Agricultural Produce (Grading and Marking) Act.The testing done across the state owned laboratories include The state-owned Agmark laboratories located across the nation which act as testing and certifying centres along with Central AGMARK Laboratory (CAL)" in Nagpur, and eleven"Regional AGMARK Laboratories (RALs)"The information regarding Agmark can be accessed by http://dmi.gov.in/GradesStandard.aspx

https://www.legalraasta.com/agmark-registration-in-india/

Requirement of Application Proceedings of Agmark

1. A copy of test report which is duly authenticated, from independent Agmark recognized laboratory.
2. There should be Document which is authenticating the establishment of the firm, such Registration by Company Registrar
3. If the applicant is a company, then the memorandum of association.
4. If the applicant is a partnership firm, then they have to submit their partnership deed which is a written document containing ruled and regulations of the partnership.
5. Name of the products for which the company wants Agmark standardization.
6. Name of the applicant should also be mentioned
7. Name of the Firm or the Company
8. Address of the Firm or the Company
9. Product sample should also be submitted in small sachets.

10. Total gross product in kg. for last year should also be mentioned
11. Turnover of last year of the company

Documents are required for Agmark Registration

- Application form
- Demand draft of Rs.1000
- Map of the factory or the office
- Memorandum of the company which represents its objective and the powers
- Company registration certificate
- List of machinery
- Trademark registration certificate

10. Marketing and Sales: It is important to work diligently on this aspect as the entire sale is dependent upon it. It is individual/company effort to establish them. The key factors governing the sales are price of the processed product and its quality.

Conclusion

A brief plan and its proper execution helps in the smooth operation for establishing Agro processing units.An agro processing complex with 2 or more units is capable of generating an income of Rs. 50,000-60,000 per month along with creating employment for 5-6 people. Since India is an agrarian nation, agro based industry seems to be a viable solution to pull the farmers out of the current critical situation. Transforming producer to processor by establishment of processing units at the village level can help us improve the farmers situation as these complexes offer a stable, economically viable and a socially respectful opportunity of sbeing an entrepreneur to the rural population.

Functional Foods Technology for Enhancing Farmer's Income

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Functional foods can be an opportunity for economic growth and enhancing farmer's income for many developing countries endowed with rich biodiversity and traditional knowledge of the health effects of certain indigenous plant species. Demand for functional foods within the developing countries is growing, presenting a lucrative opportunity to develop domestic markets. The economic returns from functional foods can offer improved opportunities for all members in the supply chain: from raw material producers and processors to retailers. Functional foods can be an opportunity for economic growth for the farmers of many developing countries endowed with rich biodiversity and traditional knowledge of the health effects of certain indigenous plant species.

Demand for functional foods within the developing countries is growing, presenting a lucrative opportunity to develop domestic markets. Consumer demands in the field of food production have changed considerably due to changes in lifestyle, awareness and interest in their own health and well-being. This recent trend is not intended to only satisfy hunger and to provide necessary nutrients for humans but it is greatly motivated by demographic changes, specifically the aging of the population in most developed countries, the higher life expectancy and the desire for an improved quality of life. Moreover, an increase in life-style related diseases, combined with constantly rising health care costs, have stimulated research to identify or produce food with functions that can improve health and well-being and reduce the risk or delay the onset of major diseases. The development of functional foods appears to be a long-term trend with important market potential and the market for functional foods. Still, relatively little is known about the current status of functional food production, products and market development in most developing countries.

The concept of functional foods includes foods or food ingredients that exert a beneficial effect on host health and/or reduce the risk of chronic disease beyond basic nutritional functions. Successful types of functional products that have been designed to reduce high blood pressure, cholesterol blood sugar and osteoporosis have been introduced into the market. There are different types of "functional foods", but basically they can be divided into conventional and modified foods. Conventional foods are those in which the components with positive effects are naturally present, such as whole grains, nuts, soybean, etc. Modified foods are those that have been transformed by technology to obtain a functional food, by enriching or adding one or more components with beneficial effects, by removing one or more components with adverse effects from the food, by replacing a component with another that has beneficial effects or by improving the bioavailability of some molecules, which show potential health benefits. With the advent of functional and nutraceutical food concept, the objectives of food processing has changed to some extent in terms of providing value, functionality and nutrition. Consumers choose food and drinks are able to be of benefit to mood, beauty body, the digestive system, regulates cholesterol and blood pressure and weight balance over conventional foods.

Technologies included in the development of functional foods that are traditionally used in food processing include formulation and blending, and cultivation and breeding. Thus, some of the crops with health-enhancing features may be native to marginal areas, where more traditional farming is difficult and returns are low. Hence, functional properties can increase the value of otherwise rare plant species, which can aid in biodiversity conservation if their sustainable use is carefully managed.

Animal breeding also offers the possibility to obtain improved food products. In this way, a lot of studies have been done to examine the sources of nutrients available for inclusion in animal diets and their subsequent transfer into products obtained. Fatty acids profile and physicochemical parameters of milk from Saanen goats can be improved by enriching with 3% of three different vegetable oils (soybean, canola and sunflower). The milks obtained presented different concentration of conjugated linoleic acid (CLA) depending on the vegetable oil added to animal fed. Many such milk modifications improve the nutritional quality of milk and it's processing into dairy products.

Vacuum impregnation has been considered as a useful way to introduce desirable solutes into the porous structure of foods, conveniently modify their original composition as an implement for development of new products. Physiologically active compounds may be introduced into fruit and vegetable products using this technique without modifying their integrity. This so-called 'direct-formulation' distinguishes it from other processing methods. The use of vacuum impregnation to develop functional foods can be orientated in two ways. On one hand, several studies use the vacuum impregnation technique to modify desirable the original composition of one porous food e.g. vacuum impregnation for mineral fortification of fruits and vegetables to achieve a 20-25% dietary reference intake (DRI). Another approach is focused on the protection of active compounds e.g. impregnation using sucrose solution for stability of anthocyanin in strawberry jam.

These technologies are widely used to prepare functional food like formulation and blending technology is used for the preparation of multigrain flour, high fibre biscuit/cookies, snacks, porridge, etc, cultivation and breeding technology for golden rice which has improved total carotenoid content etc, microencapsulation such as starch, maltodextrins, cyclodextrin can be used to encapsulate variety of nutritional component like bioactive compounds, vitamins, probiotics etc for the improved delivery of nutrient to the target molecule. In today's world the development and utilization of different functional foods is a challenging task, however, the development of new technologies of cereal processing that enhance their health potential and the acceptability of the food product are of primary importance.

However, most countries lack a suitable regulatory category for these 'hybrid' functional food products, which makes market development much more complicated. A clear regulatory system for production, sales, certification and advertising of functional foods, together with consistent enforcement are critical factors in building consumer trust in functional foods. A credible system can also help to provide a level playing field that fosters competition and encourages innovation. In many cases, development of institutional capacity is necessary. These institutions include food research centres, advisory services for producers, educators in food sector marketing and management, and authorities approving health claims for functional foods.

The development and marketing of functional foods require significant research efforts because most markets require scientific evidence and proof of functionality. Even though certain foods may have been used for a long time for health-enhancement purposes, the definitive scientific support for claims as a functional product is often lacking. This involves identifying functional compounds and assessing their physiological effect, taking into account bioavailability in humans and potential changes during processing and food preparation and clinical trials on product efficacy in order to gain approval for health-enhancing marketing claims. This research requires time, financing, and skilled labour, especially for products destined for export markets. Lastly, innovation and research capacity is required to screen local biodiversity to uncover potential new sources for functional foods. This is also a management culture challenge for researchers because the best results can be obtained through partnerships between formal science institutions and indigenous communities.

Developing countries can enjoy the benefits of the functional food sector to expand options for producers and to promote growth in the sector through partnerships between research centres, private entrepreneurs, and indigenous communities. However, the success requires sufficient proof to establish the health claim and capacity to accurately market functional foods to consumers in high-end markets. Farmer's that are interested in this sector should also assess the opportunities at the national level because functional foods cover such a broad group of products and production systems that some can find demand in the domestic market, while others can be targeted for export. Identification of specific export markets, certification and other regulations, and consumer demand for product and/or ingredient specific, and largely dictate the possibilities for development. Further studies could establish the most critical bottlenecks in production systems and identify opportunities with the greatest potential for rural employment creation and competitive advantage for small-scale farmers as producers of functional foods.

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Chemical Free Jaggery Production: Sugarcane Juice Processing for Small Scale Enterprise

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With about 70% population living in rural areas, rural has become synonym to agriculture. In fact, 58% of rural population is involve in farm related activities, which contributes only 15% to Gross Domestic Product of the nation. Income through farming is just 60%, for remaining 40% the rural household depends upon alternative sources viz., wages, salaries, non-farm business, interest etc. This inverse relation of manpower and GDP is reflected in form of widening gap of rural and urban India. In order to increase rural income and economy, there is need to enhance agriculture based industries. Primary and secondary food processing units, operated by unskilled and semi-skilled workforce, in production catchments is gaining momentum. Jaggery prepared from sugarcane juice fetches more price than white sugar. Awareness about food value of jaggery over sugar has created a huge market demand this traditional sweetener. Despite being more nutritious than sugar, jaggery consumption of jaggery has declined and per capita consumption of jaggery reduced from 13.87 kg in 1960 to 6.30 kg in past five decades. During the same period sugar consumption increased from 5.24 kg to 17.42 kg (Anon., 2011). Though this cottage scale jaggery production has often been criticised for unhygienic conditions and primitive technologies, but it has always rescued cane growers whenever there is surplus production or there is problem in sugar industry. In Indian market is dominated by solid jaggery which holds 80% share and remaining 20% is marketed in liquid and granular form. In terms of ease of utilization and handling, liquid and granular jaggery are more convenient. Thus, jaggery in all the three forms, viz., solid, liquid and granular, can be one of the cottage scale rural industry which has potential to increase rural income and employment.

Methods of jaggery preparation

In market solid jaggery is available in round, bucket, layers and brick shapes. It is often difficult to handle and use the huge sizes of different shapes. In order to use jaggery for consumption purpose either solid jaggery is melted or broken into smaller pieces. Convenient size of solid jaggery and other forms of jaggery, i.e., liquid and granular are more acceptable. For jaggery production matured cane with high sucrose content and low colloidal impurities is selected. Softness, low mineral content and light coloured varieties are other parameters for consideration. Efforts should be made to crush the cane within 24 hours after harvest to prevent inversion of sucrose. De-trashed variety suitable for jaggery making is crushed in horizontal or vertical crushers. Horizontal crushers are more efficient than vertical crushers in terms of juice recovery. Horizontal crushers yield 4-5% more juice recovery in comparison to vertical crushers. Crushed juice is allowed to settle before passing through multistage filtration to remove. Heavy impurities get settled at the tank bottom due to gravity. Thus obtained decanted juice free from dispersed foreign matter is heated on bagasse fired open pans. Two or three pan furnaces utilize the waste heat of flue gases for preheating of raw cane juice. Triple pan furnace is more suitable for continuous production of jaggery. Boiling and concentration of juice takes place in the pans. In order to remove colloidal impurities chemicals, viz., sodium carbonate, sodium bi-carbonate, sodium hydrosulphite and phosphoric acid are used. Indiscriminate use of chemical clarificants though yields light colour jaggery reduces health benefits and affect taste and storability adversely. Use of clarificants from vegetable sources, deola, okra, phalsa, caster, groundnut, soybean etc., are recommended to maintain food value and keeping quality of jaggery. Deola is most commonly used for jaggery making. The juice is concentrated in pan till it reaches the striking temperature of 114-118^{0}C. At this point, molten jaggery is transferred to cooling wooden pan before final transfer of moulds. Moulds can be of different shapes and sizes. Conditioning is done to attain jaggery moisture within moisture range of 5-7% for storage purpose. For ease of handling, packaging and increased market value, cubical moulding frames for 10 or 20 gm jaggery are preferred.

Striking point temperature is key indicator for making different types of jaggery. For making liquid and powder jaggery concentrated juice is removed from furnace at 105-106^{0}C and 120-122^{0}C respectively. To prevent microbial growth preservatives are added to liquid jaggery. In case of making powder or granular jaggery slightly warm semi-


Soild


Liquid


Granular

Process Flow Diagram


Cane Production


Detrashing


Cane at plant

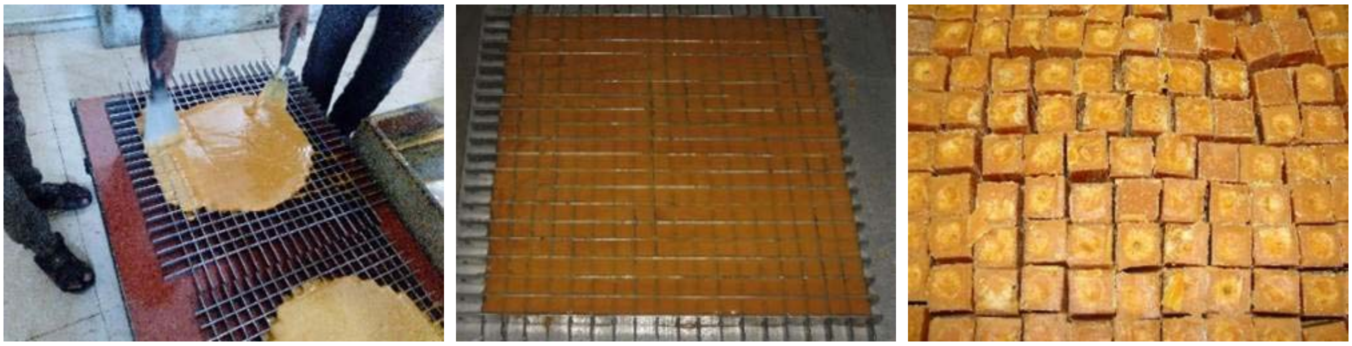


Crushing and Filtration




Concentartion in open pan using vegetative clarificants

Transfer to wooden pan for cooling



Cubical moulding of jaggery

Packaging of Jaggery

solid jaggery is rubbed manually and sieved to obtain different fractions of granular jaggery viz., coarse, medium and fine.

Raw Material

Quality of raw material, like any other industry, plays an important role in quality of jaggery. Cane must be harvested at peak maturity as staling of mature cane is slower than immature cane. Harvested cane must be stripped from green leaves and cleaned properly to minimize presence of heavy and suspended impurities. Among the vast pool of sugarcane varieties, several have been identified for jaggery making. Since jaggery is produced by unorganised sector, at cottage scale, farmers do not produce varieties specific for jaggery production. Now a days hardly 15-20% of cane produced is used for the purpose. In order to make more jaggery available for human consumption there is need to put more area under suitable varieties. Some old but rejected varieties are Co 313, Co 421, Co 475, Co 508, Co 775, Co 1148, Co 1158 and BO 70. Other varieties popular for jaggery making are CoJ 64, CoC 671, CoJ 76, BO91, CoS 8432, CoS 8436, CoS 99230, CoS 96268, CoLk 8101, CoLk 94184 and CoLk 9709 (Solomon and Gangwar, 2014). These varieties were identified by selection and none of these varieties were developed to meet the requirements of jaggery industry. Mostly varieties are developed to meet the requirements of sugar industry and sugar industries play pivotal role in popularization of new varieties. For selection of cane variety for jaggery juice recovery, sucrose content, reducing sugar, maturity indices, juice colour and clarity are some characteristics for consideration.

In order to remove foreign matter and colloidal impurities present in cane juice, chemical or organic clarificants are added while boiling and concentration in open pan. Presence of such impurities result into deterioration of colour and quality of jaggery during storage. These clarificants coagulate the impurities and make froth at the boiling surface, and can be removed easily. Some of the chemical clarificants used are lime (Calcium hydroxide), hydros (sodium hydrosulphite), super phosphate, phosphoric acid, chemiflocks, alum etc. But to improve colour of jaggery these chemicals are used beyond permissible limits which makes jaggery unhealthy. At cottage scale vegetative clarificants viz., mucilage of deola, bhindi, phalsa, semal, sukhlai, caster, soybean, groundnut etc., are used for coagulation of impurities. Fresh solutions are more effective over dehydrated powder of these organic clarificants.

Equipments Required

Cane Detrasher and Cleaner

Jaggery quality primarily depends upon sucrose content and clarity of juice. Removal of green leaves and cane washing reduces suspended impurities and soil particles in cane juice. Sugar industries are more mechanised and automated for cleaning of cane. Without mechanization cleaning individual cane is cumbersome but if adopted can enhance quality of jaggery. In jaggery units often harvested cane is crushes without proper stripping and cleaning. Though it is cumbersome but at small scale this operation must be performed to obtain good quality pure juice.

Cane Crusher

Vertical or horizontal 3-4 roller, 10 hp crushers with crushing capacity of 10 quintal/hour suits the requirement of cottage scale jaggery unit. At cottage level crushing is performed under dry condition. Three roller vertical crusher yields 50-55% juice recovery whereas horizontal crusher give better juice recovery of 55-60%. In sugar mills multi-pass wet milling gives 75-80% juice extraction. In small jaggery units multi-pass or multiple crushers can increase juice recovery. Cane shredding can also be adopted as one of the measures for increased juice recovery. Considering limitation of electricity supply in rural areas provision for animal power or power generation must be made. Efficient filtering of juice at outlet of crusher minimize the impurity load while concentrating the juice.

Open Pans

Jaggery is an age old cottage industry of rural India. Boiling and concentration of cane juice takes place in open pans made by local artisans. Traditionally single pan is used for jaggery making. To utilize heat energy of flue gases from furnace chamber, two and three pan system was developed. Bagasse obtained from cane crushing is primarily used as fuel in such furnaces. During winters and humid seasons sun dried bagasse need to be stored under shades. Depending upon capital and space availability single, double or triple pan system can be adopted. Bagasse is fired in underground chamber beneath main pan and exhaust gases preheat the filtered juice filled in first and second pan before leaving to atmosphere through chimney. Triple pan system has higher heat utilization efficiency (30%) over single or double pan system (15-20%). Vertical alignment of multiple pans allows gravity movement of juice and is more energy efficient. IISR, Lucknow designs of double and triple pan furnaces it popular among jaggery manufacturers. To improve heat transfer efficiency fins can be provided at pan bottom to increase area of heating surface. Double jacketed pan made of stainless steel allows indirect heating of juice through steam from bagasse fired boiler unit. In vacuum pans juice concentration can be done at low temperature and pressure for faster water removal.

Wooden Pan

Concentrated cane juice slurry is transferred from pan at striking temperature depending upon end product, i.e., solid or granular jaggery. For liquid jaggery slurry is removed and filled in bottles after cooling and adding preservatives. For solid jaggery slurry is allowed to cool by continuous stirring before pouring the semi-solid jaggery into moulding frames. For making granular jaggery, slurry is cooled till it starts solidifying and rubbed manually while jaggery is still hot in wooden pan. Different grades, viz., course, medium and fine are obtained by sieving of granular jaggery.

Moulding and packaging

Shape, size, appearance and packaging of jaggery can increase marketability of this nutritious traditional sweetener. Bucket, brick and round shapes of solid jaggery is more prevalent in Indian continent. But this requires additional energy for melting or grinding the solid jaggery before use. Jaggery of convenient size and shape have better acceptability and can be sold at more than prevailing market price. Jaggery of size 10 and 20 gm cubes can be prepared using moulding frames designed by IISR, Lucknow. Before packaging solid jaggery must be dried in natural ventilated chambers to attain 5-10% moisture for safe storage. Granular and liquid jaggery are easy to pack and handle. Attractive packaging with complete nutritional and manufacturing details is required to match the expectations of consumers of today.

Continuous Jaggery Plant

In recent past efforts are being made to make jaggery in continuous plants with low to modest level of success. Still batch and semi-continuous system is used for jaggery production. At cottage scale probably batch process is more convenient, requires less investment and technical skills. Several private and government agencies are working for continuous plant to meet the requirement of big industries.

Market Potential

Sugarcane is being used as natural sweetener since time immemorial. Traditionally the sweetness is preserved in form of jaggery, prepared by concentrating cane juice in open pans. Bagasse is used as fuel to heat the pans. After introduction of white sugar, due to sweetness and ease of use, handling and storage, it has almost replaced jaggery from urban Indian diets. Jaggery, apart from sucrose, glucose and fructose, is rich source of minerals and vitamins. Recently with increasing health awareness and ill-effects of sugar, demand for jaggery has shown an increasing trend. All the three forms of jaggery, viz., solid, liquid and granular, are unique in terms of texture, properties, usage and handling. India is largest producer, consumer and exporter of jaggery in the world. Apart from indigenous domestic market there is huge export potential of hygienically produced quality jaggery. By fortification of jaggery with other nutritional additives like, gooseberry, basil, ginger, black pepper, sesame seeds and spices, value added jaggery can be prepared for specific needs and requirements. Production of each product can be adopted as cottage scale units.

Performance of three pan furnace

Improved triple pan furnace design and developed at IISR, Lucknow is energy efficient furnace for jaggery making in batch or continuous production. It gives overall heat utilization efficiency of 30%. Testing and performance evaluation of Three Pan IISR Model Jaggery Furnace is given in following below :

Cost analysis for establishment of jaggery plant

An approximate cost analysis of jaggery plant for 300 kg jaggery/day capacity is discussed as under :

Assumptions :

i)	Plant capacity	= 300 kg/day
ii)	Working days	= 200 days/year
iii)	Working hours	= 12 h
iv)	Juice recovery	= 60 %
v)	Jaggery production	= 10 % of cane weight
vi)	Cane requirement	= 30 Q/day
vii)	Cane price	= Rs. 200/Q
viii)	Interest rate	= 12 %/annum
ix)	Repair maintenance	= 2.5 %
x)	Insurance	= 1 %

Cost analysis for establishment of jaggery plant per annum :

i)	Cost of machines and structure	= Rs. 20,00,000
ii)	Raw material	= Rs. 12,00,000
iii)	Wages	= Rs. 4,40,000
iv)	Utilities	= Rs. 1,00,000
v)	Miscellaneous	= Rs. 50,000
vi)	Working capital	= Rs. 17,90,000
vii)	Interest & Insurance	= Rs. 3,69,525
viii)	Total Variable cost	= Rs. 21,59,525
ix)	Total capital (Fixed + working)	= Rs. 41,59, 525
x)	Cost of production/year	= Rs. 21,59,525
xi)	Cost of production/kg	= Rs. 36.00
xii)	Turnover @ sale price 60Rs)	= Rs. 36,00,000
xiii)	Net profit	= Rs. 14,40,475
xiv)	Net profit ratio	= 0.4
xv)	Break Even Point	= 1.39
xvi)	Pay-back period	= 2.89 years
xvii)	Return on investment	= 0.67

Grading of jaggery

Quality parameters influencing the market value of jaggery are colour, hardness and texture. Light colour jaggery fetches more price compare to dark jaggery. Jaggery producers sometimes use chemicals above permissible limit to make jaggery of light colour. But excessive use of chemicals lessens the health benefits and adversely affects the storability of jaggery. Taste, flavour, sucrose, reducing sugar, moisture and ash content are other important jaggery characteristics. Quality parameters for jaggery grades as per indian standards is mentioned in following table.

Characteristics	Unit	Grade I	Grade II
Sucrose	%, db (Min)	80	70
Reducing sugar	%, db (Max)	10	20
Moisture	%, db (Max)	5	7
Water insoluble matter	%, db (Max)	1.5	2.0
Sulphate ash	%, db (Max)	3.5	5.0
Sulphur dioxide	ppm, db (Max)	50	50
Ash insoluble in dilute HCl	%, db (Max)	0.3	0.3
Total sugar as invert sugar	%, db	90	90

IS 12923 : 1990

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Spray Drying of Liquid Foods: A Novel Path towards Augmenting Farmers Income

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Drying is a mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semi-solid or liquid. This process is often used as a final production step before selling or packaging products. To be considered “dried”, the final product must be solid, in the form of a continuous sheet (e.g., paper), long pieces (e.g., wood), particles (e.g., cereal grains or corn flakes) or powder (e.g., sand, salt, washing powder, milk powder). A source of heat and an agent to remove the vapour produced by the process are often involved. In bio-products like food, grains and pharmaceuticals like vaccines, the solvent to be removed is almost invariably water. Desiccation may be synonymous with drying or considered an extreme form of drying.

In the most common case, a gas stream, e.g., air, applies the heat by convection and carries away the vapour as humidity. Other possibilities are vacuum drying, where heat is supplied by conduction or radiation (or microwaves), while the vapour thus produced is removed by the vacuum system. Another indirect technique is drum drying (used, for instance, for manufacturing potato flakes), where a heated surface is used to provide the energy, and aspirators draw the vapour outside the room.

Drying is the oldest method of preserving food. The spray drying of liquid food is an important unit operation in the food industry. In spray dryers the fluid is atomized and brought into contact with hot air. Spray dryers are mostly operated in the food industry in the co-current mode to avoid thermal deterioration of the drying product.

Theory of Spray Drying

Spray drying is a process whereby a liquid droplet is rapidly dried as it comes in contact with a stream of hot air. In a spray dryer the atomized feed travels either co-currently or counter-currently with the drying air depending upon the type of product. The materials which are heat sensitive generally follow the co-current flow of air. The liquid is transformed into fine drops by using either (i) rotary (ii) pressure nozzle, or (iii) pneumatic two fluid atomizing device. Depending on the type of atomizer and the liquid to be dried, size of atomized drops and air temperature vary between 20 to 180 micron and 150-250°C respectively. The small size of the liquid droplets allows very rapid drying, and the residence time of the material inside the spray dryer varies between 3-30 seconds. The dried material in powder form is separated from the air in a cyclone separator. The powder is continuously withdrawn and cooled. Heat may damage the product if contact with the high-temperature drying air is prolonged.

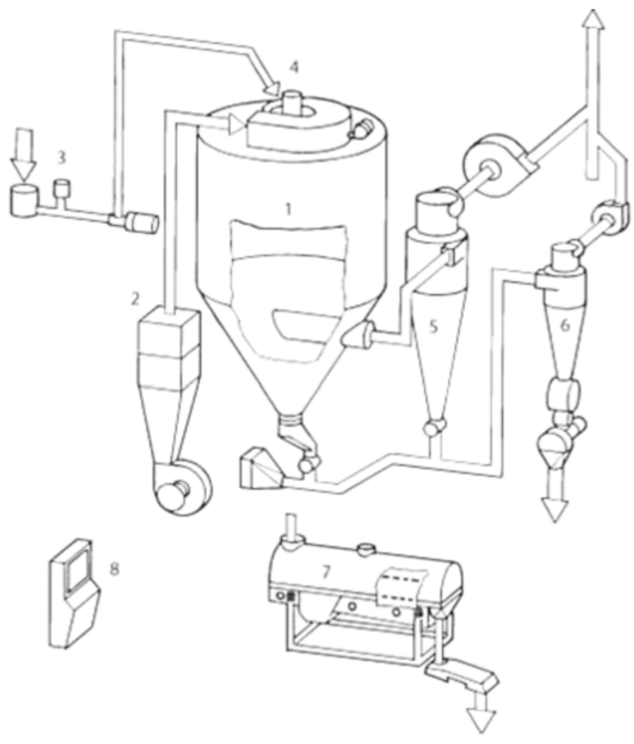

Fig. 1 A. typical spray dryer
1. Drying chamber 2. Hot air system and air distribution 3. Feed system 4. Atomizing device 5. Powder separation system 6. Pneumatic conveying and cooling system 7. Fluid bed after-drying/cooling 8. Instrumentation and automation

While the droplets are drying, the temperature remains at the wet bulb temperature of the drying air. For this reason drying air at very high temperatures can be tolerated in a dryer with a minimum of damage to the heat sensitive components. Furthermore, the rate of degradative reactions in foods slows down at low moisture contents. Thus, the portion of the drying process in which product temperatures rise above the wet bulb temperature does not result in severe heat damage to the product.

A major requirement of successful spray drying is the reduction of the moisture content of the liquid droplets to a level that prevents the particles from sticking to a solid surface as the particles impinge on that surface. The rate of drying of the particles must be such that from the time the particles leave the atomizer to the time they impinge on the walls of the spray dryer, the particles are dry. The trajectory and velocity of the particles determine the available drying time. The rate of drying and the time required to dry depend on the temperature of the drying air, the heat transfer coefficient and the diameter of the droplets being dried.

A constant rate and a falling rate drying stage are also manifested in a spray drying process. As the wet droplets leave the atomizer, the surface rapidly loses water. Solidified solute and suspended solids rapidly form a solid crust on the surface of the particle. The diameter of the particle usually decreases as drying proceeds. The formation of the solid crust constitutes the constant stage of drying. When the crust becomes sufficiently thick to offer considerable resistance to movement of water toward the surface, the drying rate drops and the art of drying is controlled by the rate of mass transfer. The temperature of the particle increases and the liquid trapped in the interior of the particle vaporizes and generates pressure. Eventually, a portion of the crust breaks and the vapour is released. Spray dried particles consists of hollow spheres or fragments of spheres. This shape of the particle is responsible for the excellent rehydration properties of spray-dried powders.

Independent Parameters in spray drying process

- ✓ Inlet Air Temperature
- ✓ Feed rate
- ✓ Atomizing Air Pressure

These independent parameters of the spray dryer are varied/optimized to get desired yield of good quality powder

Dependent Parameters measured during spray drying process

Spray dryer	Powder
✓ Outlet temperature of air	✓ Moisture content of powder
✓ Thermal efficiency of dryer	✓ True density
✓ Drying time	✓ Bulk density
	✓ Tapped density
	✓ Dispersibility
	✓ Solubility
	✓ Colour

Methodology of measuring different spray dryer parameters

Outlet temperature of air: Indicated by the panel board through a sensor attached to the outlet pipe. (Inbuilt system)

Drying time: Calculated using a stop watch. The time required for 1 litre of the solution to get spray dried.

Thermal efficiency of spray dryer

$$\eta = \frac{(T_{x1} - T_{x2})}{(T_{x1} - T_a)}$$

where, T_a-ambient air temperature, Tx_1-inlet air temperature, Tx_2-outlet air temperature

Methodology of measuring different powder parameters

Moisture content of powder- It was measured by keeping the powder in a hot air oven at 105ÚC until constant weight.

$$\textbf{Moisture content (w.b.)} = (W_1 - W_2 / W_1) * 100$$

where, W_1= Initial wt. of powder, W_2= final weight of powder

True density- A given amount of powder is mixed with a given volume of petroleum ether in a graduated measuring cylinder:

$$D=W/V_1-V_2$$

where D= particle density g/ml, W-wt of powder (g), V_1 is the volume of powder + petroleum ether in ml and V_2 is the volume of petroleum ether in ml.

Bulk density: 5 g of groundnut milk powder was freely poured into a 100 ml graduated cylinder and the volume occupied was noted to compute the bulk density (loose).

Tapped density: The same powder sample was tapped 100 times by dropping the graduated cylinder on a soft base from a prescribed height. The volume occupied was noted to compute the tapped bulk density.

Dispersibility- It is an important property determining the reconstitution of the product. The measurement was performed according to procedure described by (A= SNiro Atomizer) with some modifications. Distilled water (10 ml) at 25±1°C was poured into a 50 ml beaker. 1 g powder was added into the beaker and stirred for 20 seconds. The reconstituted groundnut milk was poured through a sieve (0.212 mm). The sieved milk was used to determine % total solids.

$$\textbf{\% Dispersibility} = [(10+a) \times \% \text{ TS}]/a\ [(100-b)/100]$$

a- amount of powder in g, b-moisture content of powder, % TS is dry matter in % in the reconstituted milk after it has been passed through sieve.

Solubility index- It is measured to analyze the extent of protein denaturation during spray drying. A 1.3 g sample was blended with 10 ml distilled water and centrifuged at 1000 rpm for 5 minutes. Total solids in the supernatant were determined. Solubility index was expressed as the ratio of total solids in reconstituted solution to that used in the preparation of the original solution.

Color- The colour of the powder samples were measured by Hunter Lab Colorimeter by noting the L, a, b values. The 'L' value for each scale indicates the level of light or dark, the 'a' value redness or greenness, and the 'b' value yellowness or blueness. All three values are required to completely describe an object's color.

SMST Tall Type Spray Dryer

The principle components of the spray dryer are described below:

Air Heater: This consists of sheathed electric heater electrically connected.

Slurry Pump: This is a motorized peristaltic pump with variable speed arrangement to control the flow. The motor is DC operated through SCR and rpm is controlled by knob.

Blower: The motorized blower is centrifugal type with variable speed arrangement to control the flow of air. The motor is AC, operated through DRIVE and rpm is controlled by knob.

Panel Board: The panel board consist of the following:

- PID Temperature controller-Indicator for inlet air temperature.
- PID Temperature indicator for outlet air temperature (it is only as indicator).
- Toggle switch for Heater-1
- Toggle switch for Heater-2
- Toggle switch for Pump

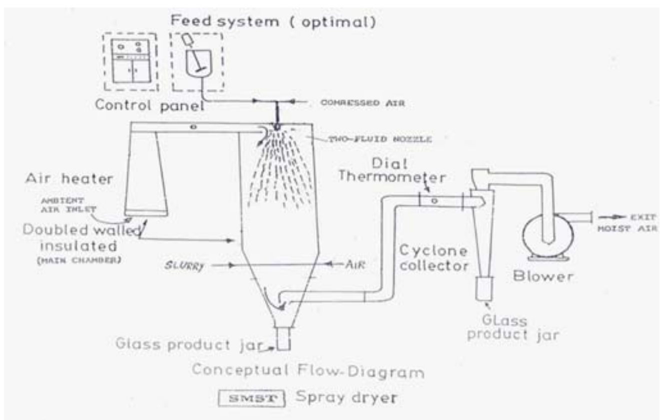

Fig. 2. Working principle of SMST Spray Dryer

- Toggle switch for Blower.
- Knob for feed Pump speed control.
- Knob for Blower speed control.

Technical Specification:

Main voltage- Three phase (415v) with neutral & earth.
Power consumption (heaters) 6×1.6 KW = 9.6 KW
Blower motor - 415v AC (DRIVE)
Feed Pump - 415v AC (DRIVE)
Max. Temperature - 350°C of drying air.
Compressed air for two-fluid nozzle – 2-4 bar.

Control:

Temperature control of inlet temperature.
Switch and knob controller or feed pump.
Switch and knob controller for blower.

Electrical and Connection:

Electrical power cable three phase (415v) with neutral and earth.
Compressed air connection through air regulator and filter.

Technical tit-bits

The capacity of the exhaust fan used for sucking the air out of the dryer is kept slightly larger than the capacity of fan used for delivering heated air to dryer. A small amount of vacuum is the created inside the dryer. This vacuum does not allow the powder to come out of dryer through leakage spaces that may be present on dryer body.

Energy cost of spray drying per kilogram of water evaporated is much higher than that takes place in evaporator. Use of multiple effect evaporator in conjunction with thermal or mechanical vapour compression device reduces energy cost. In case of milk drying in a modern plant, about 90% of total water is removed in evaporator and the rest 10% in spray dryer. Energy cost of spray drying, to remove the 10% of total water, however, comes out to be about 60% of the total cost of evaporation and drying. Maximum possible water removal prior to spray drying and improving energy use efficiency of spray dryer is of considerable importance.

Utilization of heat energy of heated air by liquid drops will increase with increased length of drying chamber, reduction of drop diameter and intimate mixing of drops with heated air. Spray-drying chamber must be adequately insulated to bring down heat loss from dryer walls to minimum.

Application of spray drying in production of non-dairy beverage

In India, groundnut is mainly used for oil extraction or consumed in roasted form prompting a need for diversification to further increase its value and utility. Development of dairy analogues from groundnut kernels was the first step by ICAR-CIPHET in this trend. Groundnut milk powder, in a manner similar to dairy milk powder, can reduce product perishability as well as storage and transportation costs. Spray drying is a process widely used to produce powders from liquid foods. This is achieved by atomizing the fluid into a drying chamber, where the liquid droplets are passed through a hot-air stream. The physico-chemical properties of powders produced by spray drying depend on the variables of process and/or operating parameters of spray dryer. The experimental plan was designed according to Box-Behnken design (RSM) to study the effect of different operating variables of spray dryer i.e., inlet air temperature (180-220°C), atomization air pressure (2-3 bar), feed pump rpm (24-36) on the various quality characteristics and reconstitution properties of groundnut milk powder. The optimized spray drying parameters for groundnut milk powder production were found to be Inlet air temperature: 194.5°C, Feed pump rpm: 24 and Atomizing air pressure: 3.0 bar.

The powder thus produced under this optimized conditions was used for conducting shelf life study of the powder in metal tin cans and aluminium foil pouches. Periodic observations were recorded for fresh product and at the end of 1st, 2nd, 4th, 8th and 12th week of storage. Moisture content, water activity, free fatty acid, dispersibility and insolubility index were determined at the end of each storage period while temperature and relative humidity were recorded daily. Variations with an increasing trend were found in case of moisture content (between 1.69-3.82% and 1.69-3.33%), water activity (between 0.44-0.56 and 0.44-0.52) and free fatty acid (between 0.48-1.86% and 0.48-1.57%) in aluminium foil packages and metal tins cans respectively. Dispersibility of powder varied between 96.10-91.77% and 96.10-92.58% while the Insolubility Index varied between 0.75-4.56 ml and 0.75-4.23 in aluminium foil and metal tin can respectively. Similar observations were also recorded during the same storage period for the dairy milk powder of a reputed brand. Results confirm that GNM powder can be safely stored in both the packaging materials for three months and metal tin can packaging is marginally better than aluminium foil packaging. The reconstituted milk was subjected to organoleptic evaluation leading to favourable score (7.53/9). The freshly prepared groundnut milk scored 7.67/9. Also, two products namely easy-to-make condensed milk and Peda (an Indian sweet) were prepared utilizing the groundnut milk powder obtained from the spray drying chamber. The overall scores from organoleptic evaluations (4.64/5 for condensed milk and 4.25/5 for Peda) indicated very good acceptability among the sensory panelists.

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Post-Harvest Losses and Food Waste: An Economic and Social Perspective

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Food losses and waste do not only have economic implications but also adversely effecting human and animal consumption, environment and ecology. Generally food losses take place at production stage (harvesting and collection), and operations performed by various stakeholders such as farmers, wholesaler, retailer, processors etc. at post-harvest stages, that are, threshing, cleaning,/winnowing, drying, packaging, transportation storage, processing (Basavaraja et al., 2007; Parfitt et al., 2010; Jha et al., 2015). Food waste is mostly at two stages, which are, (i) food services and (ii) food consumption (Segrè et al., 2014). Postharvest loss can be defined as measurable degradation of a food, both quantity and quality along the supply chain from harvest to consumption or other end uses (De Lucia and Assennato, 1994; Hodges et al., 2011). Economic loss can also occur without having quantitative loss if the produce fetches a lower market price owing to poor quality. Quantitative food loss can be measured by decrease in weight or volume whereas quality losses related to decrease or change in nutrient/caloric composition which affect the acceptability of a given product. There is a difference between damage which restricts the use of a product and loss makes its use impossible. Food waste refers to food discarded and not available for human consumption which may be due to deterioration, spoilage or date of expiry. Food waste occurs when an edible food items goes unutilized as a result of human action or inaction (Bloom, 2010; Buzby and Hyman, 2012) but has potential to recover for human consumption (Hodges et al. (2011). In US, approximately 10,205 tons of food waste was generated annually. Of all food waste, production waste comprised 20%, processing 1%, distribution 19%, and 60% of food waste was generated by consumers (Griffin, 2009).

Various attempts have been made across the globe to estimate value of food losses at different stages of production, harvest, postharvest and supply chain. For instance, losses occurred to the tune of $10.5 billion in Australia during 2004; $ 90 billion per annum loss in dairy sector in Africa and the figure touched to 100 billion in USA during 2008 (Nellemann et al., 2009).

In India, quantitative harvest and postharvest losses were estimated to the tune of Rs. 92651 crore during 2012-13 at current prices of 2014 (Jha et al., 2015). The increase in monitory loss is mainly due to three reasons, i.e., (i) natural calamities in coastal areas at the time of harvest, (ii) quantum jump in production resultant into high quantity of loss and (iii) lack of required postharvest infrastructure facilities including market. Minimizing such losses will result in improve marketable surplus at producer level and higher availability of food to the consumers. A grain saved is a grain produced. Hence, it became imperative to understand the factors contributing towards losses. This paper will throw light on various factors responsible for postharvest losses and wastage and its socio-economic perspective and technology role in reduction of post-harvest losses for additional income.

Factors contributing to food loss and waste

The magnitude and pattern of harvest and postharvest losses varies from country to country, region to region and crop to crop depending upon agro-ecological situation, geographical parameters, perishable nature of the crop/ commodity, technological advancement and stage of economic development. Nonetheless, the figure of loss varies with method of estimation. At global level, volumes of lost and wasted food in high income regions are higher in downstream phases of the food chain, but just the opposite in low-income regions where more food is lost

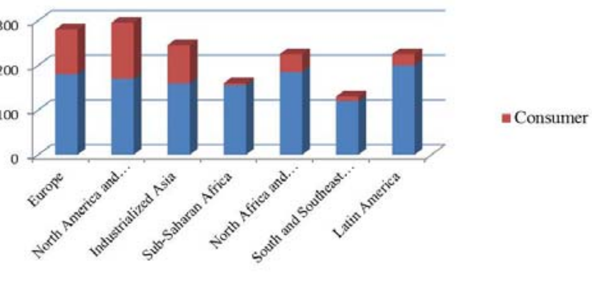

Fig. 1. Food losses and waste (kg/capita/year) in different regions (Source: FAO)

(Note: this paper is slightly revised version of my earlier lecture delivered in Summer School, Aug 2016 at ICAR-CIPHET Ludhiana)

and wasted in upstream phases (FAO, 2013). Inter-regional comparison clearly depicted in Fig. 1 that the per capita food loss in Europe and North-America (280-300 kg/year) is nearly double to sub-Saharan Africa and South/Southeast Asia (120-170 kg/year).

Further, more than 40% of the food losses occur at post-harvest and processing levels in developing countries while in industrialized countries, more than 40% of the food losses occur at retail and consumer levels. Food losses were mainly due to poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors, and lack to markets. Researchers also pointed out that retailers and consumers "behavior" is one of the key factors for food wastage in supply chain. In developed countries, a large amount of the food is not eaten but left on the plate after a meal and hence discarded. Sometimes, they purchase more quantity than their requirement and passed its expiry date.

In contrast, failure to consume available food in less developed countries is not a reported concern; instead the low-quality food remaining in markets at the end of the day is sustenance for the very poor. Hence, losses in developing and less developed countries are due to inefficient postharvest supply chain systems (Hodges et al., 2010). Social trend such as urbanization has driven more and more people from rural area to large cities, resulting in a high demand for food products at urban centres, increasing the need for more efficient and extended food supply chains (Parfitt et al. 2010). There are internal (improper harvesting methods, lack of maturity index, scanty availability of pre-cooling facility, inefficient transport system, lack of quality and safety standards, and inadequate storage processing and cold chain facilities) and external climatic factors such as temperature, humidity, etc. contributing to postharvest loss. Kannan (2014) established relationship between postharvest losses with farm size. There seems to be, by and large, an inverse relationship between postharvest loss and farm size groups indicating that marginal and small farmers encounter considerable quantity of postharvest loss due to lack of access to suitable machineries and financial capital. Further, it is clear from his findings that the largest producing states have recorded a higher level of post harvest loss. Similar findings were reported by Jha et al. (2015) that the agro climatic regions with good harvest have, by and large, higher percent of harvest and postharvest losses. These situations reinforce us to create post-harvest infrastructure facilities and establishment of Agro Processing Centres (APC) in the production catchments.

In order to reduce these losses, scientific knowledge on cultivation practices and post harvest operations need to be imparted to the farmers. It is paramount to understand that technology can facilitate the reduction of food losses and waste, but at the same time socio-cultural issues should be carefully considered to evaluate their cultural acceptability and to facilitate a successful adoption (Segrè et al., 2014). It has been observed that the same intervention can receive appreciation depending on specific circumstances. For example, metal silos have been successfully introduced in Central America but not yet in Africa, where households used to store grains at home (World Bank, 2011). Basavaraja et al. (2007) studied the influence of different socio-economic features of farmers of Karnataka on postharvest losses of rice and wheat at farm level. They found that postharvest losses were negatively association with age and education of the farmer, while inadequate availability of labour and faulty storage method influence the postharvest losses positively and significantly in rice and wheat. Further researchers reported to be variation in food waste by socio-economic factors such as age, gender, social class and working status, etc. According to a research conducted in UK, male are wasting more food than female. As far as age is concerned, highest food was wasted (42%) by age group (25-34 years). The only exceptions who claim to the contrary are those who are retired and those who are aged 65 and over - only 13% and 10%, respectively (Fig. 2), the behaviour of this group is different in respect of food waste. It was noticed that social class and status has relationship with food wastage. Preponderance to throw away uneaten food was found highest in social class DE (unemployed, semi-skilled, unskilled and low grade occupation) whereas it was lowest in social class AB (Higher, intermediate, marginal,

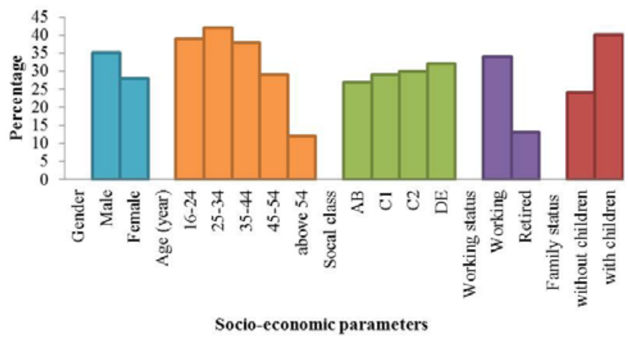

Fig. 2. Variation in food waste by socio-economic factors (Source: compiled from www.wrap.org.uk/retail)

administrative and professional occupations). Levels of food wasted by social class C1 (supervisory, clerical & junior managerial, administrative level) and C2 (skill manual) fall between AB and DE. Hence, awareness and education is long-term solution to household food loss.

Monetary losses of harvest and postharvest losses in India

The economic value of quantitative loss of 45 crops/commodities occurred during harvesting and postharvest operations was found to be in the tune of Rs. 92651 crore at average annual price of 2014 (Jha et al., 2015). Around 65.23 million tones agricultural produce was lost during 2012-13 (Table 1). Highest contribution (34%) towards economic loss was from horticulture produce followed by cereals (22.3%) and livestock produce (20%). The reasons for higher monetary loss in horticultural produce are perishable nature and comparatively higher market prices. Minimizing such losses will result in availability of greater quantity of food and would have positive economic implications, as discussed in next section.

Table 1. Estimated harvest and post-harvest losses in India (Production year 2012-13)

S. No.	Crop/ Commodity group	Overall total loss (%)	Total Loss (million tons)#	Monetary value of losses (Rs. Crore)
1.	Cereals	5.53 to 5.99	12.14	20698
2.	Pulses	6.36 to 8.41	1.03	3877
3.	Oilseeds	3.08 to 9.96	2.32	8278
4.	Fruits	6.70 to 15.88	6.12	16644
5.	Vegetables	7.32 to 12.44	8.43	14842
6.	Plantation crops and Spices	1.18 to 7.98	28.02	9325
7.	Livestock produce	0.92 to 10.52	7.17	18987
	Grand total		65.23	92651

Source: Jha et al. (2015); #Calculated by the authors

Implications for reducing food losses and waste

First, it is important to understand why food losses and waste occur, and need to identify bottlenecks and gaps on R&D and policy fronts. A comprehensive set of indicators that adequately capture broader societal impacts of tackling food losses and waste will help policy makers and researchers. Supply chain actors should contribute in terms of practical and innovative solutions and provide feedback to researchers and policy makers on the gaps. FAO (2013) estimated food lost or wasted globally, equivalent to around 1.3 billion tons per year.

In this section, the economic impact of (reducing) food losses are discussed in partial equilibrium framework. Figure 3 depicts equilibrium at point A in the market for a food commodity with supply curve (upward slope) "S1" and demand curve (downward slope) "D1", where the price is P^0 and the quantity traded is Q^0. It is hypothesized that the depicted situation capturing the full supply chain from farm to fork with existing level of losses. Postharvest losses and waste minimization strategies will shift the supply curve right hand side from S1 to S2. In such a situation, the supply curve S2, will establish equilibrium at point D with price P^1 and quantity Q^1. The action of avoiding the losses, given the original demand curve and given the underlying motivation of doing so, would result in a lower price, P^1, and a higher equilibrium quantity, Q^1,

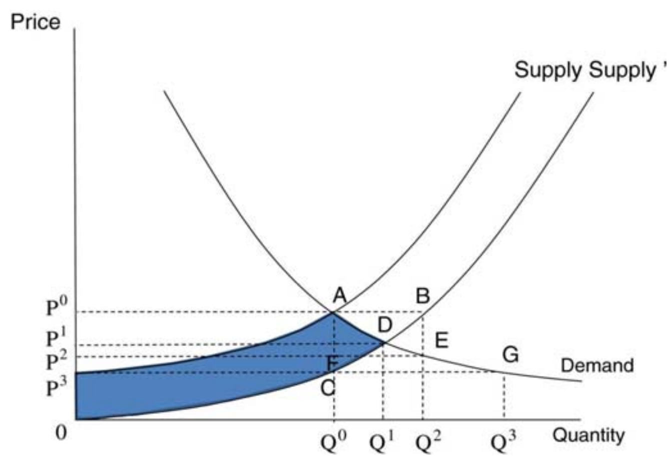

Fig. 3. Impacts of reducing postharvest losses on price, quantity and welfare Source: Rutten (2013)

in the market, as given by point *D*. Here, consumers will benefit in terms of getting reduced price from P^0 to P^1, whereas, sellers able to sell more quantity from Q^0 to Q^1 as depicted by Figure 1. At this new equilibrium, both consumer's surplus and producer surplus are positive. Given the original price, P^0, more can actually be produced and supplied to the market (Q^2 at point *B*), or the original quantity, Q^0, can actually be produced at a much lower cost (P^3 at point *C*) if losses were to be absent. Here, supply shift is considered parallel to original supply curve (S1) but note that the 'optimal' supply curve does not necessarily have to be parallel to the original supply curve, as the extent of losses may vary with the scale of production and price (Rutten, 2013),

The overall welfare gain equals the sum of the change in the producer and the consumer surplus, which amounts to the area P^3AD 0, the blue shaded area (Fig 3). Impacts also vary with the slope of the demand and supply curves and consumer preferences play an important role on the demand side. If one takes all these factors into account, one cannot be certain a prior what the impacts will be, notably when it comes to food security and welfare. The gain to consumer is certain as a result of reduction of postharvest losses but it is not certain that the producer will be benefiting always, since it depends upon elasticity of demand and supply.

Role of technology in reduction of Post-harvest losses: A synthesis from AICRP on PHET

ICAR-All India Coordinated Research Project on Post-Harvest Engineering and Technology (AICRP on PHET) mandate is to develop location specific and crop specific technology. Some technologies are found suitable for reduction of post-harvest losses, in our study "Impact Assessment of Technologies from AICRP on PHT centres' (Nanda et al., 2013). In the said study, economic benefits of developed technology at farm/firm level was estimated based on a comparison with existing practices. Here, contribution of selected AICRP on PHET technologies towards additional income from reduction of post-harvest losses are presented in Table 2.

Table 2. Additional income realized from reduction of post-harvest losses through post-harvest technological interventions

Sr. No.	Name of technology (machine/process/ protocols)	Purpose/application	Capacity per unit	Loss reduction over conventional practices (%)	No of units established	Estimated Income realized (Rs) to society
1	Millet thresher -cum-pearler	Threshing and pearling grains of finger and barnyard millet	Threshing (40-50 kg/h) Pearling (60 kg/h)	10-12 % (dehulling) 2-3 % (threshing)	730	Rs. 11.13lakh
2	PKV Mini Dal Mill	Improved milled recovery	1.25q/h dal milling and 2q/h cleaning	25% additional recovery (saving of processing loss)	538	130.47 crore
3	Maize dehusker cum sheller	Dehusking and shelling of maize simultaneously	800 kg cob/h	2%	20	18.45 lakh
4	Polyhouse solar dryer and solar tunnel dryer	Drying time reduced by 50%	72q/annum chilli	4.5% (protection from wind, rain and birds)	27	Rs. 1.41 lakh
5	Insect trap	Control of cereal insects during storage	Storage bin of 25-50 kg	0.1%	4.0 lakh	72.0 lakh (potential benefits at national level 12.6 crore)
6	Safe storage of technology using sand layer	Eco friendly pest control during pulse storage	200 kg	100% control of bruchids (storage losses 1.5%)	>1000	Rs. 60/unit Rs. 34.15 crore

Source: Nanda *et al*. (2013)

It is evident from the above (Table 2) that storage technology like insect trap and safe storage of pulses using sand layers has great potential to save an amount of Rs. 12.60 and Rs. 34.15 crore per annum if 10 percent of cereal and pulses produced in India could be stored using these technologies. The implication of the post-harvest loss reduction is far behind saving (i.e., additional income) in terms of reduction of load on natural resources, as grain saved is grain produced.

Conclusion

The postharvest losses and wastage are common phenomena across the globe, however, nature and intensity varies. The economic value of harvest and postharvest losses of major crops and commodity in India was Rs 92651 crore at 2014-15 prices, which attract the attention of researchers and policy makers. Socio-economic parameters such as age, gender, social class and working status are the key factors responsible for level of food waste. The implications of reduction of postharvest losses and waste are not unidirectional but multidirectional. There is a great potential of technology in reduction of post-harvest losses. The scientist of post-harvest engineering and technology should focus on minimizing the losses while developing value added technologies. PKV Mini Dal mill is one of the good examples for improved recovery and minimizing the losses and the adoption of the machine need to be expended throughout India more particularly in pulse producing states. Finally, it can be concluded based on the economic theory that there is a welfare gain from reduction of postharvest losses and R&D progrmme and policy need to address the underlying causes of losses. Above all, awareness and education on importance of reducing postharvest loss and food waste among different stakeholders is long-term solution.

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Project Profile Preperation for Start-Up's in Agriculture

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Agriculture is the dominant sector of Indian economy, which determines the growth and sustainability of our nation. Around 70 per cent of our rural households still depend on agriculture for their livelihood, with about 82 per cent of farmers being small and marginal. Even if we attained self-sufficiency in food grain production, we failed to maintain farming an attractive profession. Increased cost of production, distress sale and post-harvest losses led to low profit in agriculture. Farming will become lucrative only when farmers will be able to reap higher profit for every rupee invested. Therefore, for farming to become a lucrative occupation, farmers have to consider farming as a business, keeping one eye on the production and the other on the marketing.

Agribusiness is a broad term referring to different businesses involved in agricultural sector which includes input supplies, crop production, processing, value addition, marketing etc. Transforming agriculture into a business needs systematic planning and execution by considering farming as a project. Turner (1999) defined project as a venture in which various resources such as humans/machines, materials, finance and knowledge are organized to carry out work of given specification within the stipulated cost and time to deliver qualitative, quantitative and consumer oriented product and service. Converting his production system into a business, requires a wider range of support including identification of the right enterprise, organizational support, marketing opportunities, available technologies, financial and entrepreneurial information which should be provided by the research and extension system.

Selection of an Enterprise/ Project

The prima facie task that an agripreneur has to perform is to explore, identify and then select a viable and attractive business opportunity i.e. what to produce and how much to produce. While selecting any enterprise the agripreneur must consider the viability of project in terms of technical, financial and commercial feasibility. If the entrepreneur becomes successful in selecting the right produce, there is a reasonable chance for success of his venture. When number of ideas are available to start an agribusiness, how to select the most viable and profitable enterprise? This can be done using a technique known as "Micro-screening".

Micro-screening

The entrepreneur must identify at least 10 potentially feasible project ideas which he/she thinks is viable in his/her location. These 10 project ideas will be further screened to identify the most viable project in the entrepreneur's locality based on ten factors. These factors are

1. **Availability of market**: Market should be large enough so that the entrepreneur can capture a market share and get a reasonable profit from the enterprise.
2. **Availability of raw material:** Whether the raw material essential for the venture is available locally in adequate quantity, quality and at a reasonable price. Whether any variation in the supply of the raw material or price can be managed without affecting the working of the enterprise.
3. **Availability of technology:** Whether proven technology is available at a reasonable price to produce the required quantity of quality produce.
4. **Availability of skill:** Whether sufficient skilled labours required to run the project are available in the area so that even if there any unforeseen situation labours can be managed.
5. **Government priority:** Whether the project selected fits into any government schemes or priority areas from which the entrepreneur can get assistance.
6. **Strategic Fit:** The proposed project should fit into the existing situation of the farmer i.e. it should complement the existing production system, facilities and resources available with the agripreneur.

7. **Ease of Implementation:** Project should have a short gestation period and can be easily implemented and managed by the entrepreneur.
8. **Risk exposure:** The risk associated with the project should be as minimum as possible. The possible risks are competition in the market, changes in customer preference, bad weather condition, unavailability of raw material, change in government policies, priorities, technology obsolesce etc.
9. **Profitability:** It means in the agripreneur's experience, observation or feedback from others, the return on investment in a particular enterprise will be excellent, very satisfactory, satisfactory, fair or poor.
10. **Cost / benefits:** This factor is basically the summation of all the other nine factors and gives an overall impression regarding the desirability and feasibility of undertaking the project.

Micro-screening is done using a chart given below:

PJ	MKT	RM	TEC	SKL	GOP	SFT	EI	RE	PFT	C/B	TTL	CSF
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

PJ -Project
MKT - Availability of market
RM - Availability of raw material
TEC- Availability of technology
SKL- Availability of skill
GOP- Government priority
CSF-Critical success factors
SFT - Strategic Fit
EI - Ease of Implementation
RE - Risk exposure
PFT- Profitability
C/B- Cost / benefits
TTL- Total

According to the agripreneur's perception or experience for each project, the 10 factors starting from availability of market to Cost / benefits will be rated on five point continuum scale i.e. 1-Poor, 2- Fair, 3- Satisfactory, 4- Very Satisfactory and 5- Excellent. The maximum total score a project idea can get is 50 points, that is 5 for excellent multiplied by 10 factors.

Using micro screening, we can narrow down the enterprise to three highest rated projects. Micro screening leads to the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of the project ideas which will be helpful in the identification of the right enterprise. It should always be kept in mind that a project, suitable and viable for an entrepreneur in one place may not yield similar profits in another area.

Micro screening also consist of critical success factors (CSF) i.e. certain factors particular to the identified projects that are crucial for the success of that specific project. A project's critical success factor can be any of the above ten factors. If any of the certain factors is missing or inadequate or not taken care, it may lead to failure of the project.

Business Plan

Once the agripreneur identifies an enterprise and decides to launch it, he should have a clear plan of how to execute the project. A business plan is a blue print of the activities that has to be carried out to implement the basic business idea. Business plan consists of a detailed project report which enables an entrepreneur to know about the kind of resources required, the technology and process involved and amount of investment needed. Business plan serves as a guideline for the business operation, aids in to planning strategies, increases the confidence of the entrepreneur, helps in availing bank loan for the enterprise and assists in periodic monitoring of the enterprise

Components of a Business Plan: Detailed Project Report (DPR)

A detailed project report consists of the following details:

1. General Background Information:	
a) About entrepreneur/ promoters	• Name, date of birth, Permanent address, Educational qualification, Current profession, Member of farmers group/ SHG/ NGO/APMC or any government institution
b) About Project	• Name of the project, Correspondence address, Address of the project site, Rationale of the project
2. Technical Aspects:	
a) Product details and production program	• Nature of the product/ service, Process of production and technology, Scale of production
b) Suitability of the location	• Location latitude, Longitude, Altitude, No: of growers/area under crop in the area, Current usage and proposed usage of land
c) Infrastructure requirement	• Total area proposed/ required for the project, Current infrastructure facilities available like building, road, water supply, electricity, transportation, storage, work space etc., Proposed infrastructure facilities, Layout plan of the project/farm/ production unit etc.
d) Machinery and equipment required	• Availability of machineries, Manufacturer/supplier, Technical advisors, Price, Capacity of machine, Auxiliary equipment, Erection and installation process and Cost involved
e) Raw materials	• Quantity and quality of required raw material, Cost, Source of procurement, Seasonality and storage
f) Technical standards of raw material and products or other certifications required	• AGMARK/ FSSAI standards, Pollution control certificate
g) Gestation period	• Time required for the commencement of the project
h) Suggested capacity and capacity utilization	• The total capacity of the project and what percentage of the capacity will be utilized each year during the project
i) Schedule of implementation	• Works that will be carried during each month for starting the project
3. Commercial Aspects:	
a) Product strategy	• Marketing quality produce, product differentiation through branding, focusing on particular group of consumers having homogenous demand
b) Demand forecasting	• Quantity of the produce that consumers would be willing to buy at all possible prices in a given market at a given point of time
c) Demand supply gap	• Estimating demand in future and then comparing the same with present supplies and potential new suppliers. A positive demand- supply gap favours the market potential and vice versa
d) Pricing strategy	• Premium pricing, psychological pricing, market penetration pricing, economy pricing etc.
e) Distribution strategy	• Transportation facility, marketing channel (direct sale/ distributors/ whole sale, franchising), Promotion of products (advertisement/free samples)

4. Managerial Aspects:

a) Skilled Labour	• Availability of skilled and unskilled labour in the area, requirement of the labours for running the project
b) Knowledge and experience of the entrepreneur	• Prior experience of the entrepreneur in the selected venture
c) Trainings undergone	• Whether the entrepreneur/ workers has under gone any prior training in the selected venture
d) Training facilities available in the area	• Any training facilities available in the nearby areas for the skill development of the entrepreneur as well as the workers

5. Organisational Aspects:

a) Mode of organisation	• Type of organisation/enterprise (Sole proprietorship/ Informal group/Co-operative/Partnership/Registered group/any other)
b) Linkage with other farmer groups/ organization	• Whether in association with any SHG/FPO/ NGO/Producer Company for production or marketing of the produce

6. Financial Aspects:

a) Capital requirement	• Investment requirement for setting and running the project. Two types of capital investment is there: Fixed capital and Working capital
i. Fixed capital	• Cost required for investing in basic facilities such as land, building, machineries, equipment, furniture etc.
ii. Working capital	• Cost required for purchasing in raw materials/ semi-finished goods/ finished goods, salary, rent, marketing cost, administrative and utility cost. This cost is incurred only during cycle of production
b) Sources of capital	• Own/ family/ friends/ relatives/ financial institutions, percentage share of own funds and percentage share required from other sources
c) Securities offered/ available	• Securities available with the entrepreneur for pledging loan
d) Profitability	• Estimation of the profitability based on the planned projections of sales/service
i. Cash flow statement	• Statement showing the relationship between cash inflow and cash outflow of a project Cash flow= Cash inflow- Cash outflow
ii. Benefit-cost ratio (BCR)	• Ratio of the sum of discounted benefits to the discounted costs of an investment with reference to the same point in time BCR> 1, project is bankable
iii. Net Present Value (NPV)	• Sum of discounted cash flow of a project over the cost of its initiation NPV> 0, project is bankable
iv. Internal Rate of Returns (IRR)	• Rate of discount that equates NPV to zero IRR> Cost of capital, project is bankable
e) Repayment Plan	• Repayment of loans. Two types of repayment plan: Diminishing balance repayment plan and Even repayment plan
i. Diminishing balance repayment plan	• Constant principal plus interest on outstanding balance is paid till the loan is fully repaid
ii. Even repayment plan	• An equal installment is paid till the loan is completely repaid
f) Break-even point	• Point where enterprise make no profit no loss

$$\text{BEP} = \frac{\text{Fixed Costs}}{(\text{Sales projected} - \text{Variables Cost})}$$

7. Sensitivity Analysis:

- To identify how far our estimates of project appraisal remains constant under changing situation of costs, prices and yields Project worth is calculated again assuming,

(1) Price of goods and services increases or decreases by a certain proportion (10%, 20% etc.)
(2) Changes in level of cost (increases or decreases 10%, 20% etc.)
(3) Changes in the level of production of the produce (increases or decreases 10%, 20% etc.)
(4) Varying gestation period

Points to be considered while making DPR

1. The estimated costs and returns must be as realistic as possible
2. Project's overall profitability must be calculated on the basis of the expected cost and returns
3. Projected profits have to be calculated taking into account interest on loan, depreciation on assets and rates of return on investment in plant and machinery etc.

The detailed project report will give a clear picture to the entrepreneur about his enterprise like what to produce, how much to produce, when to produce, cost of production, how to sell, how much to sell, where to sell, at which price so that he will be able to earn maximum profit from the venture. DPR also provides follow-up to agripreneur about the enterprise so that they can decide on whether to expand, diversify, modernize or bring about any change in the marketing strategy.

Conclusion

An entrepreneur starts his venture with a hope to succeed. The agripreneur must select the most appropriate enterprise and should have adequate knowledge and skills to run the enterprise. Micro screening technique aids in selecting the appropriate venture. Entrepreneur has to plan adequately to work on business. Preparation of a detailed project report gives the entrepreneur a clear picture of the enterprise including technical, commercial and marketing feasibility.

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Enhancing Farmers Income through Goat Production under Zero Grazing System

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Goat (*Capra hircus aegarius*) is designated as the national meat animal of India because of wider acceptability of chevon and lack of religious or cultural prohibitions against it. India ranked first in goat milk production and second in goat population (135.17 million) in the world constituting 26.4% of national livestock population (BAHFS 2017) ensuring livelihood security to 33 million households. In year 2016-17, 96.54 million goats and 43.27 million sheep yielded 1.04 and 0.56 million tones (MT) of meat with average 10.7 kg and 12.8 kg yield per animal, respectively (BAHFS, 2017). Additionally, goats produced 5.75 MT of milk (3% of national production) with average 0.46 liter per goat per day in same year. India is one among the largest exporters of sheep & goat meat to the world. Major export destinations of India are United Arab Emirates, Saudi Arabia, Qatar, Kuwait and Oman. During 2015-16, India imported goat/sheep meat of worth Rs. 4.79 crores, whereas, earned Rs. 446 crores through export of live goat/sheep and Rs. 871.08 crores through goat/sheep meat amounting 22,060.15 tones (excluding edible offal). Goat farming is gradually shifting from extensive or grazing system towards intensive or zero grazing system due to various factors.

Role of goats in rural ecologies

Goats are mainstay in livelihood of millions of rural households. Livelihood concept is explained in terms of capabilities, assets (stores, resources, claims and access) and activities that play interconnected roles in the wellbeing of households. The term coping is generally defined as an effort to prevent or diminish distress associated with threats, shocks, harm, or loss. In India, small landholders dependent mainly on crops are at greater risk of seasonal and climatic variations especially rainfall. Many parts face challenges of droughts and floods posing severe threats to livelihood of small landholders. The key part of resilience is the diversification of activities and use of different resources to increase household income as well as stability even when uncertainties prevail. The arid and semi-arid harsh conditions affect cattle more than goats and sheep. The ability of goats to graze, utilize poor quality forages, walk long distances and withstand drought makes them better assets to sustain the livelihoods of pastoralists.

Small ruminants play key financing and insurance roles for small landholders. They are suited for diverse climatic conditions and play critical role in almost all the agro-climatic zones of India. Their contribution is more significant is eco-fragile, calamity prone and agriculturally less suited areas. Small ruminants are essential component of rainfed farming systems in semi-arid India. About 70 per cent of the landless agricultural labourers, marginal and small farmers in the country are associated with goat husbandry. Small ruminants play an important role in the food and nutritional security of the rural poor especially in the rainfed regions where crop production is uncertain and rearing large ruminants is restricted by acute scarcity of feed and fodder (Kumar *et al.*, 2010). In pastoral societies of India, goats are kept as a source of additional income and as an insurance against income shocks of crop failure. They are not only an important source of income and employment for them, but also a vital source of animal protein for the family. Understanding the roles that goats play in the livelihood and food security of pastoralists significantly enables investment in the treatment and control of small ruminant diseases (FAO, 2013; De Haan *et al.*, 2015) i.e. towards health management. A number of micro studies concluded that the small ruminants have great social and economic relevance in poverty reduction and social equity.

Women empowerment through goats

In many poor economies, women often don’t own assets in the household or have control or power over assets and their use and yet these women are over-burdened by the plight of looking for food for the household (Akejo, 2017). Gender equality contributes to economic growth; however, it is not as clear that economic growth contributes to gender equality. The household role distribution and asset ownership determine the extent to which these assets can be converted into income generating activities. Goats play a critical role in the livelihoods of rural households, where they are often the property of poor women and children (FAO, 2013). A case study of Ethiopia shows that goats distributed to women farmers brought about substantial changes in their lives by enhancing food security and diversifying the livelihoods (Tefera, 2007). Thus, through women empowerment positive social changes in the society can be rapidly taken up.

Goats: silver lining amidst climatic challenges

As per existing share of goat and sheep (20 %) in total national meat production about 1.92 MT (million tonnes) meat is required from small ruminants for domestic consumption to meet out ICMR recommendation (10.95 kg/annum/person) for 70% non vegetarian population (87.5 crores). Whereas, if share of these two species rises up to 25% of total meat then requirement may go up to 2.4 MT for domestic consumption alone (excluding export share). Hence, there is scope of more than 50% expansion in small ruminant population from current production scale. It will be more sustainable too due to lesser water foot print of small ruminant production. Global average water footprint of meat from beef cattle (15,400 m^3/ton as a global average) is much larger than the footprints of meat from sheep (10,400 m^3/ton), pig (6,000 m^3/ton), goat (5,500 m^3/ton) or chicken (4,300 m^3/ton) (Mekonnen and Hoekstra, 2012). These average values may be much lower for small ruminant products derived from Asian countries in general and its arid areas in particular.

Developing countries are highly vulnerable to climate change since their economy predominantly relies on rain-fed agriculture that totally depends on natural factors. Majority of the small ruminant producers in a case study noted increased temperature (88 %) and decline in rainfall (73 %) over last decade which causes scarcity of feed, heat stress, shortage of water and pasture (Feleke *et al.*, 2016). Traditional farming systems practiced, which have low technological capacity, cannot help to adapt and mitigate drastic climate change. Addressing the challenges imposed due to climate change requires rearing of animals that are robust, more heat tolerant, more disease resistant and are relatively adaptable to the difficult conditions. Goats contributes to the weed and grazing controls under managed conditions, enhances plant diversity and can be added to sheep or cattle units without much inputs. As temperatures increase as a result of climate change, the probability of choosing sheep and goats as livestock species will increase. Further, cattle are more prone to losses than small ruminants during adverse climatic conditions as noted in Ethiopia and Sudan in the early 1980s where cattle losses were 80%, while small ruminant losses were less than 50% (Lebbie, 2004) in adverse climatic conditions. Goat production can be an effective coping strategy for pastoralists during hunger, drought and floods.

Goats for enhancement of income of small land holders

Goat production as against large ruminant and non-ruminant production plays greater role in reducing poverty, ensuring food security and overall household wellbeing particularly in rural regions of resource poor countries. Goats can quickly multiply, are resilient and easily convertible to cash to meet financial needs of the rural producers (Feleke *et al.*, 2016). The rural poor who cannot afford to maintain a cow or a buffalo find goat as the best alternative source of supplementary income and milk. Goat rearing has distinct economic and managerial advantages over other livestock because of its less initial investment, low input requirement, higher prolificacy, shorter generation interval and ease in marketing. Goats are largely reared on extensive system using common resources, forest land and crop residues. They are well suited for mixed or integrated farming systems i.e. backbone for small landholders. Due to acceptability for wide variety of feed resources small ruminants especially goats fits well with sylvipasture, agro-forestry etc. The adaptive capacities of goats to arid and semi-arid conditions make them one of the best assets for subsistence, food security and livelihood for small holder farmers. They provide significant means through which landless, small land owners, pastoralists, and agro-pastoralists can escape the poverty trap as in times of emergency they can be used as moving bank. Goats contribute enormously towards promotion of livelihood security and as an insurance cover to cope with crop failures particularly for rural landless, small and marginal male /female farmers.

Goats are more efficient in converting poor quality feed resources into quality meat compared to most of other farm animal species. In most of the Asian and rain-fed based economies, investment for other inputs is also less for goats than other farm animals. Due to smaller size goats are more suitable for transport, marketing and even domestic consumption thus have significant contribution in improvement of diet of economically weaker sections of the societies throughout the globe. Additional advantageous features of goats are higher feed use-efficiency from coarse roughages and high tolerance to tannins and diseases, as well as marketability within one season. Goat rearing can provide part time self-employment without affecting the main occupation for small and marginal farmers. Goats have exceptional tolerance of heat stress and ability to grow on poor quality feed with one of the least water footprint value among farm animals (designated future animal). Goat rearing is shifting towards zero grazing (Stall-fed) from extensive (grazing) system at slow but steady pace. Zero-grazing system is need of the hour due to scarcity of land for grazing, increased urbanization and population pressure. Contrarily, goat being active and inquisitive animal faces several stressors in zero grazing. Though in extensive type of goat production much skill is not required but under stall-fed system various managerial skills need to be imbibed for enhanced profitability. Therefore, various strategies are being explored to maximize performance of goats through coping up with the stressors. It includes suitable design of feeders to satisfy natural browsing instinct of goats, sufficient variation in feed resources as goats are selective feeder and enrichment of sheds as goats like walking and climbing in addition to exploration. These enrichment strategies can help in minimizing stress among goats in zero grazing system. Moreover, standardization of many farm operations (breeding strategies, housing type, fodder preservation etc.) according to season and locality is also major challenge to overcome under zero grazing system.

Hurdles to overcome for goat promotion

Although goats are known to provide significant socioeconomic contributions, their role is often overlooked in the general statistics about rural household economies (Akejo, 2017). Investments from public or private sector have been very minimal towards promotion of small ruminants leading to least improvement in traditional low input-low output small ruminant production system. The pastoralists use a traditional free-range system of small ruminants' production which is generally less productive due to poor pastures and easy disease transmission. Illiteracy of majority of the small ruminant producers leads to failure in adoption of scientific farming techniques. Hence, goat husbandry has remained more casual rather than an organized activity due to following reasons: (a) animals have least benefit of prophylactic or curative medicinal treatment; (b) little or no supplementary feed is offered; (c) no good flock management is practiced; (d) poor housing, lacking processing and value addition in small ruminant's meat and milk etc.

Additional constraints includes, realization of a lower price for the animal sold mainly due to the involvement of the chain of middlemen, lack of market information and poor holding capacity followed by occurrence of diseases and parasites and scarcity of fodder. Lack of knowledge of improved flock management practices and good quality breeding bucks, lower price of goat milk and repeat breeding in goats are problems in many areas. On the one hand, institutions imparting practical training on goat-rearing are very few and on the other, the traditional goat keepers were not keen to attend training programmes. Inadequacy of veterinary facilities was a major constraint in the adoption of health related technologies. The limited available veterinarians were largely involved in the curative care of large animals. However, there were constraints such as season related low levels of nutrition, mortality and morbidity losses, lack of good quality breeding stock and poor flock management and poor marketing opportunities that need to be overcome. Non availability of grazing land with high cost of feed, especially during summer, incidences of PPR, ET and FMD diseases were the major constraints for goat farmers in Karnataka (Shiva Kumara *et al.*, 2017).

Institutional insufficiencies includes lack of effective national breeding policy for small ruminants and poor initiatives on selection and conservation of indigenous breeds, poor integration of meat quality component in to breeding and genetic selection as well as insufficient nutrition and management studies. Shrinkage of pastureland and grazing areas leading to deficiency of feed and fodder with rapid degradation of natural resources puts additional burden. Laggardness in processing and value addition of meat, milk and by-products is mainly due to less awareness and financial constraints. Lack of financial resources (Shafiq *et al.*, 2017) is the major difficulty for resource limited small ruminant holders in Asian countries. It also leads to less affordability for suitable housing design for stall-fed farming affecting animal health and in turn productivity. Insufficient modern abattoirs for slaughter of large number of animals are not available leading to poor export potential. These major bottlenecks need to be tackled in order to ensure betterment of small ruminant producers.

Interventions required to strengthen goat production

Keeping in view stiff challenge for Indian cow or buffalo milk industry with regard to dropping International market of milk or milk products, replacing some share of large ruminant heads with small ruminant can be more viable option. Average landholding in India is about 1.15 hectares. Integration of 4-5 goats to small landholder dairy farmers with meager inputs can boost their income to the tune of Rs. 18000-20,000/annum from existing farm resources itself. For capacity building of small ruminant farmers, advisory on improving goat production in India recommended that MGNREGA funds should be roped in to procure raw material which will facilitate production and distribution of complete feed blocks in a regulated manner. List of shrubs and trees suited to different agro-ecological regions of the country too have been suggested to be made integral part of land use planning to augment grazing resources for small ruminants. Small ruminant production has been given emphasis through strengthening of housing, healthcare as well as feeding via MGNREGA.

For improving fodder availability for the small ruminants, besides the development of common property resources (CPRs) by involving panchayats and user groups, there is a need to institutionalize linkages between the goat farmers in fodder scarce regions and areas with better fodder availability. Appropriate extension programmes, prophylaxis of animals, timely availability of critical inputs, remunerative price for animals and its products and easy access to institutional finance would be crucial for the sustainable development of small ruminant enterprises in the country. An effective package of interventions to promote market-oriented small ruminant production need to include development of market infrastructure and market institutions, improved access to extension and credit use, efficient reproduction, healthcare and management practices.

Skill development of goat farmers who are predominantly illiterate through set up of more training centers and establishment of co-operatives or creation of self help groups (SHGs) can increase their profitability. Providing the farmers with timely access to information on improved technologies, inputs, market and credit would be an important step in overcoming different constraints in goat production. Sustainable livestock production can be enhanced when animal health centers and professionals are made visible at local farming communities. Training institutions (particularly those for watershed development) should organize training for rural poor women in goat production technologies and its importance for income generation. Efforts should be made by both research and development institutions to link up rural poor/women with funding agencies.

Cluster model approach may be adopted in selected areas for propagation and development of goat sector. In this approach, one nuclear breeding farm with capacity of about 200 heads may associate with minimum of 5 small beneficiary farms with capacity of 10-20 heads for input and back up support facilities. For success of this model, Government should ensure legal, technical, financial, health and mainly marketing support to these cluster units. Small ruminant Co-operative societies/ small ruminant boards may be constituted to address the challenges of farming, processing and marketing. Evaluation of medicinal properties of goat milk and its promotion as nutraceutical may help in boosting farmers' income. Promotion of processing of meat and milk at own or co-operative level may increase profit by 30-50%. Facilitation of marketing federation by involving farmers, micro-financers and commercial agencies may help the goat farmers. Formation of farmers associations and development of marketing facilities would help farmers get better prices for their animals and or products.

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Cold-Chain Management for Reducing Post-Harvest Losses and Increasing Farmer's Income

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Cold Chain refers to the transportation of temperature sensitive products like perishable goods from the point of origin to point of consumption in the food supply chain, which keeps it fresh and edible for a much longer period than in normal conditions. Cold Chain helps in transporting seasonal products and also making it available throughout the year. Two main parts of cold chain are transportation and storage systems. The key Indian industries where cold chain logistics play very important role are fruits and vegetables, milk and milk products (ice cream), Poultry and processed meat, marine products, pharmaceutical (mainly vaccines) and chemicals. An efficient cold chain industry ensures availability of food products as well as prevents spoilage of medicines. Country like India, where infrastructure is one of the major challenges, cold chain plays a critical role. Analysis for this study shows that cold supply chain network does not differ significantly from products to products at least in Indian scenario. Some of the challenges to the growth of sector in India are high energy cost, power deficit, rising real estate cost, lack of logistical support and uneven distribution of capacity. All these challenges bring down the operating margin of a company and makes it not so attractive business sector. But during last couple of years there is a positive environment being created for this sector in India. The Indian agricultural sector is witnessing a major shift from traditional farming to horticulture, meat and poultry and dairy products, all of which are perishables. The demand for fresh and processed fruits and vegetables is increasing as urban populations rise and consumption habits change. Due to this increase in demand, diversification and value addition are the key words in the Indian agriculture today. These changes along with the emergence of an organized retail food sector spurred by changes to Foreign Direct Investment laws, are creating opportunities in the domestic food industry, which includes the cold chain sector. As a result of the Government of India's new focus on food preservation, the cold storage sector is undergoing a major transformation. The Government has introduced various incentives and policy changes in order to curtail production wastage and control inflation; increase public private participation and improve the country's rural infrastructure (Fig.1).

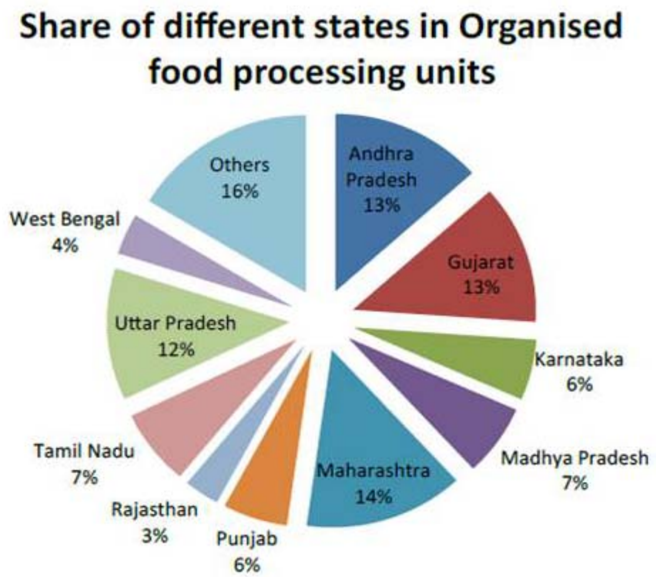

Fig. 1. Cold storage share in India

Cold chain infrastructure includes cold storage infrastructure, transport infrastructure and point of production infrastructure. There are approximately 6300 cold storages in India designed originally for single commodity storage. Refrigerated transport or cold chain distribution is still in its nascent stage in India and is way behind if compared to world standards for cargo movement. Presently reefer transport business in India is estimated at '10-12 billion which includes reefer transportation demand for both exports and domestic. Various industries covered under cold chain are agriculture, horticulture & floriculture, dairy, confectionery, pharmaceuticals, chemicals, poultry, etc. India has around ~6300 cold storage units, but can only store less than 11percent of the country's total produce. While ~105mn MT of perishable produce is transported across India annually, only ~4mn MT is transported via reefers.

With initiatives by the Indian government and a steep growth in the consumption of processed foods, cold chain logistics is expected to witness huge growth in the coming years. High growth prospects for the food-processing sector along with attractive government incentives (including 51 percent FDI) make cold chain business a lucrative proposition for foreign investors as well. It should be specifically mentioned that a large number of cold storage projects, located in different parts of the country, are based on old and inefficient technology. The user industry would expect modern plants with more automation, mechanized operations and operating conditions that are more hygienic. Currently, one of the focus areas is to make reefer trucks more energy efficient to withstand the variations in the ambient temperatures at drop-off points.

Contrary to the popular belief, cold chain is not merely refrigeration of perishable commodities. Cold chain is a logistics system that provides a series of facilities to maintain ideal storage conditions for perishables from the point of origin to the point of consumption in the food supply chain (Fig 2). The chain needs to start at the farm level – post-harvest, pre-cooling, etc. – and reaches to the consumer or at least to the retail outlets. A well organized and efficient cold chain reduces spoilage, retains the quality of the harvested products and guarantees a cost efficient delivery to the consumer. A significant aspect of the system is that if any of the links is missing or weak, the whole system might fail.

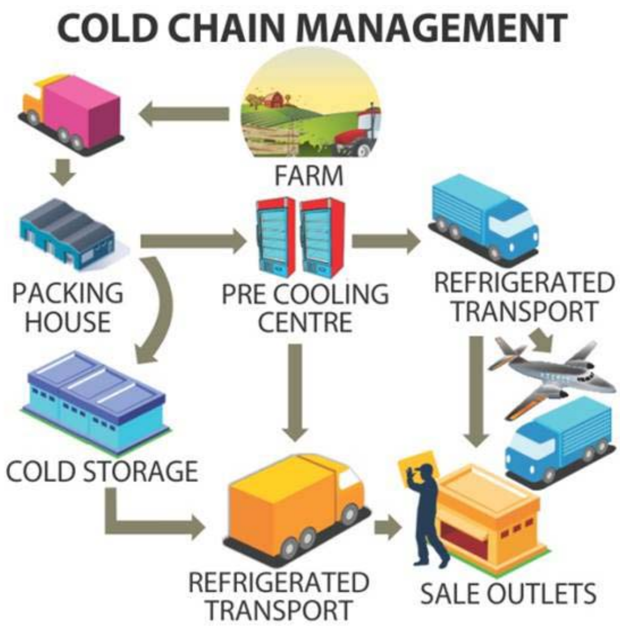

Fig. 2. Cold-chain management in the food supply chain

Cold-chain Market Demand and Market Data

The total value of India's cold chain industry is currently estimated at USD 3 billion and reportedly growing at an annual rate of 20-25 per cent. The total value for the industry is expected to reach at USD 8 billion by 2015 through increased investments, modernization of existing facilities, and establishment of new ventures via private and government partnerships.

India's cold chain industry is still evolving, not well organized and operating below capacity. Most equipment in use is outdated and single commodity based. According to government estimates, India has 5,400 cold storage facilities, with a combined capacity of 23.66 million metric tons that can store less than 11% of what is produced. The majority of cold storage facilities are utilized for a single commodity, such as potatoes. Most of these facilities are located in the states of Uttar Pradesh, Uttaranchal, Punjab, Maharashtra, and West Bengal.

In addition, India has about 250 reefer transport operators (this includes independent firms) that transport perishable products. Of the estimated 25,000 vehicles in use, 80% transport dairy products (wet milk); only 5,000 refrigerated transport vehicles are available for all other commodities.

Table 1. Distribution of cold storage facilities by commodity

Commodity	Capacity (millions tons)	% of Total	No. of Cold storages
Potato	18.43	75.4	2862
Multi-purpose produce	5.64	23.1	1584
Fruits & Vegetables	0.10	0.4	160
Meat	0.19	0.8	497
Fish	0.07	0.3	191
Milk & Dairy Products	0.03	0.1	87
Others	24.46		5381

Table 2. Region wise Number and Capacity of Cold Storages in India (2011)

Cold Storages	Central	East/North East	North	South	West	All India
Number	430 (7.00%)	975 (15.80%)	2895 (47.00%)	866 (14.10%)	990 (16.10%)	6156 (100%)
Capacity (Million MT)	1.71 (6.00%)	7.82 (27.30%)	14.95 (52.10%)	1.95 (6.80%)	2.25 (7.90%)	28.68 (100%)

India's greatest need is for an effective and economically viable cold chain solution that will totally integrate the supply chains for all commodities from the production centers to the consumption centers, thereby reducing physical waste and loss of value of perishable commodities. For this reason, the Government of India has prioritized the development of the cold chain industry. The government has laid out elaborate plans and incentives to support large scale investments essential for developing an effective and integrated cold chain infrastructure.

Opportunities and constraints

Value addition of food products is expected to increase from 8 percent to 35 percent and that of fruits and vegetable processing from the current 2 percent to 25 percent by the end of 2025. The dairy sector, which currently comprises the highest share of the processed food market, will experience marked growth. One of the most critical constraints in the growth of the food processing industry in India is the lack of integrated cold chain facilities. According to the government's estimates India has 5,400 cold storage facilities of which 4,875 are in the private sector, 400 in the cooperative sector and 125 in the public sector. Although the combined capacity of the cold storage facilities is 23.66 million metric tons, India can store less than 11% of what is produced. Most of the infrastructure used in the cold chain sector is outdated technology and is single commodity based. Many are designed for storing potatoes. The controlled atmosphere (CA) and modified atmospheric (MAP) storage facilities and other cold storage facilities with the technology for storing and handling different types of fruits and vegetables at variant temperatures would have a very good potential market in India.

It is recognized that development of cold chain is an essential next step in upgrading our food processing industry. A series of measures to reduce the production and supply chain bottlenecks in the agricultural sector in order to facilitate modernization, ease importation of foreign equipment, and attract foreign investment in India were undertaken. Some of these measures are listed below:

- Accorded infrastructure status to post-harvest storage, including cold chain;
- Raised the corpus of Rural Infrastructure Development Fund and the additional allocation would be dedicated to the creation of warehousing facilities;
- The Viability Gap Funding Scheme is extended for public private partnership projects to set up modern storage capacity;
- Air-conditioning equipment and refrigeration panels for setting up cold chain facilities would be exempted from excise duty beginning in the next fiscal year. Conveyor belts for equipment used in cold storage, wholesale markets and warehouses would be also exempted from excise duty;
- Creation of an additional 15 million tons capacity of storage capacity through public private partnerships put on a fast track;
- The National Horticulture Mission has sanctioned 24 cold storage projects with a capacity of 140,000 metric tons;
- An additional 107 cold storage projects with a combined capacity of over 500,000 metric tons have been approved by the National Horticulture Board;
- Promised full exemption from service tax for the initial set up and expansion of cold storage, cold room (including farm pre-coolers for preservation or storage of agriculture and related sectors produce) and processing units. In addition, full exemption from customs duty for the manufacture of refrigerated vans or trucks have also been promised;

- A package of measures to improve the availability of storage and warehouse facilities for agricultural produce and to incentivize food processing;
- Announcement to set up 15 more mega food parks in the country;
- States asked to reform the Agriculture Produce Marketing Act urgently to improve the supply chain;
- A National Food Security Bill was approved.

Key Suppliers

The following is a partial list of companies currently supplying cold chain technology/equipment/services in India: Ingersoll Rand (USA); Rinac; Walco Engineering; Frick India; Carrier; Bluestar; Lamilux; Dupont; Emerson Climate Technologies; Parker Hannifin; Snowman; R.K. Foodlands; Schaefer Systems International Pvt. Ltd.; Metaflex Doors India Pvt. Ltd.; Alfa Laval (India) Limited; Tolsma Storage Technology, Snowman Frozen Foods; Fresh and Healthy Enterprises, and Apollo-Everest Cool Solutions

Prospective Buyers

Following is a partial list of prospective businesses which are buyers of cold chain technology/equipment/services in India: fruit and vegetable sellers; food processors; warehouse / cold storage owners; refrigeration and cold chain equipment and technology suppliers. Others include Cold Logistics firms such as shipping lines, transporters, container companies, warehousing agents, supply chain solution providers, ports (Indian and international), large format retailers and wholesalers, academic and research institutions, government organizations, packaging service providers, specialized equipment providers, India's Cold Chain Industry refrigeration solution providers, seafood companies, and food testing laboratories.

Cold chain components

The term "cold chain" and the components thereof, refer to steps from harvest to consumption that extends the natural shelf life of a produce by controlling temperature. Typical components of a cold chain may include post-harvest handling, refrigerated transport, refrigerated storage, controlled atmosphere storage (CA), and modified atmospheric packaging (MAP), chilled or frozen processing, cold storage holding and/or distribution, retail refrigeration, institutional refrigeration, and home refrigeration.

Any food begins to deteriorate or lose quality upon harvest whether it is meat, poultry, seafood, dairy, fruit or vegetable. Most also continue to produce heat and in some cases ripening gases, even after harvest. Removing the heat from these products and maintaining product temperature and/or storage atmospheric composition, by chilling, refrigerated storage, CA/MA storage or freezing reduces the rate of deterioration and extends the shelf-life of the product. In addition to protecting quality, application of the appropriate cold chain components provides flexibility by making it possible to market products at the optimum time.

Temperatures maintained in cold chain storage facilities may be divided into "refrigerated" and "frozen" categories. Refrigerated temperatures are typically those above 0^oC and frozen temperatures those lower than 0^oC temperature. Typically fresh meat, poultry, seafood, milk, flowers, fruits and vegetables are held at 4^oC while some products such as strawberries, mango, cucumbers and tomatoes are held at higher temperatures due to sensitivity issues. Temperatures used to freeze products are normally lower than storage temperatures. Proper storage and warehousing is not only integral to maintaining quality, but to increasing prices for producers and/or distributors and providing consumers the benefit of longer consumption seasons.

The major cold chain components are described below.

Harvesting, Collection and pre-cooling

Harvesting is one of the important operations, that decide the quality as well as storage life of produce and helps in preventing huge losses of fruits. Harvesting of fruits should be done at optimum stage of maturity. During harvesting operation, a high standard of field hygiene should be maintained. It should be done carefully at proper time without damaging the fruits. The harvesting operation includes.

i) Identification and judging the maturity of fruits.
ii) Selection of mature fruits.
iii) Detaching or separating of the fruits from tree, and
iv) Collection of matured fruits.

Method of Harvesting

Different kinds of fruit and vegetables require different methods after harvesting. The methods of harvesting are:

1. Manual Harvesting and 2. Mechanical Harvesting

1. Manual Harvesting

Harvesting by one's own hand is called manual harvesting. It is done in several ways:

a. Ladder / bag picking method
b. Poles/ Clippers method
c. Harvesting by means of cutting knives
d. Harvesting by means of digging tools.

2. Mechanical Harvesting

In this method numbers of mechanical devices are used for harvesting the produce on commercial scale.

Maturity of Fruits and Vegetables

It refers to the attachment of final stage of biological function by a plant part or plant as a whole or It is the particular stage in life of plant of fruit at which they attain maximum growth and size.

Good quality of fruits and vegetables are obtained when harvesting is done at the proper stage of maturity. It is the stage where any organ of the plant attains full growth and development. So it is the stage of fruit development beyond which no further growth take place. After maturity of any organ it starts its decline stage i.e. called as "Ripening". Earlier the harvest, longer is the time of ripen. Greater the maturity, lesser are the number of days required for the fruit ripen. But the ripe fruits from early harvests and poor quality indicated by lower organoleptic ratings and with increasing maturity, quality improved. The maturity indices are also called as "Maturity Standards" or "Signs of Maturity". Maturity signs help in judging maturity of fruits and vegetables. The signs are based on experience and skill and judgment. As the market value depends upon quality of the produce, the knowledge regarding maturity indices of right stage of harvest caries vital importance. Secondly shelf life of the produce in some fruits depends upon maturity stage of harvested produce.

There are five types of indices to judge the maturity of the fruit.

1. Visual means
2. Physical means
3. Chemical analysis
4. Computation
5. Physiological method.

1) Visual Means

Skin colour, size, persistence of style portion, drying of outer leaf, drying whole plant body, change in smell or flavour, dropping down of ripe fruits.

2) Physical Means

Fairness easy separation or abscission, specific gravity, weight of the fruit.

3) Chemical Analysis

T.S.S , acids, starch, sugar, etc.

4) Computation

Days for harvesting fruits from fruit set till maturity.

5) Physiological Method

Respiration rate, internal ethylene evolution.

Collection

Depending on the type of fruit or vegetable, several devices are employed to harvest produce. Commonly used tools for fruit and vegetable harvesting are secateurs or knives, and hand held or pole mounted picking shears. When fruits or vegetables are difficult to catch, such as mangoes or guava, a cushioning material is placed around the tree to prevent damage to the fruit when dropping from high trees. Harvesting bags with shoulder or waist slings can be used for fruits with firm skins, like citrus and avocados. They are easy to carry and leave both hands free. The contents of the bag are emptied through the bottom into a field container without tipping the bag. Plastic buckets are suitable containers for harvesting fruits that are easily crushed, such as tomatoes. These containers should be smooth without any sharp edges that could damage the produce. Commercial growers use bulk bins with a capacity of 250-500 kg, in which crops such as apples and cabbages are placed, and sent to large-scale packinghouses for selection, grading, and packing.

Several methods of cooling are applied to produce after harvesting to extend shelf life and maintain a fresh-like quality. Some of the low temperature treatments are unsuitable for simple rural or village treatment but are included for consideration as follows:

Pre-cooling

Fruit and vegetables are pre-cooled by lowering the temperature from 3 to 6°C (5 to 10°F) for safe transport. Pre-cooling may be done with cold air, cold water (hydrocooling), direct contact with ice, or by evaporation of water from the product under a partial vacuum (vacuum cooling). A combination of cooled air and water in the form of a mist called hyraircooling is an innovation in cooling of vegetables.

Air pre-cooling

Pre-cooling of fruits with cold air is the most common practice. It can be done in refrigerator cars, storage rooms, tunnels, or forced air-coolers (air is forced to pass through the container via baffles and pressure differences).

Icing

Ice is commonly added to boxes of produce by placing a layer of crushed ice directly on the top of the crop. An ice slurry can be applied in the following proportion: 60% finely crushed ice, 40% water, and 0.1% sodium chloride to lower the melting point. The water to ice ratio may vary from 1:1 to 1:4.

Room cooling

This method involves placing the crop in cold storage. The type of room used may vary, but generally consists of a refrigeration unit in which cold air is passed through a fan. The circulation may be such that air is blown across the top of the room and falls through the crop by convection. The main advantage is cost because no specific facility is required.

Forced air-cooling

The principle behind this type of precooling is to place the crop into a room where cold air is directed through the crop after flowing over various refrigerated metal coils or pipes. Forced air-cooling systems blow air at a high velocity leading to desiccation of the crop. To minimize this effect, various methods of humidifying the cooling air have been designed such as blowing the air through cold water sprays.

Hydro-cooling

The transmission of heat from a solid to a liquid is faster than the transmission of heat from a solid to a gas. Therefore, cooling of crops with cooled water can occur quickly and results in zero loss of weight. To achieve high performance, the crop is submerged in cold water, which is constantly circulated through a heat exchanger. When crops are transported around the packhouse in water, the transport can incorporate a hydrocooler. This system has the advantage wherein the speed of the conveyer can be adjusted to the time required to cool the produce. Hydrocooling has a further advantage over other precooling methods in that it can help clean the produce. Chlorinated water can be used to avoid spoilage of the crop. Hydrocooling is commonly used for vegetables, such as asparagus, celery, sweet corn, radishes, and carrots, but it is seldom used for fruits.

Vacuum cooling

Cooling in this case is achieved with the latent heat of vaporization rather than conduction. At normal air pressure (760 mmHg) water will boil at 100°C. As air pressure is reduced so is the boiling point of water, and at 4.6 mmHg water boils at 0°C. For every 5 or 6°C reduction in temperature, under these conditions, the crop loses about 1% of its weight (Barger, 1961). This weight loss may be minimized by spraying the produce with water either before enclosing it in the vacuum chamber or towards the end of the vacuum cooling operation (hydro vacuum cooling). The speed and effectiveness of cooling is related to the ratio between the mass of the crop and its surface area. This method is particularly suitable for leaf crops such as lettuce. Crops like tomatoes having a relatively thick wax cuticle are not suitable for vacuum cooling.

Recommended minimum temperature to increase storage time

There is no ideal storage for all fruits and vegetables, because their response to reduced temperatures varies widely. The importance of factors such as mould growth and chilling injuries must be taken into account, as well as the required length of storage (Wills et al., 1989). Storage temperature for fruits and vegetables can range from -1 to 13°C, depending on their perishability. Extremely perishable fruits such as apricots, berries, cherries, figs, watermelons can be stored at -1 to 4°C for 1-5 weeks; less perishable fruits such as mandarin, nectarine, ripe or green pineapple can be stored at 5-9°C for 2-5 weeks; bananas at 10°C for 1-2 weeks and green bananas at 13°C for 1-2 weeks. Highly perishable vegetables can be stored up to 4 weeks. Green tomato is less perishable and can be stored at 10°C for 3-6 weeks and non-perishable vegetables such as carrots, onions, potatoes and parsnips can be stored at 5-9°C for 12-28 weeks.

Conclusion

Cold chains are fundamental for developing the time frame of realistic usability, time of showcasing, staying away from over limit, and diminishing transport bottlenecks amid pinnacle time of generation and to keep up the nature of deliver. The advancement of cold chain industry has a vital part to play in diminishing the wastages of the perishable items and therefore giving gainful costs to the producers. Additionally, it acts like a spine for reducing post-harvest losses and keeps up the viability of the food industry all through the inventory network by giving temperature controlled environment to delicate food items.

Recent Trends in Storage and Preservation of Food Grains

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Introduction

About 60 – 70 % of population of the country is linked with agriculture in one or other form. India annually produces around 270 million tonnes food-grains (third largest), 295 million tonnes of fruits & vegetables (second largest), 164 million tonnes of milk (highest in the world), 512 million numbers livestock (largest), 10 million tonnes of fish (3rd largest), 730 million numbers Poultry and 70 million eggs. India is not only a great producer of foods but also a big looser of them in post-harvest system. The monetary value of the postharvest losses was estimated to be around Rs 92,000 crores (On the basis of prices during 2014). The reasons for postharvest losses are many and mainly include lack of appropriate storage facilities, inappropriate handling and transportation, untrained manpower, lack of primary processing at farmers field etc. Grain storage is vital activity to ensure food security to the world. More than 60% of the energy (kcal) in our diet is contributed by food grins (cereals, pulses &oilseeds) and the remaining is met from sugar, eggs, milk, meat , fruits/vegetables etc. The cost of the energy from food grain is the minimum is comparison to the cost of energy derived from other sources such as milk/meat/eggs etc. Food grains provide carbohydrates, proteins, fat, minerals/vitamins & dietary fiber in our diet. The stocks of food grains are maintained by the government all over the world to tackle food security.

Grain harvesting seasons are very short compared to grain consumption which happens throughout the year. Farmers store grain for their own consumption and for seed purpose. About 70% of farm produce is stored by farmers for their own consumption. Farmers store grain in bulk, using different types of storage structures like *Bakhara*, *Kanaja*, *Kothi*, *Sanduka,* Earthern pots and Gunny bags mostly made from locally available materials. According to an Indian study on grain storage practices, 41.5% of farmers use gunny bags, 18.1% use bulk storage in rooms, 11.1% use metallic bins and the rest about 30.0 % use other traditional structures made up of local materials. The storage capacity required by farmers is small and very rarely exceeds 2 tonnes. A majority of this pertains to the cereal grains. Apart from cereals the farmers also store pulses and oilseeds as per their requirement. However quantity of pulses and oilseeds stored at farmers level is too little. The traders and marketing agents store grain for financial gains. The agro-processing industries such as rice mills, oil milling units, roller flour millers also store grain to meet their processing requirements. The requirement of storage by majority of such units ranges from 1000 – 20,000 metric tonnes. In India, Government agency FCI is the largest agency engaged in procurement, storage and distribution of food grains, mainly wheat, rice and maize. The overall objective of grain storage is to preserve the quantity and quality (including nutritive value) of grains. It is required to keep the grains in good condition for marketing and processing, thereby reducing product and financial losses. The role of storage has become more significant, as the grain quality standards with reference to pests, pesticides and other contaminants in national and international markets have become increasingly rigorous. Storage of food grains (a component of postharvest operation), is an ongoing challenge for Indian agencies to ensure food security.

Bulk storage systems with long life have been introduced in India. Selection of material of construction, design and cost are important factors to meet the requirements of farmers and processors. Bag storage of food grains seems to be more appropriate for government agencies as it is required to move the grain to distant places. In the absence of bulk transportation facilities, the existing bag storage practice seems to be appropriate. However, improvement in design of godowns, mechanisation of grain handling in godowns, environment control and fumigation etc. in godowns requires attention. Both bag storage and bulk storage systems have their comparative advantages as well as disadvantages.

The post-harvest loss of food grains especially due to storage is faced by farmers, private as well as by public sectors, though the scale of each of them is different. It is, therefore, required to look into grain storage practices and problems faced by each category and develop suitable cost effective remedies.

Grain storage ecosystem

The grains need to be stored safely until consumed. A stored grain bulk is a man-made ecological system in which deterioration of the stored product results from interactions among physical, chemical, and biological factors. The important factors are: temperature, moisture, carbon dioxide (CO_2), oxygen (O_2), grain characteristics, microorganisms, insects, mites, rodents, birds, geographical location and granary structure. The storage life of grains depends mainly on two physical factors: temperature and moisture content. The survival and reproduction of biological agents in grain are dependent to a great extent on the temperature and moisture levels. Stored-product insects can live at temperatures from 8 to 41 ^{o}C and inter-granular relative humidity's (r.h.) from 1% to 99%. Usually, development and multiplication are optimum near 30 ^{o}C and 50 – 70 % r.h. but stop at 18 ^{o}C. Mites can live at temperatures from 3 to 41 ^{o}C and relative humidity's from 42 % to 99 % with the optimum for development and multiplication near 25 ^{o}C and 70–90 % r.h. Fungi can develop at temperatures from 2 to 55 ^{o}C and relative humidity's from 70 % to 90 % with the optimum temperature near 30 ^{o}C and relative humidity around 80 %. There is considerable variation in optimum conditions for different species. Localized regions may occur in stored-grain bulks for optimum development and multiplication of insects, mites and fungi even when the average conditions of the bulk would prevent pest infestation. Mycotoxins are poisonous metabolites produced by certain fungal genera, which can infect crops both in the field and in storage. Conditions favoring the development of mycotoxins in cereals before and after harvest are not well-understood, but are of particular importance. (Jayas and White, 2003)

Grain storage by farmers

Around 60-70 % of the food grains produced in India is retained by the farming families. The quantity stored by these families is seldom large. The maximum storage capacities for cereal grains by farmers have been observed to be up to 1.5 – 2 tonnes. The storage capacity for pulses and oilseeds is much smaller (100-500 kg). The quantity of grain storage at farm level depends on overall production, family requirement and economic considerations.

Indigenous storage structures / methods

The indigenous storage structures differing in design, shape, size and functions have been made from a variety of locally available materials. The materials used include paddy straw, wheat straw, wood, bamboo, reeds, mud, bricks, cow dung etc. Grains could be stored indoors, outdoor or at underground level (Nagnur et al, 2006).

Indoor storage involved grain containment in structures like *Kanaja*, *Kothi*, *Sanduka* and earthern pots. *Kanaja* is a grain storage container made out of bamboo. The base is usually round and has a wide opening at the top. The height varies. The *Kanaja* is plastered with mud and cow dung mixture to prevent spillage and pilferage of grains. The top is also plastered with mud and cow dung mixture or covered with paddy straw or gunny bags.

Wooden boxes, also called as *Sanduka*, are used for storing pulses, seeds and smaller quantities of grains. These boxes have a storage capacity of 3-12 quintals. In some cases, partition is also made inside the box to store two to three types of grains. A big lid on the top with a small opening enables taking out the grains. To protect the grains from moisture, the box is kept 12 inches above the ground level with the help of stands/legs. The box has to be regularly polished for its maintenance. *Kothi* is used to store paddy and jowar. A room is constructed with a large door for pouring grains. A small outlet is made for taking out the grains. Earthen pots are indoor storage containers for storing small quantity of grains. These are made locally using burnt clay and are of different shapes and sizes. The earthen pots are placed at the floor level. They are arranged one above the other and known as *dokal* (Nagnur et al, 2004).

Outdoor storage of grains is done in structures made of bamboo or straw mixed with mud. Bamboo structures are used for storing un-threshed and threshed paddy. Gummi is an outdoor structure used for storing grains. This structure is made with bamboo strips or locally available reeds. It is usually circular or hexagonal in shape and plastered with mud. The base on which the structure is constructed is also made up of reeds or in some cases with stone slabs. The roof of the structure is usually made from loose straw. The structure is placed on a raised platform. Bamboo structures made on a raised timber or stone platform protect grain from rat damage and prevent moisture absorption from the ground. *Kacheri* is a traditional storage structure using paddy or wheat straw, woven as rope. It is made from either paddy straw alone or paddy straw mixed with mud. (Nagnur et al, 2004)

Improvements in indigenous storage structures

The indigenous storage structures although cost effective, suffer from many flaws. These are unsuitable for storing grains for very long periods. Regular mud plastering is required for a variety of indoor and outdoor storage containers and structures for increasing their life span and ensuring safe storage of grains.

To overcome the problems associated with indigenous storage structures, some modifications and improvements were tried to offer better grain storage structures to the farmers. For small-scale storage of grains the PAU bin, Pusa bin, Coal-Tar drum bin and Domestic Hapur tekka have been developed and demonstrated by the several scientists. The name PAU bin, itself suggest that the bin has been developed by the Punjab Agricultural University. The bin is made up of a galvanized metal iron structure. The bin has moderate capacity varying from 1.5 to 15 quintals. The Pusa bin is also called as LDPE (low density polyethylene) sandwiched bin. This means that the storage structure is made of mud or bricks with a polythene film embedded within the walls like a sandwich. The developed bin has minimal moisture migration during storage because of the good insulating properties of LDPE. The coal-tar drum bin (200 kg) was developed at Central Institute of Agricultural Engineering (CIAE), Bhopal. It is a low cost bin and can be easily available at domestic level. The domestic Hapur *tekka* or bin has capacity 200 to 1000 kg. It is cylindrical in shape, made of galvanized iron and /or aluminum sheet, has a small hole in the bottom through which grain can be removed. (Said and Pradhan, 2014; Dhaliwal and Singh, 2010)

Commercial Grain Storage

In India the major grains produced are rice and wheat. The surplus of wheat and rice sold by farmers is procured by the Government and its agencies on Minimum Support Price declared by the government every year. Private sector, of late has also started procuring large quantities of food grains for domestic and international markets.

Covered storage

The most popular storage system in India followed by FCI, CWC and State Warehousing corporations is bag (jute bags) storage in warehouses. The grain is packed in jute bags and stacked inside covered structures called warehouses / godowns. The godowns are conventional masonry structures constructed on a raised platform as per approved design and specifications of Bureau of Indian Standards. The recommended capacities and dimensions of storage structures are given in Table 1. The capacities have been estimated on the basis of 22-bags high stacks of 50 kg capacity each.

Table 1. Capacities and dimensions of bagged storage structures

Type of godown	Capacity in metric tonnes	Internal Dimensions in metres	
		Length	Breadth
Small	1000	35.5	18
	2500	97.19	14.48
Large	5000	129.74	21.34

New trends in covered storage

With the advent of technology some changes in the design of godowns have been adopted by various agencies. These changes pertain to the roofing material. The roofing material introduced is 55 % Aluminum-Zinc alloy coated sheet steel (better known as GALVALUME). The steel sheet 914 mm wide (tolerance ±2mm) having minimum thickness 1 mm (+/- 0.02 mm), minimum yield strength of 350 MPa, alloy coated (55% Aluminium, 43.5% Zinc and 1.5% Silicon) on both sides is recommended for roofing. These sheets are fabricated in one foot or two feet wide panels and are fabricated and erected on site. The final roof is in the form of arch and no support (truss) is required. The roof is directly mounted on the longitudinal walls. Such roofing’s have become popular in many industrial sheds, warehouses and godowns. These have also been recommended for godowns for storage of food grains.

Cover and Plinth (CAP) storage

CAP storage is used for short term temporary storage of wheat and paddy in the procurement areas. During procurement operations, the storage of food grains is resorted in Cover and Plinth (CAP) storage, till the grains are evacuated and transported to the consuming areas.

This is an improvised arrangement for storing food grains in the open, generally on a raised plinth (0.6 m from ground) which is damp- and rat-proof. The grain bags are stacked in a standard size on wooden dunnage. The stacks are covered with 250 micron LDPE sheets from the top and all four sides. Food grains such as wheel, maize, gram, paddy, and sorghum are generally stored in CAP (cover and plinth) storage for 3-6 month periods. It is the most economical storage structure and is being widely used by the FCI for bagged grains.

Preservation of food grains under covered storage

The following steps have been recommended to avoid damage to food grains in covered storage structures and CAP storage. These are practiced to avoid post-harvest losses of food grains:

- Covered storage structures may be constructed as per approved specifications.
- Adopt scientific code of practices for storage of food grains
- Adequate dunnage materials, such as, wooden crates, bamboo mats, polythene sheets may be used to check the migration of moisture from the floor.
- Fumigation covers, nylon ropes, nets and insecticides for control of stored grain insect pests may be provided in all the godowns.
- Prophylactic (spraying of insecticides) and curative treatments (fumigation) may be carried out regularly and timely for the control of stored grain insect pests. The prophylactic treatment involves the use of pesticides like malathion (50% EC), DDVP (76% EC) and deltamethrin (2.5% WP). Curative treatment involves use of fumigants to control infested stock or godown in airtight condition.
- Effective rat control measures, both in covered godowns as well as in CAP storage may be used.
- Food grains in ‘Cover and Plinth’ (CAP) storage may be stored on elevated plinths and wooden crates used as dunnage material. Stacks are properly covered with specifically fabricated low-density black polythene water proof covers and tied with nylon ropes/nets.
- Regular periodic inspections of the stocks/godowns may be undertaken by qualified and trained staff
- The principle of “First in First Out” (FIFO) may be followed to the extent possible so as to avoid longer storage of food grains in godowns.
- Only covered wagons may be used for movement of food grains so as to avoid damages during transit.

Bulk storage

The agro-processing industries are more inclined in favour of bulk storage structures for food grains as the operations such as loading /unloading, fumigation and aeration of grain bulk can be mechanized. The cost of construction and storage also favours bulk storage in silos. The agro-processing industries such as rice mills, oil milling units, roller flour mills store grain to meet their processing requirements. The requirement of storage by majority of such units ranges from 1000 – 20,000 metric tonnes. There are two types of silos on the basis of design: hopper bottom silos and flat bottom silos. The capacity of hopper bottom silos range from 10-1500 tonnes whereas flat bottom silos are made to store up to 15000 tonnes of grain. Various materials have been used to build silos, such as cement concrete, mild steel, corrugated aluminium and galvanized iron sheets. The galvanized iron corrugated (GIC) silos and cement concrete silos are quite popular in comparison to other materials.

The overall cost, space requirement, difficulty for engineering, difficulty for manufacturing and cost for charging and discharging are also important for an entrepreneur before deciding the kind of storage system.

Preventive treatments for grain storage

It is well known that “Prevention is better than cure”. The commonly known preventive measures are storage preparation (repairing, sealing, cleaning, disinfestation) and grain preparation (cleaning, drying, cooling etc.).

A number of preventive treatments have been tried to enhance the storage life of food grains. These include non-chemical methods such as grain drying, heat treatment, grain chilling, physical exclusion etc. Heat treatment of food grain at 55 ^{o}C for 30 min can reduce the grain infestation significantly (Seidu et al. 2010).

Towne (2001) suggested various methods of sealing bins to enable reduction in the amount of fumigant used to control insect infestation. It is required to look into the fumigation and aeration needs during design and erection of storage structures. The improvements in existing structures can also be made provided the expense will be viable.

Lopes et al (2006) developed software called AERO for simulating the aeration process in stored grain, with hot spots, using time variant ambient data. Use of aeration systems during winters and refrigerated aeration in the summer with the objective to achieve temperature below 18°C can reduce insect activity. Aeration using ambient air in tropical climates is not very effective. It can only check the build-up of hot spots.

Modified atmospheres obtained using hermetic storage, is based on the principle of oxygen depleted, carbon dioxide-enriched interstitial atmosphere caused by the respiration of grains. Silo bags made of plastic are being tried to store the grains under modified atmosphere.

Rulon et al (1999) compared the economics of grain chilling, against traditional pest control methods, such as phosphine fumigation. The model considered 34 factors including electrical power consumption, capital investment cost, chemical costs, and less quantifiable factors such as worker safety, environmental issues, and changes in end-product value. When applied to the storage of popcorn, a high value specialty crop and wheat, the annual operating costs of chilled aeration compared to phosphine fumigation with ambient aeration were up to 128 and 300% lower, respectively. The effect of high capital investment with low variable costs, as with chilled aeration, was compared to the low capital investment and high variable costs of phosphine fumigation using a multi-year Net Present Cost (NPC) model.

Thorpe (1998) described the modelling and potential applications of a simple solar regenerated grain cooling device using dessicants. The ambient air is dehumidified and used for cooling of grain. The dessicant is regenerated using solar energy.

Scientific studies conducted at University of Agricultural Sciences, Bangalore indicated that applying a 3 cm thick layer of sand on top of pulses stored in metal / plastic bins; earthen pots, brick cement structures resulted in disruption of reproductive behaviour of bruchids (Prabhu, 2007).

Detection of insect activity and removal of insects from stored grains by various devices has been reported by Mohan and Rajesh, 2016. Wandering behaviour of many stored product insects helped in their detection by devices such as TNAU-probe trap, TNAU-pitfall trap & TNAU-stack probe trap (warehouse trap). The TNAU-automatic insect removal bin has been found to be very suitable for storage of paddy. TNAU UV-Light Trap is being used by organised food grain storage agencies to detect and control the insects.

Chemical methods of preservation of stored grains

In India, phosphine is still the most widely used fumigant. The most important aspect for phosphine fumigation is maintenance of desired concentration for the required period of fumigation. It needs that fumigation of grains be conducted under gastight conditions. Fumigation of grains stacked in 50 kg bags in done by covering the grain stack with polyethylene and sealing it on floor with mud or sand snakes. Temperature & humidity of the atmospheric air are also important as fumigation is not effective under low temperatures. Evolution of gas from phosphide tablets becomes slow on reduction of temperature.

Maintaining a metal silo gastight for around 10 days for fumigation with phosphine under a hot climate is a technological challenge.

The important points related to phosphine fumigation are: sufficient gastightness, the lack of which leads to insect resistance; insufficient exposure time for complete control; and prevention of gas from diffusing into the working areas.

Food grains held in both temporary and permanent storage structures, indoors or outdoors, are vulnerable to insect infestation. Insect pest activity is generally high due to favorable climatic conditions, i.e.> 25°C and> 50% r.h., in the country and infestation problem is acute in storage centres located in coastal region. Type of pests attacking food grains varies according to commodity and climatic conditions (Table 2). The rust red beetle, Triblium castaneum (Herbst) is common but occurs more in milled rive than in rice. Khapra regions, viz. Punjab, Haryana, Bihar and Uttar Prradesh. Notorious pests such as Prostephanus trunctella, the Indian meal moth have been noticed in some of Indian grain storage centres (Bell, 2000).

As mixing of residual insecticides with food grains is not permitted in India from the beginning, we are greatly dependent on fumigants in the preservation of food grains. Supplementary control measures in grains storage premises include space sprays (fogging and misting) and hard surface sprays with contact insecticides such as deltamethrin, malathion and pirimiphos methyl (Rajendran and Sriranjini, 2008).

The use of fumigants has been done in India for several decades, but the development of grain fumigation machinery is just a new thing in recent years. With the continued development in Indian grain industry, grain fumigation machinery has made great progress. It is playing the increasingly important role in foundation and perfection and of Indian grain distribution system, keeping grain quality, decreasing grain loss and raising grain distribution efficiency.

Treatment with ozone gas have been observed to reduce the levels of pesticides (deltamethmin, Fenitrothion, pirimos- methyl) widely used in the storage units.

Ozone is a powerful antimicrobial agent orving to its potential oxidising capacity and is used as disinfectant for microorganisms and viruses, odour and taste removal and decomposition of organic matter (Khadre et al 2001)

Ozonation has been widely investigated for the removal of pesticides and implemented on stored grains to control the development of insects, fumgi & toxins (Mcdonough et al 2011, Scussel et at 2011, Savi et al 2014)

Conclusions

Safe and economical storage of food grains is essential for food security. The capacity of permanent storage structures is being augmented through various government schemes, but the pace is slow. Sanitation of structures, cleaning and drying of grains before storage, frequent monitoring of grain, aeration and fumigation are some of the strategies which need to be strictly implemented in organized and un-organized sector. It is required to put in place infrastructure required for preventive treatments (cleaning, drying, fumigation, aeration, heat treatment, grain chilling, irradiation, infrared radiation, use of ozone or nitrogen etc.) to reduce the post-harvest losses and extend storage life of grains. At present very little attention is being paid to preventive measures. R&D efforts are required in the areas of design of structures (based on local conditions, such as bearing capacity of soil, wind load/ snow load, earthquake resistance etc.), materials of construction, ease of handling (loading/un-loading), impact of biotic and abiotic factors during storage, detection and monitoring of spoilage, safe fumigants, uniform fumigation etc.

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Market for Functional and Designer Food: How to Reach Consumers

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Healthier food products so called functional and designer food have entered the global markets and have rapidly gained momentum in recent years. The concept of the functional food and designer food has emerged during 1980s in Japan and spread in USA, Europe and across the globe. We need foods and diets with functionality that meets the requirements of individuals at different life stages, i.e., early, adult and older age. Researchers have classified food related requirements of human beings at different stage of life, that are (i) foundation need to maintain normalcy (micro nutrients, fortified flour, probiotic (yogurt), extracts (chayawanprash), (ii) condition specific need to address the specific conditions ((Antioxidents, Vit. , minerals), and (iii) enhancement need for improved physical and mental health (protein and energy drinks).

The food preferences of consumers are time-varying and dependent on changing lifestyle, socio-economic conditions, ecology and environment. Under changing scenario of globalization and technological advancement in agriculture and food sector, the preference had shifted towards convenient and health food. As a result new nutritional insights emerged and food industry responded by developing a growing variety of new products with health related claim and images.

The terminology for the products in question is not uniform and ranges from 'nutraceuticals' to 'functional' and 'designer' to 'medicinal food'. Now, the questions arise in the mind of consumer that whether these functional foods are really healthy? Are all food not health food? These questions are very much pertinent to study the market situation, as marketing is not merely the popularization and spin off the product(s) but it is a management process which critically identifies (demand side) and satisfies the requirements (supply side) of the consumers or society as a whole. Hence, from a consumer perspective, functional food is difficult to quantify because different definitions are used. The present paper based on review of literature is intended to focus on philosophy; concept and origin of health food: where we stand?, Market and trade scenario (National and international), Convincing arguments and concern about functional/Health Food, Methods for estimation of consumer preference, technologies on health food and experiences with entrepreneurs

The Philosophy behind functional or health food

- Prevention: the focus on longevity with good health
- Performance: health enhancement through improved physical and mental condition
- Wellness: feeling good and finding balance (body, mind and spirit)
- Nurturing: growth, aging and healing
- Cosmetics: looking good, appearance

Functional food: Concept and Origin

The concept although introduced in Japan during late 1980s and varies from country to country. The details of definition cover under functional /health food and governing and monitoring authority are given in Table 1.

Further, different categories have been made based on uses, method of obtaining, distribution channels and regulatory body health food as comparison between functional food, medical food and drugs (Table 2).

Healthier food and diet are the integral part of the solution of above. Good health is basically a function of gene, diet and lifestyle. However, 68 to 70 percent of the people in Germany, Japan, Europe and USA are of the view that food has significant and strong relationship with good health. In India, health related problems like diabetics (55 million people in 2010), malnutrition, under nutrition and anemia (58% pregnant women and 79% children), cardiovascular death (40% in last decade) needs a cost effective solution on sustainable basis and that is possible through development and distribution of functional/health food to the indented beneficiaries.

Table 1. Concept and definition of functional food

Country	Known as	Definition cover	Governed by
Canada	Natural Health products	Vitamins & minerals, herbalHomeopathic / traditional medicine Probiotics, amino acids and fatty acids	Food and Drug Authority, 2004
European Union	Food Supplements	Concentrated source of nutrients Substances	Food Safety, 2002
USA	Dietary supplement	Vit., minerals, herbs, botanicals, amio acids, concentrate, extract	Food and Drug Authority, 1994
Australia	Complementary medicine	Herbal medicines, Vit and minerals, Nutritional supplements	Dept Health & Ageing,1991
Japan	Food for specific health use	Nutritional Sensory satisfaction, physiological improvement	Health & Nutritional Food Authority 1991
India	Food for special dietary use	Min, Vit., amino acids, enzymesPlant/ botanical	Food Safety Std. Act, 2006 (passed)

Table 2. Comparison between functional food, medical food and drugs

Difference	Functional food	Medical food	Drug
Uses	Energy enhancement,Weight management, disease reduction, memory improvement	Dietary management (loss of appetite, nutrition repletion, post surgery	Treatment of disease, symptom or condition
Method of obtaining	No prescription	Use with Medical supervision	Strictly under medical supervision
Distributional Channels	Supermarket, drugstores, retailers, online	Hospital, drug store, online	Pharmacy, hospital
Regulatory body	FDA regulation	Abide by on regulation concerning food, labeling	Multistage, multiyear review process

Source: Compiled by Dixit, et al. (2016)

India has production advantage in agriculture. For instance, country stands number one in milk production (163 Mn T), 2nd top most producer of fruits and vegetables (305.4 MnT), food grains (277.49 MnT). The post harvest losses in these crops are very high ranging from 4-10 % in cereals, pulses and oilseeds, and around 6 to 18 % in fruits and vegetables (Jha et. al, 2015). Processing and value addition of agricultural produce particularly food crops in production catchment itself has obvious advantages for enhancing farmers' income and generating employment in rural areas, besides, improving food and nutritional security. Hence, the demand (healthy food) and supply side (raw material) situation of the country motivated us towards development of and marketing for health food in India.

Growth drivers, convincing arguments and concerns pertains to health food

Factors contributing to the growth of health/ functional food on demand and supply side and convincing arguments (encourage health food) and concerns are discussed below (Table 3).

Why functional food

The factors favoring and disfavoring functional growth of functional food are discussed below (Table 4).

Consumer Perception about Health foods

Consumers' awareness and acceptance in terms of primary health concerns, familiarity with Functional food (FF) ingredients, attitude towards taste of FF with respect to health benefits, etc. strongly affect the willingness to buy health food. Undoubtedly, taste is one of the important choice factors when choosing functional food (Urala & Lahteenmaki, 2003). Further, socio-demographic characteristics, cognitive and attitudinal factors emerged as potential determinants of consumer acceptance of functional foods (Wrick, 1995; Gilbert, 1997; Childs, 1997; Childs & Poryzees,

Table 3. Demand and Supply side promoting Functional food

Demand side	Supply side
Changing lifestyles coupled with population growth and increasing purchasing power of middle class population	Scientific progress and advances in food technology (fortification, micro encapsulation etc.) and other fields agricultural sciences (GMO, tissue culture etc.)
Consumers focus on health, ageing and smartness	Corporate ambitions (competition and value addition)
Knowledge on health (physical+ mental) diet relationship	Improved accessibility due to emergence of distribution channels
Government expenditure on health care	
Expansion of global market	

Source: compiled by Dixit et al. (2012)

Table 4. Convincing arguments and concerns about Health Food

Factors in favour of health food	Factors disfavour of health food
• Benefits to consumer – Disease preventive – Illness to wellness and smartness	• Consumer less preferred (ex. GM food). Danish consumer perceive Functional Food (FF) 'unnatural and impure'
• Emphasis on preventive measures and acceptance of alternative treatments	• Premium price (main hurdle)
• Marketing environment promote the players and manufacturers benefits	• Time factor (preventive nature of FF will show results after period of usages
• Employment generation and contribution to the economy	• No post marketing surveillance system exists
• Socially acceptable as consumer feel that they take care of themselves and make right choices	• Risk to consumers: herbs based functional foods sometimes allergic to medicated person. Example: Cyclosporine level dropped (kidney transplant patient) after taking St. John's Wort Candy (Hillian 1998)
• Modern and positive impression on consumers	• Food laws lack specificity required for botanical drugs

1997; Gilbert, 2000; IFIC, 2000). The anticipated reward/benefits of functional food and the consumer confidence in functional food are the determining factors in consumers' willingness to use Functional Food.

Numerous studies have found evidence of positive consumer attitudes toward these products, suggesting the existence of robust potential price premiums. A variety of other socio-economic factors appear to be significant determinants of consumer acceptance including age, gender, income and geographic location while tangible product qualities such as the functional properties of the products, taste, side effects and price, remain important. Lastly, intangible attributes such as convenience, method of production and credibility of information regarding health claims were also identified as relevant determinants of consumer acceptance. Further premium price for functional food hinders the acceptance and buying intention of consumers'. Price and pricing perception are better predictors as compared to beliefs (Childs and Poryzees, 1997) and hence future research should focus on pricing sensitivity with respect to acceptability and purchasing power. Nonetheless, consumers' have certain expectations such as (i) quick and efficient delivery mechanism, (ii) ensure ingredient stability and viability during storage (iii) avoid unpleasant taste of the ingredients, (iv) digestibility and biomass availability, (v) proper specificity as per food law. Therefore, manufacturers should choose ingredients and packaging material having proper compatibility and should have well designed marketing system. The success of the functional food industry is largely dependent on consumer acceptance of these products. The consumers' perception that functional foods are too expensive limits the market growth of functional food.

Marketing/Distribution Channels for Health Food

With growing health awareness and concern, the functional food and drinks market is expected to grow rapidly in India. However, one of the primary challenges faced by these products is the difficulty in formulating these products into traditional food and beverage products. Fortified health food may have higher share in foods basket but subjected to well organized supply chain. Supply chain for functional food is presented as Fig. 1.

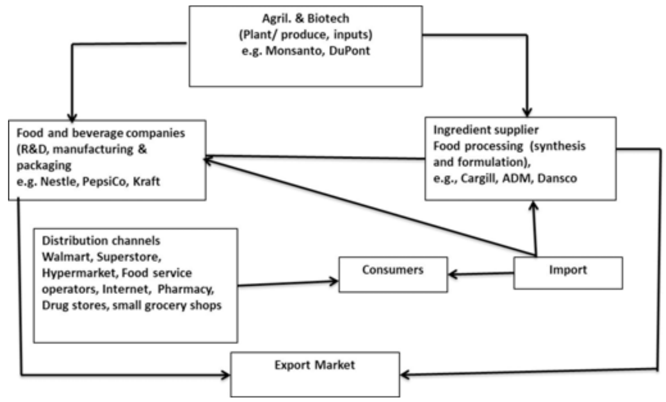

Fig. 1. Functional food supply chain;
Source: Compiled by Dixit, et al., (2016)

Problems in marketing of Health food under Indian conditions

In India, the market for health food is growing at a very high rate (i.e. 13% per annum) but its share in global market and per capita consumption is still very low. Therefore it is imperative to understand the factors hindering the growth of health food market in India and some of the factors are mentioned below.

- High logistic cost, advertisement cost and premium price of health food is the major limiting factor for the growth of health food
- Market players are getting undue benefits
- Quality assurance particularly for unbranded products
- Lack of Decision Support System (price intelligence and price discovery system)
- Overstated claim of health benefits by manufacturing agencies
- Poor market infrastructure and functional infrastructure (quality control facility at firm level, labeling and packaging)
- Poor foreign direct investment for creating market infrastructure for health food
- Supply chain is limited to Walmart, Superstore, Hypermarket, Food service operators, Internet, Pharmacy, Drug stores, small grocery shops in cities.
- Lack of proper coordination with in different government departments and ministries with respect to popularization and delivery of health food.
- Processing industry in developed countries is highly protected through tariffs (market support)

Suggestions and modalities for effective delivery of health food

- Private players should developed consumer focused products (specific target oriented). They should have two pronged strategies, i.e. i) Lowering price: per unit cost need to be lower down through adoption of improved process and technology ii) Credibility: product should launch in the market after efficacy study and should make a claim based on scientific study and evidence in the field. Public awareness and physician awareness is another task where role of private players is apparent.
- Public private partnership (PPP) model should promote for strengthening the basic infrastructure and supply chain for health food particularly in rural areas.
- The private players may have joint ventures for product development, differentiation and promotion. Partnerships amongst functional food or beverage manufacturers, pharmaceutical companies, nutrition companies and food additives companies in the formulation of the product is another key area which can lead to success of health food.
- Government can provide subsidy for promotion of health food in anticipation that the expenditure on health care and disease treatment will be reduced.
- There should be proper linkages within various schemes and among different departments/ ministries for effective and efficient delivery of health food among different stakeholders (Table 5).

Table 5. Modality for integration of various schemes for delivery of health foods

Sl. No.	Ministry/ department	Scheme	Type of health food	Beneficiary
1.	Department of food and Public Distribution	Public Distribution System	Functional Food: Protein rich food products from cereal and pulses, soybean, oil meal product and dairy based products	For BPL families
2.	Ministry of Rural Development	Annapurna scheme	Nutraceutical foods	Senior citizens
3.	Ministry of Human Resource Development	Mid Day Meal Programme	Fortified food products	Primary school children
4.	Department of Women & Child Development	Integrated Child Development Services	Weaning foods / Nutraceutical foods	Children (<6 years age and expectant /lactating women
5	National Rural Health Mission	Janani suraksha Yojana	Fortified food products	Expectant and lactating mothers
6.	Ministry of Women and Child Development	Sabla Scheme	Fortified food products	Adolescent Girls

Conclusion

In India, health food (functional, nurtraceutical, designer foods) market is in nascent stage at present, nonetheless, this is a grey area and has a good potential in terms of domestic demand and export. The success of health food depends on knowledge and belief of the consumers, cost effective product development and efficient delivery mechanism. Besides, the issue of health claim must be resolved before launching the product in the market. Therefore, it is suggested to have regulatory mechanism to check quality and efficacy of the health food. Further private players should develop consumer focused products (specific target oriented). The private players may have joint ventures for product development, differentiation and promotion. Government should invest for production and promotion of health food in order to reduce expenditure on health care and disease treatment. There is a need of more R&D and for appropriate regulatory environment and pricing sensitivity with respect to acceptability of health food.

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Utilization of Fish Processing Waste: A Waste to Wealth Approach

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With increasing global fish production, a large quantity of material is available for processing and thereby increasing the amount of waste generated. These byproducts or waste in the form of non-edible tissues like bones, skin/scales, swim bladders, fins, intestines, blood, roes, liver etc. are rich source of valuable components such as protein, lipid, enzymes bioactive peptides, pigments, flavours, vitamins and minerals. Therefore, it is imperative to recycle these wastes into marketable products so as to add value to this waste and minimize environmental threat of pollution. Globally, 20 million tonnes (approx., 12 % of total fish production, 171 MT) is used for non-food purposes. Out of which, 15 MT is reduced to fishmeal and fish oil and the rest 5 MT is largely utilized as material for animal feed, as bait, in pharmaceutical uses and for ornamental purposes. Though the classical approach utilizes these wastes for the production of fish meal, fish oil, pet foods silage or fertilizer, the recent advances in biotechnology and processing techniques changes the traditional approach and introduces new approach to produce high value components such as collagen and gelatin, enzymes etc. Therefore, we advocate the utilization of fish processing waste for turning it into wealth.

Introduction

Fish is a broad term that includes any aquatic organisms harvested for commercial purposes, whether caught in wild fisheries or harvested from aquaculture or fish farming. The term fish (whether of freshwater, estuarine/ brackish water or marine/ salt water) include finfish, crustaceans (cray fish, crab, prawn/shrimp, lobster) and mollusks (bivalves such as mussel, oyster, scallop and univalves like abalone, snail, conch and cephalopods such as squid cuttlefish, octopus) (Sachindra and Mahendrakar, 2015). Seafood, synonymously used for marine fish, generally refers to a group of biologically divergent edible animals (excluding mammals) consisting not only of fish (finfish), whether of freshwater, estuarine, or marine habitats, but also of shellfish (Suresh and Prabhu, 2012). It seafood includes a diverse range of aquatic animals and therefore the non-edible part generated varies greatly in composition and amount (Suresh and Prabhu, 2012). In 2015, fish accounted for about 17 percent of animal protein, and 7 percent of all proteins, consumed by the global population. Fish provided about 3.2 billion people with almost 20 percent of their average per capita intake of animal protein (SOFIA, 2018). Globally fish and fish products provide an average of 34 calories per capita per day. Fish has also significant dietary contribution in terms of high quality, easily digested proteins especially in fighting micronutrient deficiencies.

Generally the yield calculated by the fish processing industry is based on a gutted fish with head-on, that is typically 40% on an average (Marsh and Bechtel, 2012). Fish processing generates 35-40% edible meat and the remaining non-edible tissues are bones, skin/scales, swim bladders, intestines, roes, liver, blood etc. (Sachindra and Mahendrakar, 2015). The demand for RTE and other value added product that requires skinless, boneless fillets further increases the amount of waste generated. Many species are inadvertently caught while harvesting fish and crustaceans and that are not processed for human consumption also adds to the waste (Marsh and Bechtel, 2012). Processing of finfishes generates 10–50% of the total weight as non-edible parts, which includes head, gut (viscera), skin, bone, and flesh remaining on the bone. Shellfishes, especially crustaceans, generate up to 85% of raw material as non-edible parts, which include head, shell (carapace), viscera, and appendages (Suresh and Prabhu, 2012). Fish processing discards usually accounts for $3/4^{th}$ of total weight of catch. Discards are generally dumped in-land or hauled into the ocean. Meal and silage has also the potential of waste utilization. Recently, the focus is on the potential utilization of tongue, cheek, stomach, liver, fish skin, chitnous material, caroteniod pigments, flavourants, gut enzymes, anti-freezing proteins etc. (Shahidi, F., 1994). Filleting generates discards up to 75%. Entire offals from cod fishery may be used as a feed component, silage or fish meal. Protein value of offals is usually estimated by protein efficiency ratio (PER) and Amino Acid Score. Shahidi, F. (1994) found the quality of shrimp proteins (PER value 2.79-2.88) to be superior to that of crab shells (PER value, 2.30-2.42).

Large portion of these by-products are underutilized or wasted or discarded (Sachindra and Mahendrakar, 2015). Dumping of these byproducts not only results in loss of large amount of bioactive rich materials but also leads to pollution problems. Recycling of these by-products into marketable products can be a solid waste management strategy. Treated fish waste can have multiple applications such as ingredient in animal feed, for the production of biodiesel/biogas, cosmetics (collagen), enzyme isolation and soil fertilizer (Sachindra and Mahendrakar, 2015). Fish waste (byproduct) can be utilized for human consumption (e.g. mince, roe, fish heads, nutraceuticals), agricultural or allied uses (fish hydrolysate, fertilizer, compost) and non-nutritional uses (biodiesel and fuel, chitin and chitosan, caroteniods pigments, leather and gelatin) (Marsh and Bechtel, 2012).

Fish Production

Total global fish production in 2016 was 171 million tonnes (MT) (marine capture fisheries: 79.3 MT + freshwater capture fisheries: 11.6 MT + aquaculture: 80 MT). Out of which 151.2 MT was directly consumed by humans as food. Amount of production lost to spoilage or thrown away after landing and prior to consumption was 46.17 MT (27 % of all landings). In 2016, 20 million tonnes (approx., 12 % of total fish production, 171 MT) was used for non-food purposes globally. Out of which, 15 MT is reduced to fishmeal and fish oil and the rest 5 MT is largely utilized as material for animal feed, as bait, in pharmaceutical uses and for ornamental purposes (SOFIA, 2018). Today, Norway has developed modern processing facilities to manage over 0.65MT of seafood by-products each year and the Norwegian Atlantic salmon industry utilizes around 90% of its byproducts. In Vietnam, Pangasius by-products are well separated and directed to specific industries for value addition (Stevens, et.al. 2018). Stevens, et.al. (2018) also advocated the strategic utilization of aquaculture by-products using Fish In: Fish Out (FI:FO) concept. A responsible and sustainable use of fish resources, whether from capture fisheries or from aquaculture, foresees an efficient utilization of the whole fish including the use of the various by-products generated throughout the processing stage".

Fishery By-products

"By-product" indicates something that is not regarded as an ordinary saleable product but can be used after treatment and the term "waste" refers to products that cannot be used for feed or food but have to be composted or destroyed (Suresh and Prabhu, 2012).EC regulation on animal byproducts (EC No.1774/2002) defines animal byproducts as whole or parts of animals or products that is not fit for and intended for human consumption. Though co-products, co-streams, discrads or waste are synonymously used, the term waste seems to mean the material has no value (Sachindra and Mahendrakar, 2015). There are different terms such as "by-product," "co-product," "fish waste," "fish offal," "fish visceral mass," "fish discards," and so on that are applied to describe the non-edible parts of seafood processing (Suresh and Prabhu, 2012). Stevens, et.al.(2018) defined the term by-products as all the materials, edible or nonedible, left over following the preparation of main products. For finfishes, typical byproducts include trimmings, skins, heads, frames (bones with attached flesh), viscera (guts) and blood. Stevens, et.al.(2018) reported the fractions of byproduct as percentage of total wet weight of atlantic salmon: Viscera (12.5%), Heads (10%), Frames (10%), Skins (3.5%), Blood (2%), Trimming (2%), Belly flap (1.5%). Moreover, table 1 shows the percentage of finfish processing by-product fraction out of total weight of fish (Suresh and Prabhu, 2012).

Potential Use of Fish Waste or Byproducts

Very recently, biotechnological processes such as biocatalytic and fermentation processes have emerged as an integral part of seafood processing; they serve not only as an attractive alternative to chemical, physical, and mechanical methods in the processing of seafood by-products, but also as tools for recovering various valuable components (Suresh and Prabhu, 2012). Biotechnological processes are well recognized as eco-friendly processes which provide a possibility to recover additional useful components other than the target component from the raw materials (Suresh and Prabhu, 2012). Various other valuable components extracted from fish waste and their application have tabulated in Table 1. Table 3 shows Potential Bioactive/ Valuable Components from Processing By-Products of Finfish. Shellfish Processing By-Products with their potential Valuable/Bioactive Components have been detailed in Table 4 and table 5.

Table 1: Percentage of finfish processing by-product fraction out of total weight of fish

(Suresh and Prabhu, 2012)

By-products	Head	Gut	Skin	Bones	Trimming
Percentage of by-products	14–20	15–20	1–3	10–16	1–5

Table 2: Valuable components and the utilization of fish by-products (Stevens, et.al. 2018)

By-Product	Valuable components	Utilized as
Heads	Proteins, peptides, lipids, collagen, gelatine, minerals including calcium, flavour	Food, fish meal, fish oil, food grade hydrolysates, animal grade hydrolysates, pet food, nutraceuticals, cosmetics
Frames (bones, flesh, fins)	Proteins, peptides, lipids, collagen, gelatine, minerals including calcium, flavour	Food, fish meal, fish oil, food grade hydrolysates, animal grade hydrolysates, pet food, nutraceuticals, cosmetics
Trimmings	Proteins, peptides, lipids	Food, fish meal, fish oil, food grade hydrolysates, animal grade hydrolysates, pet food
Viscera	Proteins, peptides, lipids, enzymes such as lipases	Food grade hydrolysates, animal grade hydrolysates, fish meal, fish oil, fuel, fertilisers
Skin (with belly flap)	Collagen, gelatine, lipids, proteins, peptides, minerals, flavour	Fish meal, fish oil, cosmetics, food, fish meal, nutraceuticals, cosmetics, leather, fuel,fertilisers
Blood	Proteins, peptides, lipids, thrombin & fibrin	Fuel, fertiliser, therapeutants

Table 3: Potential Bioactive/ Valuable Components from Processing By-Products of Finfish

(Suresh and Prabhu, 2012)

Category	Bioactive components	By-products
Enzymes	Proteolytic Collagenolytic Lipases	Fish gut Fish gut Fish gut
Flavors	Finfish flavor	Gut, head, frame
Functional ingredients	Cartilage Chondroitin sulfate Fish bone Fish oil and lipid Collagen and gelatin	Head, fin, and skeleton of shark Shark cartilage Fish frames and bones Gut and head Head, skin, fin, scales, bones, cartilages
Micronutrients	Calcium Other minerals Vitamin	Fish bones Fish bones Fish oil
Nutraceutical	Lipid Omega-3 oil Biopeptides Cartilage Chondroitin sulfate Squalene Collagen and gelatin	Gut and head Fish oil and lipid Various by-products,protein hydrolysates Head, fin, and skeleton of shark Shark cartilage Shark liver oil Head, skin, fin, scales, bones, cartilages
Active pharmaceutical ingredients	Omega-3 oil Chondroitin sulfate Squalene	Fish oil and lipid Shark cartilage Shark liver oil
Biofuel	Biodiesel Biogas	Fish oil, gut, head Gut, head
Biomaterial/biopolymer	Chondroitin sulfate Collagen and gelatin	Shark cartilage Head, skin, fin, scales, bones, cartilages

Table 4: Shellfish Processing By-Products with their potential Valuable/Bioactive Components

(Suresh and Prabhu, 2012)

Sources		By-products	Percentage of byproducts	Valuable bioactive components
Crustacean	Shrimp/prawn	Head, shell	65–85	Chitin, chitosan, *N*-acetyl chitooligosaccharides, chitosan oligosaccharides, *N*-acetyl-d-glucosamine, d-glucosamine, pigment protein, protein hydrolysate, enzymes, flavor
	Crab	Back shell, viscera, gills, claws shell	60–70	Chitin, pigment
	Lobster	Head, shell	Up to 60	Chitin, pigment, flavor
	Krill	Head, shell	71–74	Chitin, pigment, protein, hydrolysate, oil
	Crayfish	Head, shell	Up to 85	Chitin, pigment, oil, flavor
Molluscs including cephalopods	Scallop, clam, oyster, mussel, etc.	Shell, nonedible body part	60–80	Protein hydrolysate, enzyme, flavor
	Squid	Ink bag, gladius or pen, liver, other organs	25–32	Chitin, enzymes, bioactive peptides, collagen, gelatin
	Octopus	Intestine, mouth apparatus, eyes	10–20	Collagen, gelatin
Coelenterate and echinoderm	Sea urchin	Shell, viscera		Collagen, gelatin
	Sea cucumber	—	—	Protein hydrolysate, bioactive, collagen, gelatin
	Jelly fish	—	—	Protein hydrolysate, collagen, gelatin

Table 5: Potential Bioactive/Valuable Components from Processing By-Products of Shellfish

Category	Bioactive components	By-products
Enzymes	Chitinases	Prawn liver, shrimp processing waste water
	Lipase	Shellfish by-products
	Transglutaminase	Shellfish by-products
	Polyphenoloxidase	Shellfish by-products
	Alkaline phosphatase	Shrimp by-products, shrimp processing waste water
	Lysozyme	Scallop by-products
	Chlamysin	Clam viscera
	Hyaluronidase	Shrimp processing waste water
Pigment	Carotenoid (astaxanthin)	Crustacean by-products
Flavors	Shellfish flavor	Lobster/crab/crayfish/clam by-products
Functional ingredients	Chitin and chitosan	Crustacean head and shell, squid pen
	Chitin and chitosan oligomers	Crustacean head and shell, squid pen
	N-Acetyl-d-glucosamine and d-glucosamine	Crustacean head and shell, squid pen
	Collagen and gelatin	Outer skin and cartilaginous tissues of cuttlefish, octopus, and squid Exumbrella and mesogela Shell of sea urchin
Micronutrients	Calcium	Exoskeleton of various shellfish
	Biopeptides	Protein hydrolysates
	Collagen and gelatin	Outer skin and cartilaginous tissues of cuttlefish, octopus, and squid; Exumbrella and mesogela Shell of sea urchin
Active pharmaceutical ingredients	Carotenoid	Crustacean shell
	N-Acetyl-d-glucosamine	Crustacean shell
	Collagen and gelatin	Outer skin and cartilaginous tissues of cuttlefish, octopus, and squid; Exumbrella and mesogela Shell of sea urchin

Future

There is an increased demand for complete utilization of the abundant fish processing by-products not only as untapped sources of bioactive molecules but also to minimize the related environmental issues (Suresh and Prabhu, 2012) and thereby the future of fish processing waste for its utilization and bioconversion is promising with the right state of mind and interest. The fish processing industry and related stakeholders can intervene and make progress in future in terms of resource mobilization, value addition, product diversification and sustainable growth.

Conclusion

Fish processing waste or by-products have vast potential for their utilization. It is possible to recover the bioactive components and molecules using appropriate technologies and recent technological advances. Presently, the utilization of biomolecules have come a long way and have received an increased interest from many researchers across the globe. Literatures are available for the process which can be applied for easier processing and recovery of bioactive components and biomolecules from some of the prospective fish processing by-products or waste. However, the technical feasibility does not necessarily translate into economical feasibility and therefore, a fish processor should critically review by-product utilization options before committing to a specific process.

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On-Farm Practices to Maintain the Quality of Horticultural Produces

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Introduction and Background

India has diverse agro-climate and produces a wide range of fruits and vegetables. It is the 2nd largest producer of fruits and vegetables in the world and produces 250 million meteric tonnes of fruits and vegetables. Owing to lack of production planning, post-harvest, infrastructure and climatic factors, a huge accumulation of particular fruit take place in a particular region resulting in glut. Therefore, growers are forced to make distress sale and substantial quantity of the produce goes waste. Hence it is necessary to have proper postharvest handling and wide market distribution system so that growers get remunerative prices and consumer pay less.

Horticultural crops play an important role in generating employment, improving economic conditions of the farmers and entrepreneurs and above all providing nutritional security to the people. Horticultural crops typically have a high moisture content, tender texture and high perishability and deteriorate rapidly, if not handled properly. Losses during post-harvest operations are enormous and the matter of great concern. The important sites where postharvest losses are noticed are farmers' field, packaging area, transportation, storage and wholesale or retail markets. Actual post-harvest losses of fruits and vegetables have been estimated to be as high as 25-40%. The major contributory factors for post-harvest losses of fruits and vegetables are:

- Lack of awareness about harvesting techniques for fruits and vegetables
- Improper packaging & transportation techniques
- Gaps in cold Chain
- Insufficient cold storage capacity,
- Unavailability of cold storages in close proximity to farms,
- Poor marketing infrastructure etc.

This results in instability in prices, farmers not getting remunerative prices, rural impoverishment resulting in farmers' frustrations and suicides.

Adequate postharvest handling of produce will result in a product with better appearance and shelf life and thus better price. The knowledge and practical approach of postharvest management of horticultural produce offers good opportunities for entrepreneurship and employment generation especially for rural youth and women.

Importance

Postharvest technology plays an important role not only in minimizing the postharvest losses but also maintains the quality and regulates the marketing of horticultural produce. Importance of post-harvest technology lies in the fact that it has the capability to meet food requirement of growing population by eliminating losses from farm to consumers. The farmer whose role has been reduced to producer can be transformed into producer cum processor and thus getting more dividends for hard labour, input, kind of risk taken and generating resource for socio-economic advancement keeping pace with the modern times. The use of some of the techniques like sorting, grading, packaging and storage leads to value addition of horticultural crops and income generation. In this paper some useful technical guidelines have been discussed for proper postharvest management of horticultural produce.

Technical Aspects

Harvesting

Growers often do not understand the effect of harvesting and handling on the quality of produce. Ideally, harvesting should take place when the crop and climate is cool and plant has highest moisture content. The shelf life of the crop and its suitability for long term storage is affected by the maturity of the crop at harvest. The optimum harvesting stage for most crops depends not only on the climate and market distance but also on growing conditions. After investigating the market distance, the harvesting of produce should be decided. Harvesting of fruits at immature stage or over mature stage leads to loss of quality. It is imperative that fruits should be harvested at proper stage of maturity with no physical damage or bruise. The fruits should be harvested with clippers or scateurs and they should not be harvested by pulling, which leads to injury in the stem end. However, the vegetables can be harvested with hands but gentle picking will help to reduce crop losses.

Grading

Produce brought to many markets often has variable characteristics and sometimes it may be delivered immature or contain shriveled, damaged and rotten materials. Delivering such produce generally results in lower prices. Grading helps to develop greater confidence between buyers and growers. Systematic grading is pre-requisite for efficient marketing of fruits and vegetables. The bruised, damaged and mis-shapen produce should be sorted out and healthy fruits or vegetables should be graded according to their size, weight, shape, colour, maturity etc. The graded produce fetch better price in the market. The fruits or vegetables can be graded in extra fancy, superior and standard grades or class I, II and III, respectively. Grades and standards are extremely important for earning good income. Grading can be done by hands or using machinery at packhouse. Rural women can be trained for performing sorting and grading operations of horticultural produce at farm level. Grading is sometimes carried out on the farm ground under the shade of tree. This is an unhygienic practice. The sorting and grading of produce should be carried out in shed/ pack house having grading tables, knives and packaging materials etc.

Precooling

The produce should be kept in shade immediately after harvesting. It is essential to remove field heat of the harvested produce in order to extend their shelf life. The temperature of the fruits at harvest is close to that of ambient air and could be as high as 40°C particularly during summer season. At this temperature, the respiration of produce is extremely high and storage life is short. It is often good practice to harvest the fruits early in the morning to take advantage of lower temperature. Various methods like room cooling, forced air cooling, hydro-cooling are used depending on the type of fruit or vegetables to be pre-cooled. However at farm level the farmers can pre-cool their produce under shade of trees. Farmers can also make a low cost pack house at their farms for holding the fruits or vegetables.

Waxing (Food grade)

The post-harvest losses of fruits can be reduced to some extent by use of various food grade waxes. Certain edible coatings like shellac, carnauba and bees-was approved by PFA also help to improve the shelf life of fruits and vegetables. The waxing of fruits can be done manually or through mechanical waxing machines.

Methodology for Manual Waxing (For small scale):

- Select diseased and bruise free fruits
- Clean the fruits with the help of moist soft cloth
- Allow the fruit to dry under shade
- Drench a piece of foam pad with wax coating and apply it on fruit surface gently
- Allow the fruit to dry under shade
- Pack the fruits in plastic crates or corrugated fibre board boxes.

Packaging

The main functions of packaging are to help prevent mechanical damage and enhance the attractiveness of the produce. Proper packing of produce will ensure safe transportation from the farm to the storage and consumer centre, while reducing the damage during transportation. The produce should be packed in such a way that they do not collide with each other during transportation.

Bulk packaging

A wide variety of containers such as wooden boxes, plastic crates, and corrugated fibre board boxes are important package used in the transportation and distribution of fruits in most of the developing countries. All the packages must have some amount of ventilation in order to prevent physiological break down. Corrugated fiberboard boxes (CFB) are comparatively new and making significant entry into this field. These have many advantages such as light in weight, cause much less damage to the fruits, easy to handle and print and improve product image. Plastic crates can also be used successfully for bulk packaging of produce.

Consumer packaging

The fruits or vegetables can be packed in consumer packs of half kilogramme to two kilogrammes polythene bags or plastic net bags for direct distribution to consumers in the retail markets. Some fruits and vegetables like cauliflower, cabbage, kinnow, tomato, capsicum etc can be successfully wrapped in shrink or cling films for retail marketing.

Storage

The primary purpose of storage is to control the rate of respiration, transpiration, ripening and also undesirable biochemical changes and disease infection. Proper temperature management can be very effective tool in ensuring that produce remains in good condition through out the storage and transportation. It may be necessary to seek expert guidance whether long term storage could significantly increase farmers' income. The storage conditions for different fruits are given in Table 1.

Table 1. Recommended storage conditions for fruits and vegetables

Name of Commodity	Temp(°C)	RH (%)	Approximate Shelf-Life
Apple	0-2	90-95	1-6 months
Asian pear	0-2	90-95	2 months
Grape	0-2	90-95	2 months
Guava	6-10	90-95	2-3 weeks
Lemon	10-13	85-90	1-6 months
Mandarin (Kinnow)	5-6	90-95	2 months
Mango	13-15	85-90	2-4 weeks
Papaya	7-13	90-95	1-3 weeks
Peach	0-1	90-95	2-4 weeks
Plum and prunes	0-1	90-95	2-4 weeks
Cabbage	0-1	90-95	2-3 months
Carrots (topped)	0-1	90-95	3-6 months
Cauliflower	0-1	90-95	3-4 weeks
Cucumber	10-11	85-90	10-14 days
Eggplant	10-12	90-95	1-3 weeks
Okra	7-10	90-95	7-10 days
Peppers	7-10	90-95	2-3 weeks
Tomato	10-13	90-95	1-3 weeks
Potato (seed)	0-1	90-95	5-6 months
Onion	0-1	65-70	4-5 months
Garlic	0-1	65-70	5-6 months

Marketing

It is quite apparent that marketing plays a key role in the postharvest operation of fruit. Marketing of perishable fruits presents more problems as compared with other durable agricultural commodities. Due to the presence of middleman, the price of the fruits is 50-100% higher in *mandis* than growing areas. The producers have to sell their produce at throw away prices and consumers have to purchase it at high prices. The cooperatives can play a very important role in the marketing of fresh fruits. HPMC in Himachal Pradesh is a successful attempt, which has become landmark for apple industry in India. National Dairy Development Board has also established outlets for fresh fruits and vegetables in New Delhi. Concept of *Apni Mandi* is another good example, where producer sell their produce directly to consumers without chain of commission agent.

Digital Image Processing and Machine Vision Technology for Quality Evaluation of Food

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Influence of digital computers has reached to almost every field in science and technology. Visual information is not an exception to this. Coding of pictures for transmission through cables was attempted way back in 1920 (even before advent of digital computer), but serious attempts for digital image processing commenced in late 60s and early 70s. Importance of image processing and machine vision increases due to the fact that vision is one of the most dominant human senses. Figure 1 shows the electromagnetic spectrum that can be used to generate an image.

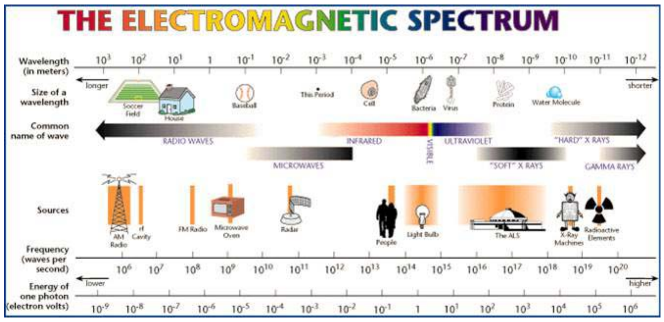

Fig. 1. The complete electromagnetic spectrum that can be used to generate images

The terms, 'digital image processing' and 'machine vision', are sometimes used interchangeably. However, in strict sense, digital image processing is a pre-requisite for machine vision. A machine vision system encompasses, digital image processing and a decision support system to take an action such as, sorting of objects, movement control of a robots, etc. Basics, like definition of digital image, their formation, low level processing, and meaning of various terms used in the field of digital image processing/ machine vision are introduced here.

Quality control is an important aspect of food production and processing from the point of view of providing foods of acceptable nutritional value, and for providing safety of products. Several characteristics such as size, shape, density, maturity, moisture content, oil content, flavour, firmness, tenderness, colour, defects, blemishes, etc., are routinely used in the quality control of agricultural and biological food products. Until recently, most analytical techniques used in quality control, required isolation of the food component of interest. The original properties of the product are, therefore, destroyed during sample preparation and analysis. Oftentimes, such analyses are expensive, time consuming, and require sophisticated instrumentation, and hence are not suited for "on-line" quality control of food products. Recent progress in the development of instrumentation utilizing some physical, optical, acoustic and electromagnetic properties of food products has provided several non-destructive techniques for quality evaluation. Many such methods are highly sensitive, rapid, and reproducible, and have been successively used in routine "on-line" quality control of a large number of samples.

Analog Vs. Digital Image

An image is two-dimensional representation of a real world scene. A seen observed by a human eye or imaged on a photographic film is considered as analog image. In an analog image all the information is in seamlessly continuous manner, continuity of which is unbroken even after infinite magnification. A digital image, however, is discrete in nature and there is some point, which cannot be magnified further. This point is called a pixel (picture element) of that digital image. In other words, an image is a single or multi layered matrix, where each cell of the matrix is a pixel that contains an integer. This integer represents intensity of some quality attribute of the image e.g., in visual sense the integer represents brightness level of that pixel, in a cartographic image the integer could be a representative of altitude.

Digital cameras

Digital cameras use three types of signals viz., data lines, a pixel clock, and enable lines. Data lines are parallel wires that carry digital signals corresponding to pixel values. Digital cameras typically represent pixels with 8, 10, 12, or 14 bits, and colour digital cameras can use up to 24 bits or more for each pixel. Therefore, depending on your camera, you may have as many as 24 data lines, or wires, representing one pixel. The number of data lines per pixels determines the pixel depth.

Major stages of image processing

Depending upon nature of the task, there could be different stages in an image-processing project. Nevertheless, image sensing is the first task, using whatever sensors appropriate for imaging. The first stage of any "vision" system is a subsystem for acquiring raw image data and transforming it into a form suitable for digital, optical, or biological processing. This subsystem must be:

– *Accurate*: correct descriptions, representation, and interpretations of the objects perceived can be made later.
– *Fast:* if real-time processing is required.

Acquisition implies a sensing of the environment, in the form of reflected or radiated energy, e.g. X-rays, Visible light, Heat, and Ultrasound etc.

Sensing can be accomplished either passively or actively.

– Passively: the radiation originates in the surrounding environment, is reflected or absorbed and re-emitted from objects, and then sensed by eyes, cameras, thermal cameras, etc.
– Actively: the radiation is artificially introduced in the environment, as an integral part of the vision system, e.g., X-ray, sonar, radar, etc.

Since, image processing is applied to a digital image; digitisation of the image is the second task. These two tasks can be done together by some detectors like digital camera. Alternatively, scanning or other means of digitisation can be employed to digitise an analog image. As shown in Fig. 2, the digital image can be stored with or without any compression or can be processed directly. Tasks in primary processing generally include: representation and modelling; enhancement; and restoration of image content. Secondary processing could include tasks like analysis, reconstruction, compression, etc. While, higher level processing may include some tasks similar to primary and secondary processing using complex mathematical and stochastic techniques.

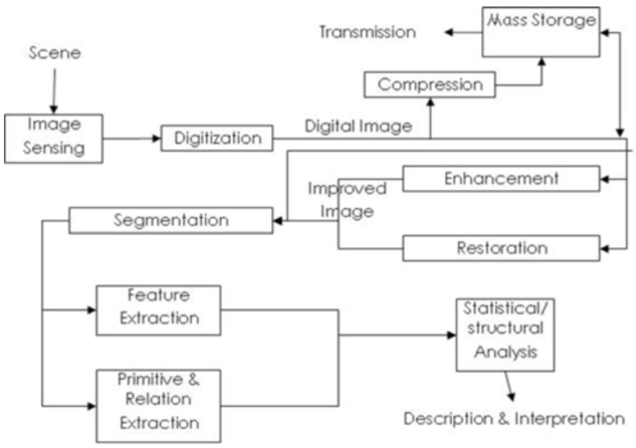

Fig. 2. Different stages of image processing

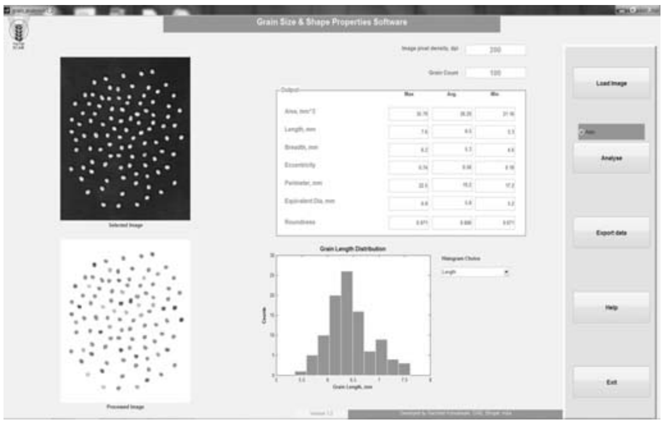

Fig. 3. Screen shot of software developed for determination of grain size and shape properties developed at ICAR-CIAE, Bhopal

Measurements

One of the most important prerequisite for taking a decision based on a digital image is measurement of properties related to physical world. Such measurements could be size properties viz., length, width, diameter, perimeter, area of the particular blob/ particle or size properties of a circle, rectangle, oval or a polygon inscribing or circumscribing the particular blob/ particle. The measurement could also be of position of the blob in respect to some fixed point or some other blob. The shape of a particle can also be measured in terms of properties like 'eccentricity', 'roundness', 'convex hull length', 'elongation factor' and so many other derived parameters. Since primary element of a digital image is a 'pixel', the image analysis algorithm returns values of these measurements in 'pixel' unit, i.e. length is number of pixels in a particular direction, area is total number of pixels contained in the blob etc. It is therefore very much important to calibrate an image in order to get the measurements in terms of physical units. Simply speaking calibration is the process where we define size properties of a pixel. Using different combinations of the features and parameters, software have been developed which help in quick and accurate determination of certain physical or optical properties. Screenshot of one such software is shown in Fig. 3.

Image Analysis

Next stage of image processing leading to machine vision or computer vision or robotics etc. is analyzing the image to reach to appropriate decisions. Major components of image analysis are segmentation, edge and line detection, feature extraction, image description, and feature recognition. While image processing techniques give an improved (enhanced, restored, or compressed) image, the image analysis techniques give out somewhat detail description of the scene whose image is being considered. Techniques used for image analysis could work in spatial domain or frequency domain (i.e. FT domain). These techniques range from simple matrix operations to complex stochastic approaches.

Colour measurements

The optical properties of a material are defined by the percentage of incident light that is reflected, transmitted or absorbed by each wavelength. Reports of use of optical properties are as old as 1958 when skin color light transmittance could be used to indicate the flesh color of intact fruit. Researchers observed a correlation between wavelength of peak transmittance and loss in firmness occurring during maturation and ripening. They also observed a high correlation between reflectance wavelength and soluble solid/ acid content of freshly harvested fruits, their maturity. Light reflectance techniques have been used to detect surface defects and contamination of dried prunes; mechanical injury, rot, molds scars, mite injury and scrab on oranges and tomatoes.

Measurement of light in the visible range (Fig. 4) of the electromagnetic spectrum (approximately 400-700 nm) is used to define colour of an object. Instruments have been designed to quantify colour as humans see it and represent it in terms of some absolute numbers. Some of the popular colour definitions or colour coordinate systems are:

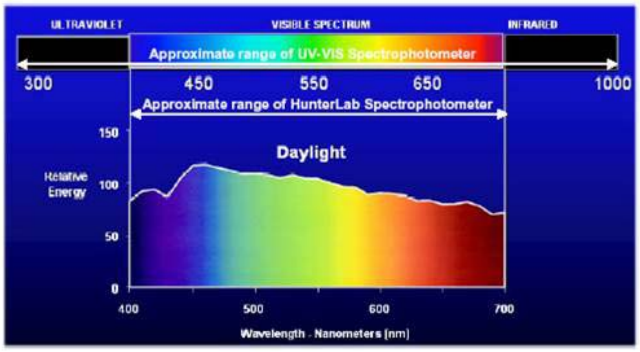

Fig. 4. The visible spectrum

1. CIE-RGB System: Three monochromatic primary sources (Red, Green and Blue).
2. CIE-XYZ System: Provide full gamut of reproducible colors
3. CIE-UVY System (UCS): u,v=chromaticicities, Y=luminance.
4. CIE-U*V*W* System (Modified UCS): Good for measuring color difference quantitatively.
5. S, q, W* system: Polar representation of U*, V*, W* system- S(saturation) , q(hue), W* (brightness).
6. NTSC Receiver System-RN ,GN , BN : Standard for TV receiver.
7. NTSC Transmission (YIQ) System – Facilitate transmission of color images via monochrome TV channels without increasing bandwidth. Y (luminance), I , Q (chrominances).
8. L, a*, b* System: Yield perceptually uniform spacing of colors (classification), L (brightness), a* (red-green), b* (yellow-blue).
9. CMYK system: Mostly used in printing industry. Colours used to reproduce a specific colour are Cyan (C), Magenta (M), Yellow (Y) and Black (K).

Near-infrared spectroscopy

The use of near-infrared spectroscopy as rapid and often non-destructive technique for measuring the composition of biological materials has been demonstrated for many commodities. This method is no longer new; as it started in early 1970 in Japan, just after some reports from America. The National Food Research Institute (NFRI), Tsukuba has since become a leading institute in Near Infrared spectroscopy (NIR) research in Japan and has played a pivotal role in expanding near-infrared spectroscopy technology all over the country. Now various NIR spectrometers are available and are being used commercially. Some modifications in these available spectrometers, especially for holding the intact samples, are reported. In the same sample holding a test tube for holding liquid food such as milk was also used to determine fat content.

Miscellaneous techniques

Quality attributes such as invisible surface bruises, colour, gloss, firmness, density, volume expansion of processed food etc are also important. Often consumers select food materials, particularly fruits and vegetables by judging these parameters visually. Multiple efforts have been made to determine these parameters visually. Techniques based on fluorescence, surface gloss, delayed light emission etc. is some of the other techniques, which are used to determine surface, and sub-surface quality attributes using sensors.

Non-destructive internal quality evaluation of food

External appearance may be one of the quality indicators but many times the external appearance does not sufficiently represent the internal quality of a product. Packaging, surface treatment (like washing, polishing, etc.) and some inherent properties of a certain cultivars make it difficult to judge the quality from outside. It is therefore a challenge to see the inside of a product without destructing it. Some of techniques with proven applications in the field of medical or other industrial applications are now available for agricultural produce as well. These techniques are: X ray imaging or Radiography, Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and Ultra Sonography (USG).

Radiography

X-ray radiation was discovered by Wilhelm Conrad Röntgen in 1895. X-ray imaging techniques have mainly been developed for medical, particle and material physics. With this in mind, the use of X-ray imaging techniques in the agricultural and food industries has not been exploited to its fullest potential. As a sub-surface technique, X-ray radiation can give three-dimensional information about the spatial density differences and changes of the atomic number within a sample.

Applications of X-ray imaging in non-destructive quality evaluation

Many applications are reported using human intervention for making decisions about presence of defects in various commodities like apples, meat, particle boards, pistachio nuts, almonds, wheat, pecans etc. X-ray with energy ranging from 15 to 80 kVp at various current levels has been reportedly used. However, higher energy of 100 kVp has been found not suitable for radiography of food products.

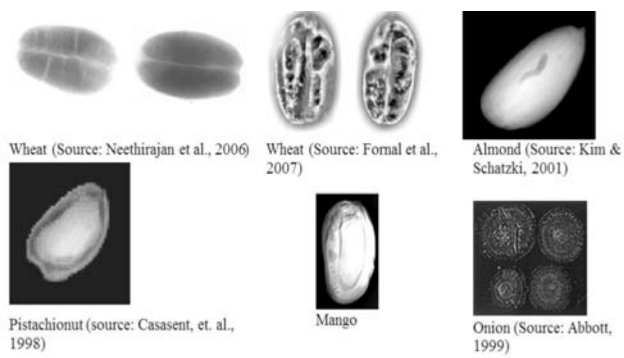

Fig. 5. Radiographs of some agricultural commodities showing internal artifacts

Computed Tomography (CT)

The technique of X-ray computed tomography (CT) enables the acquisition of two-dimensional X-ray images of thin "slices" through the object. CT, originally known as computed axial tomography (CAT or CT scan) and body section rentenography, is an imaging method employing tomography. The basic principle behind CT is that the internal structure of an object can be reconstructed from multiple X-ray projections of an object.

Figure 6 shows a modern (2006) CT scanner with the cover removed, demonstrating the principle of operation. The X-ray tube (T) and the detectors (D) are mounted on a ring shaped gantry. The object is placed in the centre of the gantry while the gantry rotates around them. This arrangement, a broad fan-shaped X-ray beam (X) with rotating source and detectors, is the 'third-generation' configuration.

Application for detection of physical foreign materials in foods

Several successful attempts have been reported. The feature identification process is manual however use of image processing algorithms (readily available or tailored) has been reported for image enhancement and better readability. A possibility of determining chemical composition of agricultural materials has also been explored using CT. Some of the specific applications have been monitoring woolly breakdown of cool stored nectarines; ripening assessment of peaches and mangoes; monitoring healthy and defective tissues in pears; airflow paths in stored wheat; and monitoring microstructure of variety of food products.

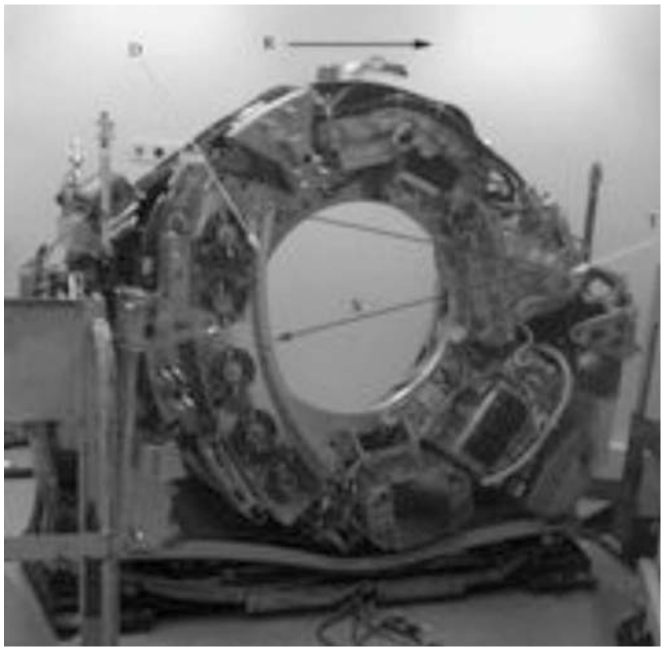

Fig. 6. CT scanner with cover removed to show the principle of operation

Magnetic resonance imaging

MRI is based on the principles of nuclear magnetic resonance (NMR), a spectroscopic technique used to obtain microscopic chemical and physical information about molecules. Magnetic resonance imaging is an imaging modality, which is primarily used to construct pictures of the NMR signal from the hydrogen atoms in an object.

Application of MRI for quality detection of agricultural produce

Results of some successful applications of MRI to see internal defects in mangoes are shown in Figure 7.

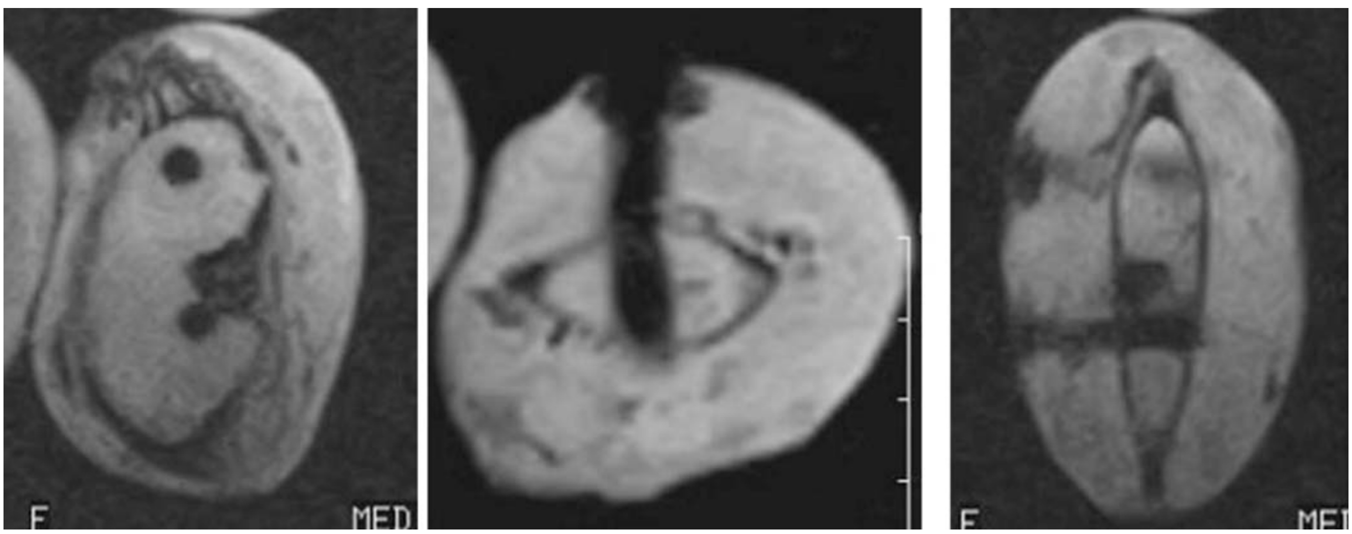

Fig. 7. Axial, Coronal and Sagittal views of mango in MRI scan showing physical and physiological disorders

Ultrasonic

The technique, sonar, of sending sound waves through water and observing the returning echoes to characterize objects submerged in the way of ships was used before the World War II. The sound ranging from 0 to 20 Hz is known as infrasound, the example is earthquake. Within the frequency range 20 to 20000 Hz is the audible sound. However sound having frequency greater than 20,000 Hz is defined as ultrasound and the typical example of this is bat or quartz crystal.

Figure 8 shows simple sketch of ultrasonic wave formation and reception after hitting any disorder in material under study. In imaging of biological materials, vibrations produced by ultrasound probes transmit into the tissue. When this sound wave passes through a joint of tissues of different density (such as soft tissue and hard tissues or bones/stones etc.) some vibrations are reflected back and reach the probe. At this moment, probe acts as a receiver, which converts mechanical energy into an electrical signal. A monitor thus displays an image of reflector and can provide size of object. As velocity of ultrasound waves is constant, the time taken for the wave to reach back to the probe can be used to know the depth of the object, which caused reflection of waves.

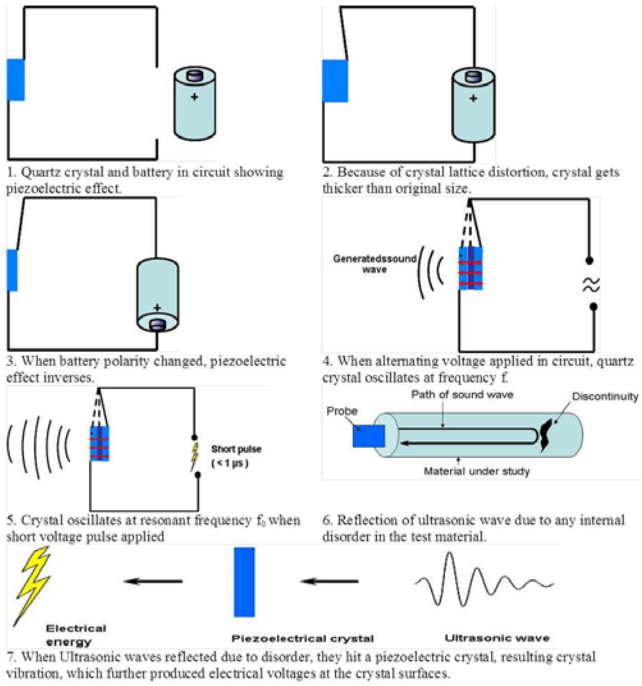

Fig. 8. Signal generation and reception in ultrasonography

Application of ultrasonic technology in food processing field

Researchers have shown considerable interests for use of ultrasound in food science and technology in last some years. In food industry, low energy (Low power, low intensity) ultrasound and high energy (high power, high intensity) ultrasound are being used for different purposes. Former uses frequencies higher than 100 kHz at intensities below 1 W.cm^{-2} while later uses intensities higher than 1 W.cm^{-2} (generally in the range 10-1000 W.cm^{-2}) at frequencies between 18 and 100 kHz. Low intensity ultrasound does not cause any changes in physical and chemical properties of food through which they travels. As a nondestructive measure and being a rapid, precise method of physicochemical composition, many researchers used low intensity ultrasound technology. With the use of low intensity ultrasound technology composition of dairy products were determined. In case of fruit and vegetable, ultrasound parameters related physicochemical indexes are: dry matter content, oil content, total soluble solids (TSS) and acidity. Ultrasound technology can also provide information regarding changes in the physicochemical characteristics of fruit/vegetable tissues, such as mealiness, softening and other flesh-quality indices, during storage and shelf life, so facilitate determination of proper marketing time. The textures of fruits and vegetables are strongly correlated with ultrasonic indices such as propagation velocity and energy attenuation. Firmness is the most important mechanical property of fruits and vegetables, which correlates with ultrasound characteristics.

Comparison of techniques

X-rays (radiographs) are the most common and widely available diagnostic imaging technique. Small level and short duration of radiation exposure from X-rays is not harmful. The images are ready quickly. X-rays may not show as much detail as an image produced using newer, more powerful techniques.

A CT scan can show the size, shape, and position of structures that are deep inside. A CT scan costs more and takes more time than a regular X-ray. Although CT scan technique gives maximum 3-D information, it requires narrow X-ray beam, special hardware to continuously rotate and shift the source and camera or the object, high energy X-rays, and extensive computation. For these reasons the time required for scanning an object is far more than taking one radiograph. Although CT is a relatively accurate test, it is liable to produce artifacts such as: Aliasing

Artifact or Streaks; Partial Volume Effect; Ring Artifact; Noise Artifact; Motion Artifact; Windmill and Beam Hardening.

Unlike radiography and CT, which require ionizing radiation, MRI is based on a safe interaction between radio waves and hydrogen nuclei in the body in the presence of a strong magnetic field. MRI has much higher detail in the soft tissues. One of the greatest advantages of MRI is the ability to change the contrast of the images. Different contrast settings will highlight different types of tissue. Another advantage of MRI is the ability to change the imaging plane without moving the object. Presence of metal in the samples cause malfunction during an MRI. MRI equipment is expensive to purchase, maintain, and operate. Like any other imaging technique there are certain artifacts NMR images which can lead to wrong identification of internal features.

Ultrasonic measurements also do not require ionizing radiations and hence much safe compared to radiography and CT imaging, they are much faster than MRI, they can perform testing from one accessible surface as opposed to radiographic techniques, which require at least two opposite surfaces. Compared to CT and MRI, the cost of hardware is cheaper and much smaller, hence portable, a variety of probes are available for specific use. However, effectiveness of the measurements heavily depends upon the structure of material being tested. In fine-grained materials the penetration could be much larger than courser structures, which scatter ultrasound waves very strongly. The basic requirement for ultrasound measurements is that the sonic probe should touch the sample or the sample should be immersed in some liquid. In food quality detection such conditions may be prohibiting for certain types of food products. Skill of operator is also a critical parameter in probe placement and contact.

Conclusion

Machine vision based techniques have high potential for quality evaluation of agricultural produce. The techniques are based on basic mathematics and rely heavily on computation power. The techniques could be quite robust and reliable if appropriate hardware is used for imaging. These techniques could be employed for online quality determination using appropriate imaging device(s) and computers with suitable computational power.

Good images, showing enough contrast among the different features of interest, are the primary pre-requisite for implementation of machine vision protocols. Various imaging tools like visible light camera, infra-red light imaging, X-ray imaging, CT imaging, MRI, Ultra Sonography etc. have their own advantages and limitations. Knowing them, one can effectively design a hardware setup and software protocol for quick quality evaluation of different foods.

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Solar Refrigerated Evaporatively Cooled Structure for Fruits and Vegetables Storage**

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Evaporatively cooled (EC) storage structures have been evaluated in India and a number of other countries for storage of a variety of fresh fruits and vegetables (Chopra *et. al.* 2001; Chouksey, 1985; Roy, 1989; Roy and Khurdiya 1986; Umbarkar *et. al.*, 1998). These have been suggested to be a better option in comparison to refrigerated storage structures, owing to less initial capital investment and minimal operational cost, making them accessible to lower-income farmer/ entrepreneurs (Vala *et. al.*, 2014). The overall technology is environmentally friendly as it depends on evaporative cooling due to forced or natural convection, although it has limitations in utility in high humidity climates. Improved capacity for on-farm storage is expected to provide benefits to smallholder farmers (Athreya et al., 2008). No work has been done on using solar refrigeration to further cool the EC rooms.

The EC storage structure is based on the principle that evaporation causes cooling. In most configurations, a room is built with a wetted medium sandwiched between outer and inner walls (Fig. 1). The exterior wall is porous and permits water vapor to be lost from the wetted medium. As the water evaporates, heat is drawn from the structure, cooling it and any produce that resides within.

There are two different kinds of evaporative cooled storage structures: active and passive. Active EC storage structures use fan-pad systems and need electrical energy to operate. Active EC rooms achieve somewhat lower temperatures than passive EC rooms while maintaining nearly 80-90% humidity inside the structure. Variations on both of these designs have been tested in Indian institutes and are being used at farm level in many villages (Anon. 2009; Basediya *et. al.* 2013, Vala *et. al.*, 2014), but they are not a common form of storage.

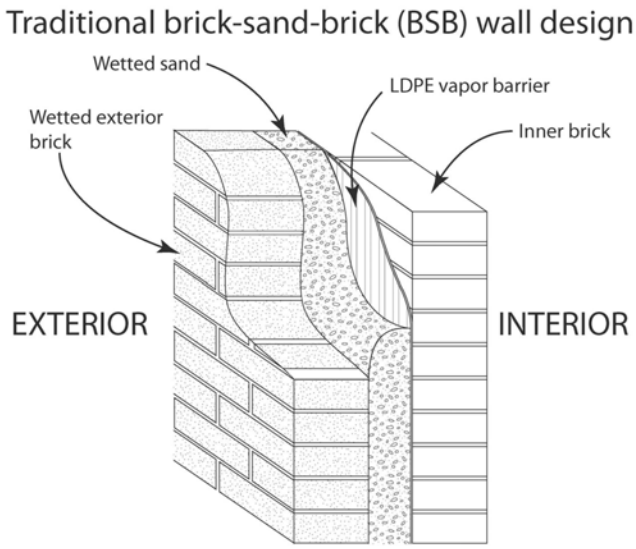

Fig. 1. A brick-sand-brick design for the walls of an EC room, commonly used in India. In this concept, the exterior wall is composed of a high porosity brick (Chopra et al., 2008) with a water barrier between the wetted sand and the inner wall to prevent free water migration to the room interior.

Technological innovations in EC rooms are needed to make them more effective, more desirable and, in the end, more impactful on farmer profits. Typical temperature reductions are on the order of 5 to 10 °C relative to ambient and the room interior can actually be warmer than the ambient temperature at night. The EC rooms envisioned and modeled (Chopra. Beaudry, 2018) will be able to hold one or two tons of produce and are constructed primarily of bricks, sand and concrete. Thus, construction by farmers or farmer communities is possible using local skillsets and materials and implementation is easily scalable.

Our long-term goal is to design an EC storage structure that is efficient in terms of heat loss from the commodity, is inexpensive and easy to construct and is capable of being converted into a refrigerated storage. To date there has been no quantitative evaluation of the performance of wall construction materials for produce cooling. We developed a mathematical model for EC room thermal analysis to predict the functionality of wall composites. Using the model, our first objective was

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to predict the cooling capacity of wall materials for EC structures capable of holding up to 2.2 metric tons of produce. The second objective was to create a design incorporating one or more of the most functional composites that can be retrofitted with refrigeration in a staged construction.

Model development

Heat load calculation. Hourly ambient temperature and humidity data for a typical day in mid-May for Rajasthan, India (average of May 16 to May 31) was used to calculate the environmental heat load and the wet-bulb temperature (Table 1), which was taken to be the outside wall temperature for the EC structure. The soil temperature was taken to be 28 °C, the average for a Rajasthan at a 1-m depth. Heat load from the produce was a function of the initial heat content (the assumed initial temperature was 40 °C) and the respiratory heat production as affected by temperature. A mixed load of apples, potatoes, broccoli, onions and cabbage weighing 2200 kg was assumed, for which respiratory heat calculations were taken from Gross et al. (2016) (Table 2).

Heat flux calculation. The flux of heat into and out of the room was calculated for walls, floor, ceiling, door and window using known or derived thermal constants (Table 3). This heat flux was used to calculate the change in temperature of the produce within the structure over the theoretical three-day period

Table 1. Diurnal variation in the average temperature, humidity, dew point, and wet bulb temperature for the period of May 16-31 in Jaipur, India.

Hour of day	Ambient temperature (°C)	RH (%)	Dew point (°C)	Wet bulb (°C)
0	33	32	14.1	26.7
1	32.5	34	14.6	26.5
2	32.3	35	14.9	26.5
3	32	37.5	15.7	26.6
4	31.5	39	15.9	26.3
5	30.5	40.5	15.6	25.5
6	31	41.5	16.4	26.1
7	32.5	40	17.2	27.4
8	34	40	18.5	28.8
9	36	38	19.5	30.5
10	37.5	33	18.5	31.2
11	39	28.5	17.5	31.8
12	40.5	24	16.0	32.3
13	41	20	13.6	31.9
14	42	18	12.8	32.3
15	42	16	11.0	31.7
16	41.5	15	9.6	30.9
17	40	16	9.4	29.8
18	38	20	11.2	29.1
19	37	23.5	12.8	28.9
20	36	27	14.1	28.7
21	35	28.5	14.1	28.0
22	34	29.5	13.7	27.2
23	33.5	30.5	13.8	26.9

Table 2. Equations for estimating the heat of respiration for five perishable products and their weight used for the model in this study. *T* is temperature in degrees Celsius. Equations are derived from data collated by Gross et al. (2016).

Product	Heat of respiration (mW/kg)	Product wt. (kg)
Apples	$5.4T - 2.5$	1000
Broccoli	$42T + 78.7$	100
Cabbage	$15T - 20.3$	100
Onions	$2.3T + 3.3$	500
Potatoes	$2T + 13.2$	500

Performance of wall materials

The impact of wall composites with varying properties of thermal transmittance and thermal mass on cooling of produce was determined. Wall composites included traditional brick-sand-brick (BSB), polyurethane foam (PUF), aluminum aerated concrete (AAC), pervious concrete (PC), iron, and mesh-supported fabric (MSF). In each case, the assumption was that the material or its outer surface was wet and its outer surface was maintained at the wet bulb temperature due to evaporative cooling. To compare wall composites, we determined the expected temperature drop in the first 24 hours for the produce held within the storage using the environmental data for Rajasthan previously described.

Predicted cooling curves were generated for BSB and MSF composite walls (Fig. 2). According to these curves, MSF walls will cool produce much more quickly than BSB walls, even though both will eventually cool to near the same

Table 3. Physical and thermal properties of structural elements of a 3 x 3 x 3 m EC storage structure having walls composed of various composites or materials.

Composite/material	Thickness (cm)	Dimensions (m)	Thermal transmittance ($W/m^2 \cdot °C$)	Thermal mass (W·h/°C)
Walls				
Brick-sand-brick (BSB)	11.43	3 x 3	2.01	5804
Iron	0.635	3 x 3	6.67	236.8
Polyurethane foam (PUF)	5.08	3 x 3	0.47	23.92
Pervious concrete	6.35	3 x 3	4.12	749.7
Mesh-supported fabric (MSF)	0.1	3 x 3	6.60	41.58
Aluminum aerated concrete (AAC)	6.35	3 x 3	1.47	61.56
Roof				
AAC block	5.08	3 x 3	1.62	12.3
Floor				
AAC-brick	5.08	3 x 3	1.77	152.913
Door				
Iron-PUF	0.15, 5.08	2 x 1	0.476	4.45
Window				
Glass	5.08	0.3 x 0.6	1.772	5.406

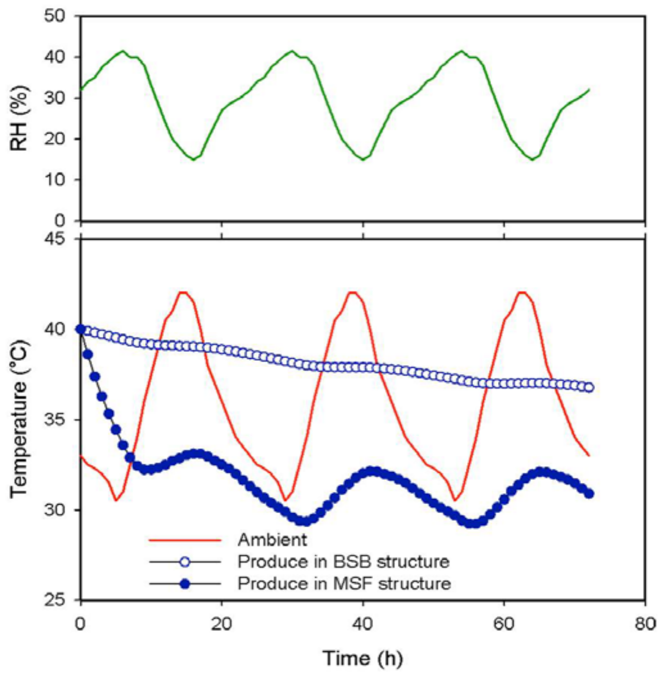

Fig. 2. Humidity (upper panel) and temperature (lower panel) for three consecutive days in Rajasthan in mid-May. Cooling of 2200 kg of produce in a 27 m³ EC room covered with wetted mesh-supported fabric (closed circles, MSF) is projected to be much more rapid than in the wetted traditional brick-sand-brick (open circles, BSB) wall construction.

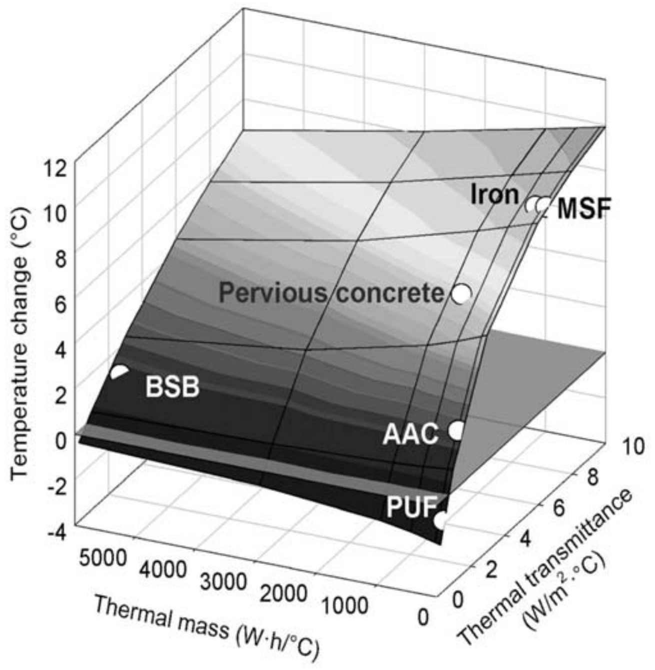

Fig. 3. Predicted temperature drop in a 24-h period for 2200 kg of produce in 27 m³ EC rooms with wetted walls having a broad range in thermal transmittance and thermal mass. Some materials (e.g., PUF), would cause the produce to warm, while others would permit slow (BSB and AAC) or rapid [iron and mesh-supported fabric (MSF)] cooling

temperature. The average steady-state temperature for the EC room was predicted to be approximately 30 °C, which is about 7 °C cooler than the average external environment. This modest cooling, while likely to be beneficial to the storability of the produce (Chouskey, 1985; Chopra et al., 2004 a,b), it is still far less than is required for optimizing the storability of the produce (Gross et al., 2016).

The rate of cooling was far greater for the MSF structure compared to the more massive BSB structure. This is in part due to the low thermal mass (41.85 W·h/°C) of the MSF structure compared to that of the BSB structure (5804 W·h/°C). For product stored for a day or two, a great deal of the benefit from cooling will be a function of its rapidity, so an MSF-type structure might be much preferable over the more traditional BSB structure.

The response surface generated by the model (Fig. 3), demonstrates the effects of both of thermal mass and thermal transmission on the rate of cooling of the 2200 kg of produce in the storage structure according to the thermal model. According to the data, a well-insulated EC structure, such as one constructed of polyurethane foam (PUF), would become warmer because respiratory heat is unable to escape. Structures with walls composed of very massive materials and modest heat transmission characteristics, such as BSB, would cool only slowly. AAC has very low thermal mass compared to BSB, but because its thermal transmittance is low, it too cools only slowly. Pervious concrete (PC), such as that used in concrete blocks in US construction, has a relatively low thermal mass compared to BSB and much higher thermal transmittance, making it significantly more effective at cooling than the traditional brick wall structures used in India.

An iron wall, while not practical really, has extremely high thermal transmittance compared to other wall materials and despite its high density, actually has low thermal mass, making it an effective wall material for cooling. However, wetting the surface of iron is not easily accomplished. Thus, combining iron (as in an iron mesh) with a material that holds and distributes water is a more practical option. In our case, we considered a thin iron mesh covered with a water-sorbent fabric has the thermal transmittance of water and the water handling characteristics needed to effect evaporative cooling. Of the composites and materials considered in this study, a mesh-supported fabric (MSF) surfaced as the best option for rapid and effective evaporative cooling.

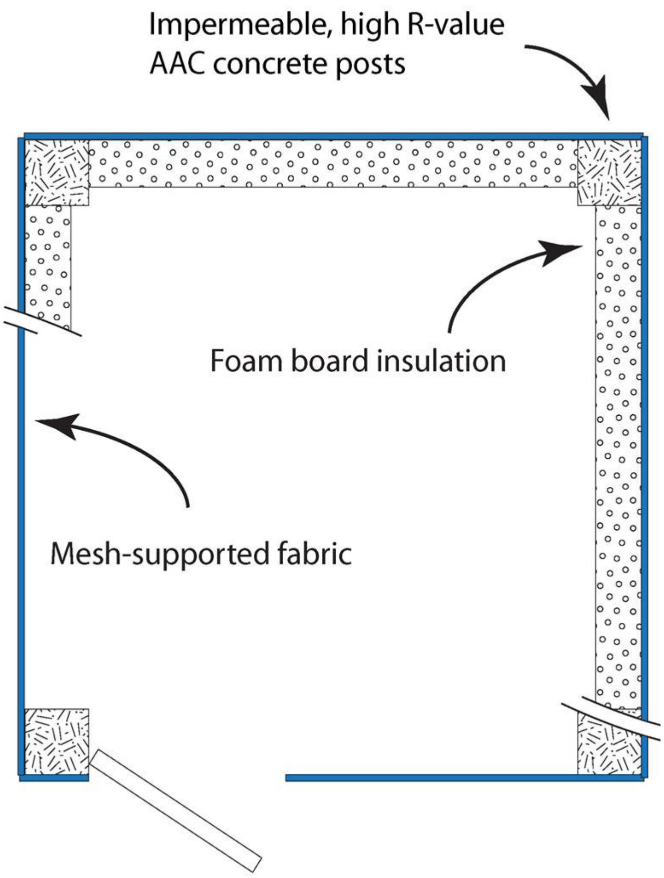

Fig. 4. Proposed EC room design. When transitioning to a refrigerated room, we only need apply water impermeable insulation (e.g., AAC, PUF or extruded polystyrene) within the external EC wall material

The implications of the data are that a wall composite having low thermal mass and high heat transmittance will be much more effective at cooling produce than the traditional brick-sand-brick sandwich design. Even so, cooling potential is limited. As a result, additional cooling would be highly desirable. To this end, it would be preferable to develop a design to permit the structure to be fitted with insulation so

Fig. 5. Stand-alone, batteryless, off-grid, solar-refrigerated evaporatively-cooled (SREC) structure (*proof of concept*) at ICAR-IARI, New Delhi

that refrigeration would cool the produce to a lower temperature and benefit from the reduction in heat load offered by the evaporative cooling. We propose a design in which the mesh-supported fabric is wrapped around four insulative posts (perhaps composed of AAC blocks) (Fig. 4). In this configuration, insulation can be added to the room between the columns. The insulation would need to be waterproof (e.g., extruded styrene, PUF, or waterproof AAC) to avoid futile cycling of water by condensation on the evaporator coils.

Prototype structures have been constructed at the IARI PUSA campus to validate the models developed and discussed here. We have developed the BSB, pervious concrete, and mesh-supported fabric structures and created two full-scale EC rooms, one of which is anticipated to be outfitted with a refrigeration system, preferably one designed to run on grid-independent solar power for which photovoltaics are becoming increasingly affordable (Romm, 2013).

A stand-alone, batteryless, off-grid, solar-refrigerated evaporatively-cooled (SREC) structure (Fig. 5) for storage of perishables has been developed and evaluated at Agricultural Engineering Division, IARI. The SREC structure can easily achieve daytime temperatures as low as ~5-10 °C and nighttime temperatures below 14 °C when the daily maximum temperature is approximately 45 °C. The SREC structure employs walls composed of inexpensive fabric over iron mesh to make a chamber of size 3x3x3 m for a storage capacity of 2000 kg fruits and vegetables. The columns and roof are made from lightweight aerated concrete blocks. It utilizes inexpensive styrofoam panels as insulation. Refrigeration is provided by a mini split inverter air-conditioning (IAC) unit, available locally and providing a low cost per BTU of cooling and markedly improved mechanical performance (COP of approximately 4.3). The evaporator coil is split to shunt cooling to the thermal reservoir in a maximally efficient manner. A simple cold-water reservoir provides low cost thermal storage obviating the need for batteries for nighttime cooling. The grid independent inverter with secure power supply is used to operate the refrigeration system from solar panels. The passive evaporative-cooling results from the use of wetted fabric walls stretched over metal mesh. The evaporative cooling can achieve modest temperature reductions and reduce the heat load that the refrigeration system must remove, enabling the use of smaller solar panel arrays and smaller capacity refrigeration systems and hence reducing initial capital costs. The SREC structure can achieve temperature reductions of about 10 to 12 °C in Delhi area at about half the cost of traditional brick structures. In drier regions, temperature reduction would be further improved. A replicated trial to evaluate the impact of the stores on the quality and storage life of leafy greens (amaranth leaf used as model system) has been done. There was very little leaf abscission in amaranth leaves stored in solar refrigerated store as compared to those stored in evaporatively-cooled store or uncooled laboratory.

The IARI SREC storage structure is 'one-of-a-kind'. Despite its novelty, it can be self-built by the farmer with locally available materials, minimizing extra labor cost. The SREC chambers can be built to completion from the start or construction may be divided into two stages. The first stage entails use of EC only, which provides modest cooling. Farmers can self-build this chamber with locally available materials easily. At the second stage, solar refrigeration is to be installed with minimal investment and no major structural modifications. The staged construction is unique among clean energy storage concepts and will help make the technology more accessible to smallholder farmers as it facilitates affordable entry into cold storage enterprises. This work has been done under IARI-MSU collaborative project funded by Global Centre for Food Systems Innovation (GCFSI), USAID, USA.

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Extraction of Oil from Cereal Grains using SCFE

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Cereal grains are generally low in oil content and the oil is mostly confined to the embryo and scutellum (Banas et al., 2007). Cereal grains and oilseeds are rich sources of tocols / vitamin E.

Wheat germ oil

Wheat germ is a by-product of the wheat milling industry. Germ constitutes 2-3% of wheat grain. Wheat germ contains about 10-11 % oil (Piras et al., 2009). Wheat germ oil has the highest tocopherol content of all vegetable oils, up to about 2500 mg/kg as per Shuler, 1990 and also contains the highest content of á-tocopherol and plant sterols. Tocopherols and tocotrienols together abbreviated as tocols are also known as vitamin E. Wheat germ oil is rich in unsaturated fatty acids: it has about 80%, mostly linoleic (18:2) and linolenic (18:3) (Wang and Johnson, 2001).Because of its high content of polyunsaturated fatty acids and bioactive compounds, wheat germ oil processing presents challenges. These compounds are prone to oxidation and degradation under the conditions used for conventional edible oil extraction and refining methods. Wheat germ oil has received much attention as one of the richest natural sources of vitamin E and is used as a component of health foods, cosmetics and toiletries.

Corn germ oil

The parts of maize seed/kernel are endosperm (82%), germ (embryo and scutellum) (12%). About 80 to 84% of total kernel oil is present in the germ region followed by 12% in aleurone and 5% in endosperm (Rajendran et al., 2012). In kernels of high-oil maize (*Zea mays*), the oil-rich embryo and scutellum are enlarged, leading to higher oil content than in traditional varieties.

Corn germ is a substantial byproduct of the wet milling and alcohol industry of corn. Corn germ (dry) contains 35–56 % oil with linoleic acid (C18:2) being the predominant fatty acid (49–61.9%) and the high amount of tocopherol and phytosterols. Maize having oil content of more than 6% is called high oil maize.

Barley oil

Oil content of Barley ranged from 1.9-2.8% (Osman et al., 2000) and oil contained 22-23% saturated fatty acid and 77-78% unsaturated fatty acids of total fatty acids. Barley oil has long been recognized as potential functional oil because of its cholesterol-lowering properties which could be due to high levels of tocotrienols. Although the yields of oil are very low (H”2%) from ground barley kernels, several studies have reported that milling or abrasion can produce fractions with higher oil content. Barley oil is a good natural source of different tocol isomers rich in tocotrienols.

Oat oil

Oat seed (also grain, kernel) in strict botanical terms is a fruit called *caryopsis*, or groat of the family *Poaceae*. The main constituents of the oat seed are bran, embryo, scutellum, aleurone layer and starchy endosperm. The kernel can be naked or covered by husks (hulls) which consist of outer lemma and inner palea. The term *bran* used in milling industry designates outer layers of oat seeds under the hull: pericarp, seed coat (or testa), nucellus, aleurone layer and part of the starchy endosperm adjacent to aleurone cells called the subaleurone layer.

Oat grains are relatively rich in oil compared with other cereals. Oat (*Avena sativa*) is the only cereal that accumulates substantial amount of lipids in the endosperm (Price and Parsons, 1979) and oil content can vary from 3% to 11% of grain weight in different cultivars, with lines containing up to 18% (Frey and Holland, 1999). Most oat cultivars have about 5–6% of oil (Doehlert et al., 2001). Lipids in oat endosperm have been reported to exist as non-structured oil smear and are not enclosed in oil bodies. Oat has the highest lipid concentration among the cereal grains, ranging from 2% to11% and that of ninety percent of about 4000 oat cultivars in the world is in 5% to 9%

range. 90% lipid exists in the bran and endosperm of oat seeds. Generally, content of total unsaturated fatty acid is above 80%.

Rice Bran oil

Rice processing produces polished rice or the parboiled variety, in addition to two residues: 13%, husk and 8% bran used as a fuel and animal feed, a food supplement and for edible oil production, respectively (Sarmento et al., 2006).When rice is milled to get white rice, the outer layers of the rice kernmal are removed which include hull, germ and bran. Depending on the type of variety and stabilization method rice bran contains 0-23% oil (Sparks et al., 2006). Rice bran oil contains 3 to 5% unsaponifiable lipids, a source of complex naturally occurring antioxidant components such as tocopherols, tocotrienols and oryzanol (Lloyd et al., 2000). Rice bran is a good source of nutrients that have large amounts of phytochemicals and antioxidants. Conventional rice bran oil production requires many processes that may deteriorate and degrade these valuable substances.

Table 1. Oil content and fatty acid composition of oil from cereal grains

Cereals & Millets	Oil %	Palmitic acid (16:0)	Stearic acid (18:0)	Oleic acid (18:1)	Linoleic acid (18:2)	Linolenic acid (18:3)	Arachidic acid (20:0)
Wheat germ	10	18	1	18	57	5	-
Maize/Corn germ	5	12.4	11.4	37	47.2	1.3	0.29
Barley	2.8	19.2	0.28	21.5	53	4.7	-
Oat oil	6-18	15.7	-	42.6	29.4	1.4	-
Rice Bran	23	21.5	2.9	38.4	34.4	2.2	-

Supercritical fluid extraction (SCFE)

Supercritical fluid extraction (SCFE) has proven to be technically and economically feasible method as compared to traditional/conventional extraction methods. Supercritical fluid (SCF) extraction is a novel separation technique which exploits the solvent properties of fluids near their critical point. Supercritical fluids *viz.* Propane and toluene are used in the petroleum industry to remove asphaltenes containing catalytic poisons from heavy hydrocarbon fractions prior to catalytic hydrotreating.

Industrially, oil can be extracted using pressing technique or using solvent extraction (n-haxane). During pressing most of the oil is extracted from the seeds, but a considerable amount remains in the cake. Remaining oil from cake is then extracted with n-hexane. After solvent extraction solvent has to be removed. Because of the ill effects of chemical solvent other alternatives are being explored. Supercritical (SC) carbon dioxide has nowadays emerged as a suitable solvent to produce these oils.

The use of supercritical fluids (SCF) has been attracting widespread interest owing to their unique properties (e.g., liquid like solvent power, negligible surface tension, and gas like transport properties), versatile applications, and strict environmental rules and regulations encourage the utilization of green solvents. Among various supercritical fluids, carbon dioxide has been widely adopted as it is non-toxic, non-flammable, and inexpensive, can be recycled, is totally dissipated from extracts at atmospheric pressure, and moreover, has easily accessible critical conditions and generally recognized as safe by FDA and EFSA (Beckman, 2004).

Therefore, $SCCO_2$ is becoming popular in food and pharmaceutical sector owing to fast and chemical free extraction. Pressure is important parameter in SCFE as by changing pressure solvating power can be modified. So SCFE can be used to extract different components at different pressure conditions. Since the late 1970, supercritical CO_2 has been applied for decaffeination of coffee and tea, refining of oils, extraction of flavors and other bioactive compounds from different plant materials.

The solvent power of SC-CO_2 as reviewed by Abbas et al., 2008 : It dissolves non-polar or slightly polar compounds. The solvent power for low molecular weight compounds is high and decreases with increasing molecular weight. SC-CO_2 has high affinity with oxygenated organic compounds of medium molecular weight. Free fatty acids and their glycerides exhibit low solubilities. Pigments are even less soluble. Water has a low solubility (<0.5% w/w) at temperatures below 100ºC. Proteins, polysaccharides, sugars and mineral salts are insoluble and;

SC-CO_2 is capable of separating compounds that are less volatile, have a higher molecular weight and/or are more polar as pressure increases Brunner, 2005.

Extraction of oil using SCFE

Different workers have optimized oil extraction parameters from cereals and work of a few of them is summarized .The effect of pressure and temperature on the SC-CO_2 extraction yield of wheat germ was examined by Molero and Martinez de la Ossa, 2000. They optimized conditions for wheat germ oil extraction and reported that for pressure, temperature and solvent flow rate was 150 bar, 40°C and 1.5 L/min respectively. The yields and fatty acid compositions obtained were found to be similar to those resulting from the conventional extraction process using hexane as solvent (8.0 wt %), although a higher-quality oil was obtained by using CO_2 as solvent. They reported that extraction of oil using SCFE simplified the oil refinement stages and completely eliminated the solvent distillation stage, which are the most costly processing steps in terms of energy consumption.

Zacchi et al., 2006 obtained wheat germ oil by mechanical pressing using a small-scale screw press and by supercritical extraction in a pilot plant. Their results showed that oil with a higher tocopherol content was obtained by supercritical extraction-fractionation and that FFA were removed by countercurrent rectification while the tocopherol content was slightly compromised.

The effect of the operating conditions on the degree of extraction of wheat germ oil, were examined in terms of the extraction time, temperature and pressure and maximum oil yield of 9% was reported at 48 min, 40ºC and 44.2MPa, respectively (Gelmez et al., 2009).They also reported that by varying the extraction conditions availability of bioactive compounds like tocopherols in oil can be affected.

Rebolleda et al., 2012 carried out the supercritical fluid extraction of corn germ oil to analyze the influence of pressure, temperature and flow rate on the extraction kinetics and the quality of corn germ oil obtained. Oil was characterized for refraction index, density and color. No significant differences were observed in the fatty acid composition of the oils extracted by both methods. Oxidative stability test using the rancimat showed that supercritical CO_2 extracted corn oil was less protected against oxidation than n-hexane extracted oils. They also observed that increase in extraction temperature from 40–85 °C, led to oils with higher tocopherol content and higher antioxidant activity.

The moisture content and configuration of the sample have been reported to affect the extraction of compounds with the supercritical CO_2. Further, the addition of water or alcohol to supercritical CO_2 would make it possible to increase the solubility of substances of low volatility in supercritical CO_2 (Taniguchi et al., 1985).

Parboiled rice bran oil was obtained with supercritical CO_2 at temperatures and pressures varying from 25 to 60ºC and from 150 to 250 bar, respectively. Under these extraction conditions, they performed experiments with two separators in series. The temperatures and the pressures of the first separator were 25 and 40ºC, and 100 and 150 bar. The second separator was maintained at 2ºC and 25bar. They revealed that the differences in the conditions lead to the extraction of rice bran oil with different concentrations of tocols in the first and second separators (Sarmento et al., 2006).

Extraction of rice bran oil using supercritical carbon dioxide (SC-CO_2) and compressed liquefied petroleum gas (LPG) was carried out by Soars et al., 2016. For the supercritical extractions, the influence of pressure and temperature on the extraction yield was evaluated from 150 to 250 bar and from 40 to 80 °C, whereas for compressed LPG extractions were performed at 5–25 bar and 20–40 °C. The highest yields were 12.68 and 12.07 wt%, whereas the maximum antioxidant activities were 71.67 and 67.49% for extraction using SC-CO_2 and compressed LPG, respectively. They recommended that considering the slight difference in the yield and antioxidant activities of extracts between the solvents, compressed LPG is a more promising solvent than supercritical CO_2 for extraction of rice bran oil since the extraction period can be considerably reduced while lowering the energy required for solvent recompression.

Temelli et al., 2013 studied the samples of whole grain and 35% pearling flour of 20 different barley varieties grown in Alberta were analyzed for their lipid contents. Total lipid contents of whole grains were within 1.9% to 3.0% (w/w), whereas those of the 35% pearling flour were 4.3% to 7.9%. Lipids of 35% pearling flour fraction of Tercel barley were extracted using supercritical carbon dioxide (SC-CO_2) at different pressures (24, 45, and 58 MPa) and temperatures (40 and 60æ%C) for 3 h with oil yield ranging from 73% to 97%. Tocol contents and compositions of whole grain, 35% pearling flour, and SC-CO2 extracts were analyzed using HPLC.

The optimal parameters for the supercritical carbon dioxide (SC-CO_2) extraction of oat bran oil were determined by orthogonal array design and were pressure 15 MPa, temperature 35!, and time 3 h. Fatty acid compositions of oat bran oil extracted by SFE showed palmitic acid 17.60%, stearic acid 1.32%, oleic acid 40.15%, linoleic acid 37.55%, linolenic acid 1.89% and elaidic acid 1.52% Shun yu et al.,2010.

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Requisite Headways for Modern Food Grain Warehousing in India

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Introduction

According to the 3rd Advance Estimates, the estimated production of food grains during 2017-18 is 279.51 Million Tonnes (MT) which is higher by 4.40 MT than the previous record production of food grains achieved during 2016-17. The current year's production is also higher by 19.33 MT than the previous five years' (2012-13 to 2016-17) average production of food grains. Total production of **rice** during 2017-18 is estimated at record 111.52 MT. Production of rice has increased by 1.82 MT than the production of 109.70 MT during 2016-17. It is also higher by 5.22 MT than the last five years' average production of 106.29 MT. Production of wheat during 2017-18 is estimated at record 98.61 MT is higher by 0.10 MT as compared to wheat production of 98.51 MT achieved during 2016-17. Further, the production of wheat during 2017-18 is higher by 5.28 MT than the average wheat production of the last five years. However, total storage capacity with FCI, CWC and other state warehousing corporations and other agencies is about 85 MT and the shortage is 45-55 MT. The problem is aggravated further by the need to maintain buffer stocks and other operational stocks. With increasing production of food grains due to better inputs, normal monsoons and improved mechanization, the shortfall is expected to rise to approximately 70 to 80 MT. Therefore, the country currently requires 130 to 140 MT of dry storage for the annual produce of approximately 220 MT of food grain. Any bumper harvest could prove to be the last straw that could break the back of camel and bringing our warehousing system to the edge of disaster.

FCI has admitted to the losses of 79 MT between 2009-2013 which amounts to more that the production of countries like Australia. Large amount of food grains to the tune of 12-15 MT remains under Cover and Plinth Storage (CAP) vulnerable to the adverse weather conditions. Adding to this is the decline of private investment in Agriculture from 12% in 1999-2000 to 6% currently which mars the chances of modernizing of warehousing infrastructure in India. There are also issues with the location/distribution of warehouses in India. Northern states of India house 48% of storage spaces whereas southern India has only 22% of storage infrastructure. Western, Central and eastern India possess 13%, 9% and 7% respectively of total storage capacity of India. It is in this back drop we would examine the requisite headways for improving food grain warehousing in our country.

Challenges in Warehousing

- Highly fragmented sector with presence of many local players: The warehousing industry in India is dominated by several unorganized players with low capacities and poor deploying, handling, stacking and monitoring facilities. There is high competition from smaller players ranging from small truckers to non-registered business entities that offer only small space for storing goods.
- Small and poor quality warehouses: A majority of the warehouses in the country are about 5,000 square feet in space against an average size of approximately 50,000 square feet in developed countries. Smaller sizes (and related economics) limit the ability of warehouse owners to invest in high–quality construction, technology and modern material handling equipment.
- Non-uniform distribution of warehousing facilities: Existing warehousing capacities are concentrated in four states – Uttar Pradesh, Punjab, Haryana and Andhra Pradesh and account for 60 percent of the warehousing capacities nation wide.
- Lack of supporting infrastructure like power, specialized transportation: Lack of power and specialized transportation to carry goods to and from warehouses leads to increase in the operating costs, making it economically unviable for the warehousing company.

Opportunities and requisite headways

It has been well established that vertical silos are much better than the flat warehouses we currently have in our country so far as scientific storage of food grains in concerned. Looking at the International Best Practices in Grain storage and movement, there are some worth examining cases that should guide us in our endevours to modernize our warehousing network into a robust and scientific storage system in our country.

- USA has more than 310 MT Silo storage capacity. On farm /Silo capacity is almost equal to off farm capacity. Hub and Spoke System: On farm storage helps farmer to store Grain at the site at harvest time and move to off farm contrast this with Punjab/Haryana where the scene is chaotic at harvest time and Mandis are chock a block.
- Canadian Wheat Board is the nodal agency for wheat storage in Canada. Major food grains holdings of CWB is at farm level and grain terminals with similar Hub and Spoke System.
- China procures, handles, stores & transports its food grains viz., wheat, paddy, rice & corn in bulk only. Bags are used at the final stage i.e. while selling to consumer. State intervention in China is quite strong. Just like India they want remunerative prices for farmers and low prices to consumers.
- China has no CAP storage system currently. Transition from CAP to Flat Warehouse happened in 1998 when China realized the quantum of wastage in CAP. This should be a lesson to us. Punjab/Haryana stores a lot of Grains in CAP.
- Interestingly, China stores grains in Bulk in their warehouses also. About 80% of food grain is stored in Horizontal Bulk Warehouse
- Silo Storage: 20%. Transition from Warehouse to Silo came when China realized construction of Warehouse more expensive than Silos and storage is more effective in Silos.
- An efficient, integrated and mechanized bulk handling, storage and transportation system should be promoted and developed in the country. Warehousing should be accorded the full-fledged infrastructure status with all financial benefits like cheap loans, IT and Service tax benefits.
- Hub and Spoke System needs to be implemented in India. Smaller Silos at Mandi level connected to Mother Silos. Mother Silos should have bulk handling and rail connectivity. Upcountry Silos also should have rail connectivity.
- Change over from Box Wagons to Top Loading/ Bottom discharge should be taken up and expedited. Wagons would go a long way in improving capacity utilization for Railways. Suitable Top loading/ Bottom discharge wagon should be made available for handling grain. If railways is stressed for funds private sector should be suitably incentivised to create required wagon capacity.
- Silo sites should be notified as Mandis under relevant APMC Act by State Governments.
- Our Port Infrastructure should be suitably tweaked to receive and store grain in bulk. This will facilitate both import & exports.

Novel Processing Techniques for Pulse Milling

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India is producing and consuming many varieties of pulses which are important components of the diet of rich and poor Indians. Pulses are basic segment of the human diet in the under developed and the developing nations. Pulse processing mainly focuses on complete removal of the hull with minimum generation of powder, broken, with dehulled split formation. Pulse possess an imperative place on the planet nourishment and sustenance economy. Pulses are very good source of protein even from early civilization era and supplement cereal diets by improving their protein nutritive values (Darmadi- Blackberry et al., 2004). Protein content of different pulses varies from 20–30%. They also provide substantial qualities of minerals and vitamins to the diet.

The world production of pulses was 67 MT in 2012 (FAOstat, 2012) in which India alone contributed 17 MT. India is the largest producer and consumer of pulses in the world with 25.5% share in total world pulse production (DAC, 2015). Pulse production in India increased to 19.27 MT in 2013–14; even then it imported 3.05 MT pulses during this period to fulfil the domestic demand (DAC, 2015). Among different pulses, the leading contributors are chickpea and pigeon pea. The availability of pulses is reducing in India over the past few years due to ever increasing Indian population, increase in per capita income and considerable increase in prices. Further, the losses during harvest and postharvest operations, handling, storage and processing also reduce the availability of pulses. According to one study, the harvest and post-harvest losses of four pulses (chick pea, pigeon pea, green gram, and black gram) in India are 6.36–8.41% (Jha et al., 2015) whereas the processing losses in pigeon pea are 8.6–16.6% (Goyal et al., 2005). Thus, the pulse availability can be enhanced to a considerable extent by reducing these losses.

The major post-harvest operations involved in pulse processing are cleaning, grading, pretreatment, drying, milling, packaging, handling and storage. About 75-80% of total pulses produced in India are milled into splits (dhal). There are about 15,000 dhal mills in India (Ali, 2004) out of which about 2000 dhal mill have an average capacity of 10–20 T/day (MFPI, 2009).

Pulse Dehulling

Conversion of pulses into dhal is the third largest food processing industry in the country after rice and wheat milling industries. Pulses are unique among the food grains because gums present between hull and cotyledon binds them together. Chemical nature and quantity of the gums determine the strength of hull and cotyledon attachment, and, therefore plays important role in dehulling (Tiwari and Singh, 2012). Therefore, dehulling is an important unit operation in pulse processing. Pulse dehulling is an age-old technology for which several processes and machines have been developed through trial and- error method. The processes adopted for dehulling and the machines employed for dehulling are not uniform and batch type i.e. one to one operation in different process. Majority of pulse milling is done at domestic, cottage and small to medium-scale industries. About 10-25% of pulses are converted into dhal at the domestic level and the rest are sold in the market at low price for conversion into dhal by organized pulse milling industries.

Pitting or surface scratching is one of the basic unit operations performed prior to application of any pre-milling treatments in the pulse milling (Singh, 1995; Narasimha et al., 2003). Passing the seeds quickly through the roller mill results in scratches or cracks in hull and removal of waxy layer of seed coat is known as pitting (Singh, 1995; Sokhansanj and Patil, 2003). This operation improves absorption of the pretreatment agents (Narasimha et al., 2003; Rodi~no et al., 2011). Dedicated machine for pitting of pulses has not been reported in the literature and generally pulse dehulling machines are used. Process and machine parameters such as moisture content, size of grains, emery grit size, type of cracks developed due to pitting, mechanism of force application, clearance between roller and concave, speed of roller, duration of pitting, etc., may affect the efficacy of the pitting operation and need to be studied. The pitting operation reduces the force required to separate the cracked hull from the cotyledons and facilitates subsequent pretreatment and dehulling.

Pre-milling treatments are generally employed to loosen the seed coat (Singh, 1995). It is also aimed to reduce breakage and improve product quality. Various methods of pre-milling treatments such as wet, heat, edible oils, and chemicals (Singh 1995); enzymes (Verma et al. 1993), hydrothermal (Tiwari et al. 2010), and microwave (Joyner and Yadav, 2015a) are developed for dehulling of pulses. Wet pretreatment is the oldest pre-milling treatment method for loosening the bond between hull and cotyledons of pulses. The process involves soaking the seeds in water for 6–8 h; mixing with 3% red earth slurry; sun drying for 2–4 days; tempering for 8–12 h; and, separation of red earth (Singh et al., 1992; Deshpande et al., 2007; Lal and Verma, 2007). This pretreatment method was practiced for commercial processing of pulses in India (Singh, 1995). Soaking in water results in expansion of the seeds and when seeds are dried, the cotyledons shrink more than the hull resulting in a bubbled hull, which can be removed during dehulling (Sokhansanj and Patil, 2003). The wet method has the disadvantage that it has very time consuming process, labor intensive, weather dependent, and adversely affects the cooking quality (Singh, 1995).

Pre-milling treatments using edible oils are commonly practiced at present in commercial milling of pulses. The process involves pitting of seeds (at 10–12% moisture content), application of edible oil at 0.1–1% (w/w), sun drying in thin layer for 2–5 days, addition of desired amount of water to increase moisture content by 2–5%, tempering in heaped form for 12–18 h, sundried to about 10–11% moisture content, and milling (Narasimha et al., 2003; Sokhansanj and Patil, 2003; Tiwari et al., 2007). By this process about 40–50% grains are dehulled during milling with the abrasive roller mill in single pass. Dehulled lot is separated and unhulled/partially dehulled material is again treated with 0.1–0.3% edible oil and water (2–3%) followed by Sun drying. The major disadvantage of this method is high dehulling losses due to breakage and powdering.

In hydrothermal treatments, heating has been found to facilitate dehulling of pigeon pea and the process has been standardized at Central Food Technological Research Institute (CFTRI), India (Singh, 1995). The process involves pitting, oil application and conditioning for 6–8 h, heating grains at 120–180^{o}C in LSU (Louisiana State University) dryer and conditioning for 5–6 h in the drying bin, heating grains again for some time, conditioning for 10–12 h in the drying bin and dehulling with abrasive mill (Singh and Ilyas, 1987). The dhal yield of 81–86% has been reported for different pulses. This process is also time consuming.

Alternate pre milling treatments like microwave treatment methods was not performed for pulse dehulling performance and not been reported in the literature. Due to above limitations of the wet and dry pretreatment process, enhanced pre milling treatments with microwave pretreatments was done for enhancing recovery in pulses for commercial utility.

Dhal milling machines

Dehulling of pulses for dhal production with abrasive machines is performed when the grain attains moisture content of around 10% and it is irrespective of the pretreatment method employed. Dehulling of the pulses is usually done with the application of abrasive forces (Sokhansanj and Patil, 2003). In the early seventies, vertical stone mills were commonly used for dehulling of pulses in India. Stone mills are no longer used due to grain damage up to 20–45% and inferior product quality (Ali, 2004). Consequently, several machines have been developed for dehulling of pulses. Most common commercial machine for pulse dehulling is the emery-coated cylinder-concave system (Singh, 1995; Tiwari and Singh, 2012). Pulse dehulling machines developed by different research organizations of India are the modified versions of the batch type dehulling machines used in the commercial pulse milling industries. It may be observed that all the dehulling machines are based on the principle of abrasion and these dehull 80–88% pigeon pea seeds using different pretreatments in 3–4 passes. Dehulling efficiencies of Indian Institute of Pulse Research (IIPR) dhal chakki, Central Institute of Agricultural Engineering (CIAE) dhal mill and CFTRI dhal mill were 49.53%, 40.35%, and 45.35%, respectively, for untreated pigeon pea grains (Lal and Verma, 2007).

Therefore, pretreatment of pulses considerably improves the performance of dehulling machines. Systematic research work to dehull pulses at higher moisture contents has not been reported. It showed that the machines and processes for pulse milling are still conventional batch type and very time consuming. These machines dehull 40–50% seeds without any pretreatment. However, 80–88% seeds are dehulled in 2–4 passes through these machines when pretreatments are employed.

Microwave pre milling treatment

Microwave pre milling is a technology that may be used increasingly in the pulse industries due to its considerable advantages in heat transfer comparing to conventional process (Lombrana et al, 2010). As compared to conventional heating systems, microwave heating system penetrates a food product and heating extends throughout the entire food material. Microwaves represent the electromagnetic spectrum between frequencies of 300 MHz and 300 GHz. The absorption of microwaves by a dielectric material results in the microwaves giving up their energy to the material, with a consequential rise in temperature. The speed of heating of a dielectric material is directly proportional to the power output of the microwave system. Although a high speed of heating is attainable in the microwave field, many food applications require good control of the rate at which the foods are heated. Very high-speed heating may not allow desirable physical and biochemical reactions to occur. A higher amount of water in a food increases the dielectric loss factor, å'', which expresses the degree to which an externally applied electrical field will be converted to heat. The shape of the food material is important in obtaining uniformity of heating. Non-uniform shapes result in local heating; similarly sharp edges and corners cause non-uniform heating. Heating is a consequence of interactions between microwave energy and a dielectric material. The conversion of microwave heat is expressed by the following equation (Linn and Moller, 2003):

$$\mathbf{P = 2\pi\ f\ E2V\ \varepsilon''\ \varepsilon0}$$

Where P = power, E = electrical field strength (V/m), V = volume of the material, m3, f´ = frequency (Hz), E = relative dielectric constant, å´´ = Dielectric loss factor, å0 = Permittivity of free space, 8.854 x 10-12 F/m.

Microwave pre milling technology may be used in pulse processing to reduce post-harvest losses during drying, milling, cooking and storage. As pre milling treatment of microwave in milling of pulses reduces milling time and increases the milling efficiency compared to all traditional methods. Microwave cooking, although not convenient for mass cooking, is very convenient for cooking small quantities, especially in households helps in reducing energy consumption with retention of nutrients. Several studies are focused on the uses of microwave energy for processing of pulse steps. Therefore, the use of microwave heating technology in processing of pulses to reduce post-harvest losses in pulses was done for commercial applicability.

Milling after microwave treatment

The study has been carried out on microwave treated black gram and pigeon pea on improving the dehulling efficiency. Using microwave treatment, a maximum dehulling yield of 73.7% and dhal yield of 72.7% was achieved as compared to 50.6% and 47% respectively for control sample. Microwave pre-treatment eliminates (Joyner and Yadav, 2015b) unit operations and thus reduces the total processing time, which ultimately results in energy saving. Microwave treatment also eliminates the usage of oil which adds to the processing cost of the conventional oil pre-treatment method. In addition to that, the microwave treatment also helps in reducing the cooking time for dehulled dhal by approximately 50% which would be helpful in saving cooking energy. The use of microwave energy before (Porohit et al., 2013) milling increases dal recovery by 76.2% at 700 W, 80^{o} C in chickpeas, 73.7% at 560 W, 70^{o} C in pigeon pea and 76.7% at 140 W, 40^{o} C in green gram.

Current status and further usage of microwave treatment in pulse processing

Dehulling process called as primary processing, converts the whole seed of pulses into dhal. It is most important operation of post-harvest handling of pulses, and hence plays an important role in processing and utilization of pulses in the daily diets of the people. Pretreatment influences the dehulling process and consequently the dhal yield. Different milling methods i.e., dry and wet milling, CFTRI method, Pantnagar process (chemical and enzymatic process), CIAE method. By using different dehulling methods with pre-treatment an amount of 20-25% of milling losses takes place because, the pulse milling industry is running with batch processing, involves excessive material handling and lot of dust is generated inside the mill which can be reduced by introducing continuous type processing system. This review introduces by using continuous microwave heating system at different power levels as pre-treatment before dehulling of pulses helps in reducing dehulling time, increases dehulling efficiency, reduces cooking time, less energy consumption, improves nutritional quality and also uses as non-chemical alternative for post-harvest insect control in dried agricultural commodities.

Conclusion

The applications of microwave heating in pulse processing such as grain drying, cooking, microwave–assisted extraction, disinfestation has a great effect on the quality parameters and also extends storage life. Furthermore, microwave heating could significantly requires less energy consumption for cooking, drying than conventional methods. Processing of pulses requires pretreatments such as heat treatment, pretreatments confer some nutritional benefits. Consumer and environmental concerns over the use of traditional methods during pulse processing and has generated interest in non-chemical alternatives. In these days, the potential of continuous flow microwave heating methods at commercial scale are trying as pretreatment technique for dehulling of pulses because pulse processing industries are still running under batch processing.

Microwave treatment of pulse plays an important role in improving the dehulling qualities of pulse. The dehulling time for black gram and pigeon pea was reduced by 62.3 % to 70 % when compared to that of the control sample. Using the microwave treatment a maximum dehulling yield of 73.7 % and dhal yield of 72.7 % was achieved as compared to 50.6 % and 47 % respectively for control sample. Microwave pre-treatment eliminates water soaking, oil treatment, drying, pitting etc. unit operations and thus reduces the total processing time, which ultimately results in energy saving. Microwave treatment also eliminates the usage of oil which adds to the processing cost of the conventional oil pre-treatment method. In addition to that, the microwave treatment also helps in reducing the cooking time for dehulled dhal by approximately 50 % which would be helpful in saving cooking energy. These novel pre milling process are useful for pulse processors as well as in designing a micro-wave assisted continuous type pulse dehulling system. Thus it could be concluded that the microwave treatment is beneficial for pulse dehulling and also presents an alternative to be commercially adopted.

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Low Temperature Grinding (LTG) of Spices: A Novel Technology

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Introduction

The Prime Minister's vision of doubling farmer income by 2022 is worth serious objective. Our various problems could be solved automatically, if we will achieve this. Because the holistic development of India is going through our agrarian status. Yes, it is not so easy, we have to find the right approach. Certainly, post-harvest technology will play a crucial role to achieve the vision of doubling income of farmers. In this context, novel technology such as low temperature grinding (LTG) or cryogenic grinding need to be implemented, where product quality is a matter of concern.

India is known for their spice richness, we are the number one producer as well as exporter of spices. The total production and export of spices were 6.17 MT and 1.489 MT, respectively (Anon., 2016). But our spice grower farmers don't get an appropriate price for their spices because usually a raw form of spices is being exported. If processed spices matching with international quality standards would be exported, definitely our farmer gets a good price.

Spices like black pepper, turmeric, nutmeg, fenugreek, curry leaf and cinnamon are being used in almost every kitchen in India for making food tasty and healthy. Besides this, these are used as a preservative in food preservation because of their anti-microbial and anti-fungal properties.

Generally, the quality of spices is depended on their essential oil, which is present inside the cells or tissues. Mostly spices are utilized in powder form. The availability of essential oil and phytochemicals are increased when it is converted into powder.

Often, grinding of spices is done by hammer mill, and pin mill. Grinding is an important unit operation to convert spices into powder form, in which the size of the particle is reduced and the surface area is increased. But there is a problem in conventional grinding, the 99% of input energy is dissipated in rising the temperature of the ground product whereas only 1% is utilized for size reduction operation (Sigh and Goswami, 1997). The temperature may rise to the extent of 42-93°C, which is adversely affected the quality of powder in terms of loss of volatile oil and flavoring constituents. In case of high oil bearing materials, oil comes out during conventional grinding making the product gummy, sticky and hence choking of sieves through which product passes (Singh and Goswami, 1997; Barnwal *et al.*, 2014; 2015). Thermal damage is reported as one of the main limitations of conventional grinding process (Meghwal and Goswami, 2010), it was suggested to perform the grinding under controlled conditions. It was also suggested that better product can be obtained by reducing the temperature of two rubbing surfaces (Malkin and Guo, 2007). The temperature rise of the product can be minimized to some extent by circulating cold air or water around the grinder (Murthy *et al.*, 1996; Singh and Goswami, 1999). But this technique is not sufficient enough to significantly reduce the temperature rise of the product to a safe level and not affect its quality characteristics. Pruthi (1987) reported that the loss of essential oil and heat labile constitutes can be significantly reduced by cryogenic grinding technique. Thus, during the conventional grinding, the medicinal values powder are reduced, so the need of grinding of such spices at cryogenic condition using a cryogen (liquid nitrogen) to retain the medicinal properties of spices and produce high quality powder.

Cryogenics

The terminology 'cryogenics' is related with a Dutch physicist, Kamerlingh Onnes, who wanted to produce a gas in his laboratory that could be refrigerated. As per National Bureau of Standards, UK, cryogenic temperature has been defined as -150°C and below. Table 1 represents some thermo-physical properties of liquid nitrogen (LN_2) and liquid carbon dioxide (LCO_2). According to the definition, liquid nitrogen (boiling point -195.6°C) qualifies in cryogenic range, whereas carbon dioxide (boiling point -78.5°C) does not. However, in general, cryogenics is defined as a branch of engineering specializing in technical operations at very low temperature, generally below -50°C. Cryogenic liquids are those which boil at cryogenic temperature and atmospheric pressure. The word 'cryogen' was created to describe a low temperature boiling liquid. Liquid forms of hydrogen, helium, nitrogen, oxygen, inert gases, air, methane, carbon dioxide, etc. are common cryogens. Liquid nitrogen (LN_2) and carbon dioxide (CO_2), in liquid or solid form, are the two major cryogens used in food processing

Cryogenic grinding

Grinding at cryogenic temperature is called as cryogenic grinding. In order to obtain high quality spice powder through cryogenic grinding technology, a cryogenic grinding system is needed to cool the spices before feeding to the grinder and also to maintain the cryogenic temperature in the grinding zone (Figure1).

Cryogenic grinding system has two main components:

- Pre-cooling unit
- Grinding unit (pin mill and a hammer mil)

The purpose of cryogenic pre-cooler is to remove the heat from the material before it enters the grinder. The pre-cooling unit consists of a screw conveyor assembly, an air compressor, liquid nitrogen (LN_2) Dewar, a power transmission arrangement and control panel. The cryogenic pre-cooler is made up of a screw conveyor enclosed in a properly insulated barrel and a system to introduce liquid nitrogen into the barrel, thereby providing refrigeration (liquid and cold gas) within the system. The particle temperature should be low enough to absorb the heat generated in the grinder and still fracture. Pre-cooling unit, therefore, must have the ability to reduce the temperature of the seed below its brittle point as well as the freezing point of its oil, before it enters the grinder. There must be provision to control the temperature of the pre-cooler as well as feed rate to the grinder for controlling the grinding process.

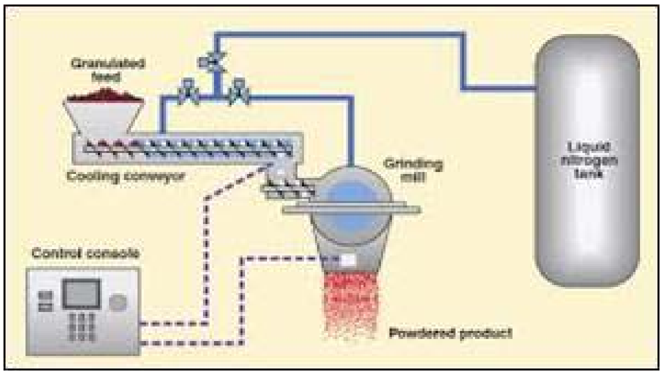

Fig. 1. A schematic diagram of cryogenic grinding system

Fig. 2. Grinding of spices at ambient and cryogenic conditions using lab model at ICAR-CIPHET Ludhiana

Fig. 2 shows a cryogenic grinding system for spices, available at ICAR-CIPHET, Ludhiana for high quality ground spice products. In this system, the LN_2 and spice seed are fed in the cryogenic pre-cooler inlet and travelled to outlet of the pre-cooler and enters into grinder inlet. Thus, cryogenically cooled seed of spices are ground in the grinder and high quality spice powder is collected at outlet of grinder in collection system.

Consumption of liquid nitrogen and the operating cost are important considerations and matters of concern for a cryogenic pre-cooling system. The liquid nitrogen losses can be minimized to a great extent by proper consideration of the design and insulation of the pre-cooler. The proper design of the pre-cooling unit is necessary to prevent the spice being heated up during grinding process. The pre-cooling unit should pre-cool the spice before the actual starting of the grinding operation. Thus, the pre-cooling unit should be designed to match with a commercially available grinder (a pin mill and a hammer mill) that could withstand low temperature operations.

In nutshell, cryogenic grinding process has several benefits-

- Ability to process soft or elastic material
- Increased productivity
- Low Power Consumption
- Smaller particle size
- Minimal loss of volatile components

The main engineering considerations in the design of a cryogenic pre-cooler are as below (Singh and Goswami 1999a):

1. Retention time of the seed in the liquid nitrogen and gaseous zone should be accurately proportioned so that the available refrigeration could be utilized at its optimum level.
2. Appropriate insulation should be used such that losses to the ambient could be minimized.
3. Various components of the pre-cooler should be arranged in such a manner that dismantling and cleaning could be easier.
4. Cool down losses should be reduced by keeping the machine size and structural components to a minimum.
5. Material, which is contacted with food stuff should be food grade strain less steel (304 SS).

Effect of cryogenic grinding on quality of spices

Studies reveal that cryogenically spice power is a high quality product in terms of volatile oil, colour, particle size, fineness modulus.

Murthy and Bhattacharya (2008) reported that 50% more volatiles were retained in cryogenic grinding of black pepper in comparison to the ambient grinding. The study conducted on cryogenic grinding of spices is significant contribution for characterization of grinding parameters vis-a-vis quality of the product. The cryogenic grinding is better than conventional grinding to obtain high quality ground spices in terms of higher retention of volatiles and flavouring components, color, particle size distribution of ground powder, free and continuous operation of the grinder without any choking, less energy requirement in grinding.

Singh and Goswami, (2000) reported that cryogenic grinding resulted in 29.5% more volatile oil in comparison to that of ambient grinding of clove. Saxena *et al*., (2013) investigated that Cryogenic grinding technology was found superior in recovery of more diosgenin content from fenugreek seeds. In conventionally ground seeds it ranged from 1.3 to 1.5% while increased significantly in cryogenically ground samples and ranging from 2.1 to 2.5%. Saxena et al., (2015) studied the effect of cryogenic grinding on volatile oil, oleoresin content, total phenolics, flavonoid content and antioxidant properties of seed extract of nine coriander (*Coriandrum sativum* L.) genotypes have been analyzed

Table 1. Effect of cryogenic grinding on spices qualities

An increase in temperature in the cryogenic range (-110 to "50°C) had no significant effect on volatile oil content, of clove, whereas temperatures in the range of 55 to 85°C significantly reduced the volatile oil content from 11.0 to 9.3 ml/100g. Thus, cryogenic grinding resulted in 29.5% more volatile oil in comparison to that of ambient grinding.	Singh and Goswami (2000)
Cryogenic grinding technology was found superior in recovery of more diosgenin content from fenugreek seeds. Diosgenin percentage was significantly more in all three studied genotypes. In non cryo seeds it ranged from 1.3 to 1.5% while increased significantly in cryo ground samples and ranging from 2.1 to 2.5%.	Saxena *et al*., (2013)
Effect of cryogenic grinding on volatile oil, oleoresin, total phenolics, flavonoid content and antioxidant properties of seed extract of two cumin (Cuminum cyminum L.) genotypes have been analyzed. Cryogenic grinding not only retains the volatiles in both the genotypes but enhanced the recovery also.	Sharma *et al*., (2014)
A project on cryogenic grinding of spices (coriander, fenugreek, cinnamon, black pepper & turmeric) has been completed at ICAR-CIPHET Ludhiana under NAIP program; the results showed that cryogenic grinding technology is capable to prevent the quality losses during conventional grinding studied.	ICAR, (2014)

by volatile oil and oleoresin content was significantly high in cryogenically ground samples. Cryogenic grinding technology is able to retain flavour and antioxidant properties of coriander irrespective of the genotypes. Baranwal *et al*., (2015) carried out the grinding characteristics of fenugreek (cv. AM-1) were carried out at cryogenic and ambient conditions. It was observed that it affected average particle size, volume surface mean diameter, mass mean diameter, volume mean diameter, specific surface of mixture, number of particles per gram, energy constants – Rittinger and Kick's and specific energy consumption. Comparative study showed that ambient grinding needs more power and specific energy than cryogenic grinding.

Singh and Goswami (1999a) conducted experiments on grinding of cumin seed at different temperatures from -160°C to -10°C. The sieve choking, particle size distribution, specific energy consumption and quality of the final product were observed using 8 number of grinder's rotor ribs in the grinder. The choking of sieves was observed by taking photographs of the sieve either at the completion of grinding or when the machine was stopped due to sieve choking. Above -70°C, the grinding experiments could not be completed successfully. This is so because the sieve perforations were blocked soon after running the machine and it stopped due to overloading with the incoming material. The accumulation of powder on the sieve surface might be due to the fact that during grinding at a temperature higher than the brittle point of the seed and freezing point of its oil, the seed was soft and behaved like glue in the grinder. Also, during grinding the oil might have released out of the cells, which had sticky characteristics and formed a layer over the sieve surface. The powder was deposited above this layer and formed a thick layer on the sieve surface which created obstruction in grinding process. At the same time, the incoming raw material overloaded the grinding surface and stopped the grinder.

It was observed that at the grinding temperature of -70°C, the deposition of cumin powder was minimum. Below -70°C, grinding was smooth without any deposition and the sieve was very clear. This is so because at temperatures lower than the brittle point of cumin seed and freezing point of cumin oil, the oil got solidified and the grinding operation was smoother. Thus, cumin seed could be successfully ground below the temperature of -70°C whereas above this temperature, sieve clogging took place.

It was to be observed that as the grinding temperature increased from -160°C to -70°C, there was an increase in the particle size for the same cumulative volume fraction for both the rotors. Thus, increase in grinding temperature from -160°C to -70°C resulted in a significant increase in particle size of the product. The volume mean diameter increased from 153.2 to 215 μm with increasing grinding temperature from -160°C to -70°C.

The specific energy consumption increased from 55 to 98 kJ/kg with increasing grinding temperature from -160°C to -70°C. This is so because at low grinding temperature, degree of brittleness of cumin seed increased which resulted in less energy requirement in grinding operation. Thus, increase in grinding temperature from -160°C to -70°C resulted in increase of specific energy consumption in grinding. The volatile oil content decreased from 3.30

Table 2. Comparison of traditional and cryogenic grinding

Parameter	Traditional Grinding	Cryogenic grinding
Energy Consumption	High	Low
Throughput	Low	High
Mill Clogging	Frequent	No Clogging
Volatile Losses	Higher	Minimum
Motor Capacity	High	Low
Control on particle size	No control	Effective
Grinding of soft material	Very difficult	Possible
Fire Risk	High	No
Air Pollution	Yes	No

to 3.26 ml/100 g with increasing grinding temperature from -160°C to -70°C, but this variation was found to be non-significant at 5% level (Singh and Goswami 1999a).

The grinding of cumin seed at various cryogenic and ambient temperatures were also carried out using 12 number of rotor ribs in the grinder to observe its influence on volatile oil content and its components, particle size distribution, volume mean diameter and specific energy consumption (Singh and Goswami 1999b). It was observed that an increase in temperature in the cryogenic range (-160 to -70°C) had no significant effect on volatile oil content, whereas increase in temperature in the ambient range (40 to 85°C) significantly reduced the volatile oil content from 2.86 to 2.26 ml/100g. The volatile oil components, a-pinene, β-pinene, γ terpinene, p-cymene and cuminaldehyde were not significantly affected by grinding temperature in the cryogenic temperature range. However, these components decreased significantly with increase in grinding temperature under ambient condition. With increase in temperature from -160 to - 70°C for 12 number of rotor ribs, the volume mean diameter of cumin powder increased quadratically from 129 to 164 ìm and the specific energy consumption increased from 72 to 108 kJ/kg.

Conclusion

The cryogenic grinding technology would ensure production of better quality ground spices in terms of retention of aroma, flavor and color which may be utilized in preparation of foods. Cryogenically ground spice powder have more volatile oil and attractive color than conventionally ground powder. Conventional grinding consume more energy than cryogenic grinding. The high quality ground product would have better or more domestic as well as international market. Adoption of this technology, our agrarian will get appropriate prices for their product. Cryogenic grinding of spices thus seems to be a promising technology for food and pharmaceutical industries as well. Hence, this technology has a potential for increasing the farmer's income and providing a better lifestyle to our farmers.

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Process Protocols for Development of Quality Green Raisins

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Introduction

Raisins are one of the most important dry fruits in India. They are good source of carbohydrates, fibres, vitamins and minerals (Table 1). They are fat free, cholesterol free and contain 70% fructose. Raisins contain the highest concentration of total phenolic compounds and antioxidant activity among solid fruit products. They are rich in polyphenols, phenolic acid, tannins and antioxidants. They contain phenolic compounds such as anthocyanins, flavonoids and resveratrol. Raisins are mainly included in breakfast cereals, dairy, bakery, confectionery, *farsan* items, desserts, herbal medicines etc. Consumption of raisins helps in decreasing the CVD risk due to presence of dietary fibers which lower LDL-C. Raisin polyphenols can decrease plasma TG by reducing apo-E as shown with lyophilized grape powder (LGP) supplementation in women. The efficacy of raisins in reduction of post-prandial glucose levels, HgbA1C and blood pressure is also reported (Nettleton et al., 2006, Bays et al., 2012). A routine consumption of raisins three times a day may significantly lower blood pressure, especially when compared to common alternative equi-caloric snacks.

Table 1. Nutritional composition of grapes and seedless raisins

Nutrient	Units	Thompson seedless grapes (135 g)	Seedless raisins (32.5 g)
Water	g	109	5
Energy	kJ	389	408
Carbohydrates	g	24.6	25.7
Total Sugars	g	21.4	19.6
Glucose	g	9.8	9
Fructose	g	10.9	9.7
Sucrose	g	0.2	0.14
Iron	mg	0.48	0.6
Magnesium	mg	9.6	10.6
Potassium	mg	258	243

(Source: USDA, http:/www.nal.usda.gov/fnic/foodcomp)

Raisins can be produced from all the grape varieties but not all the varieties yield good quality raisins. In India, Thompson seedless is the most utilized variety for this purpose. About 95% of the raisins are prepared from Thompson seedless grapes alone whereas remaining raisins are produced from clones of Thompson Seedless like Manik Chaman. Besides, E 12/7, E 12/3, Mint Seedless and KR White also proved to be promising varieties for raisin production. Grape varieties are very climate specific and hence grape production is concentrated in very limited part of India. Consequently, raisin production is also concentrated in limited area of the country. In India, raisins are mostly produced in Sangli, Solapur and Nasik districts of Maharashtra, and Bijapur district in Karnataka (Adsule et al., 2012). These raisins are produced for local consumption as well as exported purpose. Export of raisins from India is reported to be 140 tonnes. India's share in the total volume of raisins exported in the world is only 0.02%. It may be due to measurable quality of raisins produced in the country. It emphasizes that the great scope lies in the country to increase the production of export quality raisins.

In India, about 78% of the freshly harvested grapes are used for table purpose whereas almost 17-20% grapes are utilized for raisins production. Utilization of grapes for production of juice and wine is miserable merely 1.5% and

0.5%, respectively. Therefore, large consumption of raisins makes the process of raisin production important. Raisins are usually produced by drying the grapes under the sun (for 2 to 3 weeks) or convective drying at 71°C for 20 to 24 h.

Characteristics of good raisins (USDA Raisin standards)

i. Good and uniform appearance of produce in terms of its color (perfectly green or grey-green), size (round) and smooth texture.
ii. Higher pulp content and pleasing taste without any sugar coat outside.
iii. Intact skin and its outer layers, free from injuries, dust and foreign matter.

Characteristics of grape variety suitable for raisin production

i. Thin skin but thick pulp
ii. A minimum Brix value of 19°
iii. It should preserve flavour and color, well after dehydration
iv. It should be preferably seedless. If seeded it should be bold so that seeds can be removed
v. Berry should detach from the pedicel clearly and easily so that there is no oozing of juice
vi. It should have uniform hue with brilliant color.

It is observed that green raisins (Fig.1) are preferred more over brown or golden-brown raisins. Green raisins fetch 2 to 3 times more price in the market as compared to brown or golden brown raisins.

Green Golden-brown Brown

Fig. 1. Green, golden-brown and brown raisins

Conventional grape drying method

Conventional grape drying method involves dipping the grapes in dipping oil and drying them under shed till they achieve 13% moisture content (w.b.). Dried raisins are further graded, packed and sent for storage or marketing. The flow chart of conventional drying method is shown in Fig. 2. Low cost sheds and racks are developed for production of raisins in Karnataka and Maharashtra (Fig. 3). Temperature in these sheds varies from 25 to 45°C. Although these sheds are useful in hot and dry climates, their efficiency is reduced during humid climates.

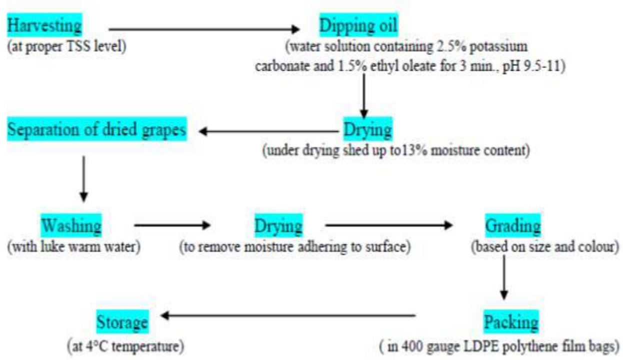

Fig. 2. Flow chart of conventional raisin making process

Fig. 3. Sheds and racks used for grape drying

During grape drying, high moisture of freshly harvested grapes (75 – 80%, w.b.) is reduced to the moisture level safe for storage (about 20%, w.b.). Conventional grape drying process requires about 15 to 20 days, depending on the relative humidity and temperature of ambient air. Such long drying durations deteriorate the color and overall quality of the raisins. Hence, drying time should be as smaller as possible. (Fig.2). Grape drying method is a very slow process taking almost 15-20 days. The drying time is governed by both extrinsic factors and intrinsic factors. Extrinsic factors include drying temperature, relative humidity of drying air, method of drying etc. whereas intrinsic factors include berry peel composition, peel thickness, pre-harvest treatments etc. Effects of these factors on drying rate and the quality of raisins have been evaluated by various studies.

Factors affecting the grape drying process

Temperature and RH of drying air

Various studies have been conducted to evaluate the effect of temperature and RH of drying air on drying rate. Higher the temperature higher is the drying rate. On the contrary, lower the RH higher is the drying rate. Temperature of drying air decides the berry temperature. Berry temperature is the most important driving force in the drying process. The moisture diffusion rate is mainly controlled by difference between vapor pressure within the grape berry and that of surrounding air. This vapor pressure difference is called as vapor pressure deficit. Vapor pressure deficit is higher at high berry temperature and vice versa. Relative humidity depend on air temperature and speed of air movement. High air temperatures and speedy air movement gives low relative humidity.

Composition and thickness of berry peel

Prior to raisins production, it is indispensable to understand the peel composition of grape berry. Unlike many other fruits, peel of grape berry has different composition which offers resistance to the moisture diffusion from berry. The primary barrier to the moisture loss is offered by berry cuticle (Fig.4). Hence, an understanding of the structure and properties of waxy cuticle is of considerable importance to the grape drying industry, where rapid loss of water from berries is desired. Cuticle includes the outer layer of epicuticular wax. This wax consists of partially overlapping flat platelets that are irregular or lacelike in texture. The structural arrangement of the wax platelets is thought to be the controlling factor in non-stomatal water movement through the peel, and therefore affects the water loss from fresh grape berries and drying rates of grapes. During drying, moisture in the grape berry moves in the liquid phase through the cells to the cuticle. It must then pass as vapor through the wax platelets and evaporate from the outside surface. Water movement within the grape berry is speedy in comparison to the slow transfer of water through the waxy cuticle. Therefore, it is essential to alter the structure of waxy cuticle in order to increase the grape drying rate. Various treatments have been identified to impart permeability to the waxy cuticle of grape berry. These treatments are found efficient in increasing the drying rate.

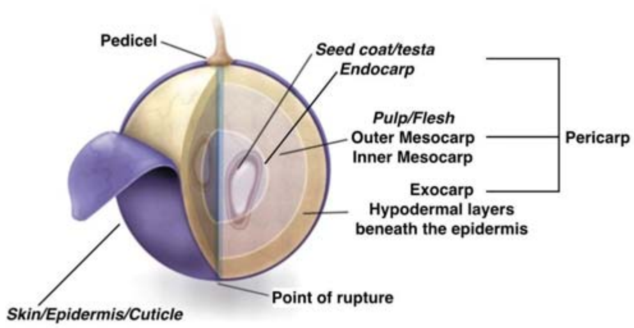

Fig. 4. Physical composition of grape berry showing outer waxy cuticle

Problems associated with raisin production method

Retention of green color of the grape berries should be the aim of the drying process. However, green color of the grapes is lost during drying. There are two major factors that affect the drying rate, drying duration and final quality (especially color) of the raisins.

1) Waxy grape cuticle

It reduces drying rate. Prolonged drying duration causes browning of the raisins.

2) Degradation of chlorophyll pigments

During drying at high temperature, chlorophyll pigments get degraded. Pigment degradation causes darkening/ browning of the grapes.

Production of Green Raisins

Two approaches:

1. Chemical approach
2. Non-chemical approach

Chemical approach

Increasing the permeability of grape skin

Grapes are complex system with an outer waxy cuticle and pulpous material inside. During drying, waxy cuticle reduces the permeability of water through it. Hence, chemical pretreatment is applied to the grapes to decrease the skin resistance for improving moisture diffusion through waxy cuticle. Dipping in hot water or the use of chemicals such as sulphur, caustic and ethyl or methyl oleate emulsions are some of pretreatments widely used for grape drying (Fig.5). Ethyl oleate acts on grape skin by dissolving the waxy components, which offer a high resistance to moisture transfer. But higher alkali concentrations and longer dipping times can cause adverse changes in the quality of dried grapes.

Fig. 5. Dipping grapes in ethyl oleate prior to drying

Formation of mettalo-complexes

During thermal processing (drying), chlorophyll pigments are degraded and grape color turns in to olive-brown or golden brown. Loss of green color in thermally processed products results from formation of pheophytin and pyropheophytin. Commercial heat sterilization can reduce chlorophyll content by as much as 80–100%. Chlorophyll derivatives formed during thermal processing are classified into two groups based on the presence or absence of the magnesium atom in the tetrapyrrole center. Mg-containing derivatives are green in color, while Mg-free derivatives are brown in color. When sufficient zinc or copper ions are available, Mg-free derivatives forms green zinc or copper complexes. Such zinc or copper complexes are called as metallo-complexes. Grape de-greening during their drying can be prevented by treating the grapes with zinc, magnesium or copper solutions. The two hydrogen atoms within the tetrapyrrole nucleus of the magnesium-free chlorophyll derivative are displaced by zinc or copper ions to form green metallo-complexes. The Zn and Cu complexes are more stable in acid solutions than in alkaline. Also, Zn and Cu complexes are more stable at high temperature as compared to Mg complex.

Hence, efforts should be made to preserve green color in raisin by retaining chlorophyll, forming or retaining green derivatives of chlorophyll, that is, chlorophyllides, or creating a more acceptable green color through the formation of metallo-complexes. The Food and Agriculture Organization (FAO) of the United Nations has certified the use of metallo-complexes as safe in foods. The copper complexes have greater stability than comparable Mg complexes; for example, after 25 h at 25°C, 97% of the chlorophyll degrades while only 44% of the copper chlorophyll degrades.

Re-greening

The process involves treating grapes in water containing sufficient amounts of Zn2+ or Cu2+ salts to raise the tissue concentration of the metal ions to between 100 and 200 ppm. The direct addition of zinc chloride has no significant effect on the color. Chlorophyll-A decreases to trace levels after only 20 min of heating. Accompanying this rapid decrease in chlorophyll is the formation of zinc complexes of pheophytin and pyropheophytin. Further heating increases the zinc pyropheophytin concentration at the expense of a decrease in zinc pheophytin. In addition, zinc pyropheophytin may form through decarboxymethylation of zinc pheophytin or by reaction of pyropheophytin with Zn2+. These results suggest that the green color in grapes processed in the presence of zinc is largely due to the presence of zinc pyropheophytin.

Ascorbic acid spray

Ascorbic acid is an anti-browning agent. Hence, its spray on the grapes during drying may be practiced (Sharma et al., 2016). Reports indicate that ascorbic acid spray (200-300 ppm) at the interval of 2-3 days prevents browning and produces green colored raisins.

Non-chemical approach

Non-chemical approach involves freeze drying, shed drying and forced ventilated drying under shed in dark.

Freeze drying

Freeze drying is the removal of ice or other frozen solvents from a material through the process of sublimation and the removal of bound water molecules through the process of desorption. Lyophilization and freeze-drying are terms that are used interchangeably depending on the industry and location where the drying is taking place. Controlled freeze-drying keeps the grape temperature low enough during the process to avoid changes in the dried product color and characteristics. Freezing - The product is completely frozen, usually in a vial, flask or tray. Use of vacuum - The product is then placed under a deep vacuum, well below the triple point of water. Drying – Heat energy is then added to the product causing the ice to sublime.

Low temperature drying

Traditionally, green raisins are produced by keeping the grapes on the vines itself and letting the cool dry air temperature (<35°C) to dry it and convert it to green raisin. So with that concept, different drying methods were tested for production of green raisins. Care was taken that temperature was not allowed to rise above 35°C in any of the drying method.

Shade drying

Drying in shade is slower than drying in the sun but produces raisins with a better color. Both drying by direct exposure to the sun and drying in shade are natural drying methods, as no mechanical means are used to start or accelerate the process. Shade drying is carried out for products which can lose their colour and/or turn brown if put in direct sunlight. The principles for the shade drying are the same as for sun drying. The material to be dried requires full air circulation. Shade drying of grapes takes little more time than is normally required for drying in full sunlight.

Force ventilated shade drying in dark

It is reported that fruits dried in the dark remain more green and lighter in color than shade-dried fruit. *Green naturals* produced in Afghanistan and China retain much of their original green-golden color due to the tradition of drying in dark, vented drying houses. Hence, a study was conducted at ICAR-CIPHET Abohar to produce the green raisins using forced ventilated shade drying in dark. In this method a close chamber (dark chamber) was used with an artificial arrangement of exhaust fan. The grape bunches hanged to bars were dried under force ventilation.

Grapes were also dried under the sun, polyhouse and shed. Results indicated that the shade drying under force ventilation (in dark) took 3-4 days for drying and green raisins were obtained (Fig.6). These raisins had good color appearance.

Polyhouse dried sample Sun dried sample Shade dried sample Force ventilated shade dried sample

Fig. 6. Effect of drying method on color of raisins

Conclusions

In India, the raisin industry has tremendous prospects of increasing the national wealth and hereby achieving social and economic benefits. An improvement in the technology of raisin production may improve the acceptance of our raisins at international market. Presently the quality of India raisins is not up to the mark as far color of the raisins is concerned. Indian raisins are mainly golden-brown to dark-brown in color. However, price of the green raisins is 2-3 times more than that of the brown raisins. There are two approaches of producing the green raisins. First one is chemical approach which is easy to adopt and involves low cost. However, it may harm the consumer. Another approach would be the non-chemical approach. It involves modification in the drying structure and drying conditions that enhance the drying rate and retains the green color. Establishing the industries for production of quality green raisins with international standards can derive the potential benefits of grapes cultivation. Production of green raisins alone has ability to improve the profitability and sustainability of grape industry.

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Advances in Fish Processing and Transportation Techniques

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Fish processing includes fish handling, transportation, preservation, product development and value addition to it. The objective of handling, processing and preservation is to control or reduce the spoilage process so that the final product is wholesome and safe for the consumer. Value addition is one of the possible approaches to raise profitability of industries. A large number of value added and diversified marine products both for export and internal market based on shrimp, lobster, squid, cuttlefish, bivalves, certain species of fish and minced meat. Similar as paddy and wheat, each and every part of fish can be profitably utilized for product or by-product development. Approximately half of all the species caught in the world today go into the production of fish meal and oil which are generally considered to be the major-by-products. Development of procedures that will make these resources directly available for human food would greatly improve their efficiency of use. Advances in our knowledge of the chemistry and biochemistry of the unstable components and improvement in processing procedures will be necessary to adapt these species for human food. Waste in the food industry is characterized by a high ratio of product specific waste which consists primarily of the organic residue of processed raw materials, can scarcely be altered if the quality of the finished product is to remain consistent. The generation of this waste is unavoidable and the amount and kind of waste product are also almost fixed. The utilization and disposal of product specific waste is difficult, due to its inadequate biological stability, potentially pathogenic nature, high water content, potential for rapid auto oxidation and high level of enzymic activity. We must face and accept this challenge. Rather we can explore this situation in an advantageous way by extracting high valued by-products. The modern research is in the track and by-products may fetch higher value than that of base product with which the by-product may be associated.

Introduction

India has vast fisheries resources with 8118 km coastline, 2.02 million sq. km EEZ, 0.53 million sq. km continental shelf area; 7.31 million ha total inland water area. Contrastingly the area of the country is 3.29 million sq. km with agriculture land area of 1.98 million sq. km (60.3% of 3.29 million sq. km, according to FAO). Fish production was a total of 9.58 million tonnes with Marine: 3.44 million tonnes and Inland: 6.14 million tonnes during 2013-14. The country earned a whopping **30213.26 Crore** by exporting 983.76 thousand tonnes of seafood during 2013-14. Recent fish production data has been shown as 10.790 million tonnes (3.58 million tonnes for marine and 7.21 million tonnes for inland fisheries) in 2015-16 (Source: Dept of Animal Husbandry, Dairying & Fisheries, 2016-17, GOI). However, about 25% of the fish production in India is lost due to poor infrastructure facility and inappropriate handling, packaging and transportation practices.

Fish Handling

The intrinsic and extrinsic qualities of fish vary considerably depending upon the location of the fishing ground, species, water quality and harvesting techniques. The primary objective of any handling method is to preserve the quality of the fish by bringing down the temperature near to 0^{o}C as quickly as possible. The effect of temperature reduction on the rate of spoilage and shelf life of fish is given in Table 1. The factors such as delay in handling and chilling the catch, poor temperature control in the fish hold, damage from rough handling, poor standards of gutting,

Table 1. Effect of temperature reduction on fish spoilage

Reduction in temperature (^{o}C)	Rate of spoilage	Extension of shelf life
0	100	-
5	50	x2
10	25	x4
15	12.5	x8
20	6.25	x16

bleeding and washing the fish and mechanical damage due to the ‘overfilling of the containers have a deleterious effect on the quality of fish and result in reduction of shelf life and loss of weight. Handling practices vary with location and harvesting techniques, availability of infrastructural facilities and technical know-how.

Handling during pre-processing and processing

The type of handling the fish receive on land during preprocessing and processing will determine the quality of the final product. Every stage from capture, handling and processing, and eventually to sale, to the consumer, involves some loss of quality. Different raw material specifications are used for each product. For example, chilled fish for immediate sale on the local market may not be perfectly fresh. but may still be acceptable to the consumer. But in the case of a product such as frozen fillets, fresh raw material will be required as it will have to withstand the rigors of the freezing process and extended cold storage before it reaches the consumer. Hence during pre processing stage raw material is graded according to the suitability for various processing methods. Handling the fish (raw material) during processing varies with type of the fish, the processing methods and the intended final product. However, there are some important good practices to be followed, which are described below:

- As far as possible, every precaution should be taken to avoid the warming of fish, as this will favour the action of enzymes and bacteria.
- Avoid mishandling of the fish. This will damage the skin and flesh and accelerate the process of bacterial contamination and enzymatic action.
- Cool the fish as quickly as possible by any convenient method. Whatever be the method, it is important to cool the entire fish.
- The fish, which are caught at different times, have to be kept apart since they will be at different stages of spoilage.
- Small fishes have to be kept separately from large fishes, as they tend to spoil more rapidly than the latter.
- Soft -bellied fishes are to be kept separately and if the guts are being removed or the belly has burst, the body cavity has to be washed to remove any traces of the gut.
- The containers used for the transportation of fish should be cleaned after every use. Chlorinated water should be used, whenever possible for every fish washing operation.
- Do not put fish on the ground; it can be kept on simple concrete / wooden platforms, which, if frequently cleaned, will reduce contamination.
- Fish handlers at every pre processing and processing stage should learn about and adopt good hygienic practices.

Chilled storage of fish

Chilling is an effective way of reducing spoilage in fish if it is done quickly and if the fish are kept chilled and handled carefully and hygienically. The objective of chilling is to cool the fish as quickly as possible to as Iowa temperature as possible without freezing. Chilling cannot prevent the spoilage together but in general, the colder the fish, the greater the reduction in bacterial and enzyme activity.

Transportation of fish

The mode of transportation of fish on land depends upon the distance to be covered, quantity, facilities available for the quick and safe despatch and the expenses involved. Conventional containers for transportation include bamboo baskets, wooden boxes or second-hand plywood tea chests. Aluminum and galvanized iron boxes are also used. Recently plastic containers have become common for fish transport since they are non- corrosive, re-usable, non-conducting, lightweight and are available in the required sizes. Open or closed, un-insulated, insulated or refrigerated vehicles are in use for the transportation. Un- insulated trucks will use about twice as much as ice as insulated trucks for transportation of iced fish. Insulated trucks with refrigeration facilities are employed for the transportation of frozen fish.

Handling live fish

Many fish harvested from the aquaculture systems are maintained in the live condition for periods varying from a few hours to many months depending on the end use. In the case of crab and lobster fisheries, it is preferred to keep the animals live during the harvest and marketing to ensure good returns. There are three general systems in vogue for keeping the aquatic animals alive during harvest and transport.

Waterless system

Many aquatic animals can be kept alive outside of water provided they are kept moist and cool. Waterless handling is used widely for molluscs and crustaceans with only limited application to finfish. Cooling reduces the metabolic rate and oxygen consumption of molluscs and crustaceans and hence this is widely used for the shipment of these animals in live condition.

Tank system

This involves the transport of fish in tanks of water, which can be as simple as a hand carried jar or as complicated as a heavily loaded tank truck with forced aeration. The following factors play an important role in deciding the survival of the animals in this system:

Oxygen

Catching the animals can cause stress resulting in an “oxygen deficit” Even after the animal calm it will take 24 hours to reduce the oxygen deficit to zero. While packing the fish in containers or tanks for live transport, fish size as well as the weight of fish per unit volume of water is important because small fish use more oxygen per unit weight than large fish.

Carbon dioxide

Increasing the free carbon dioxide concentration decrease the oxygen uptake ability of the fish. Hard water has greater capacity to buffer the free carbon dioxide produced by the animals. Carbon dioxide concentrations above 20 to 30 ppm in air supplied transport tanks can cause severe oxygen stress to the fish which to a certain extent can be tolerated by higher oxygen concentrations.

Ammonia

In transport tanks ammonia is excreted by the fish and also by bacterial breakdown of organic compounds. Un-ionized ammonia is generally considered as toxic to fish with varying tolerance limits among the species. Higher pH values favour toxic NH3 form. Hence pH control, change of water and starving the fish prior to transport are employed to control ammonia during transport.

Temperature

Temperature increase in the transport system cause increased metabolic activity, which increase oxygen demand and ammonia production. Warmer water will hold less oxygen than cold water. The affinity of blood for oxygen decreases with increased temperature while carbon dioxide and ammonia are more damaging at elevated temperatures. Temperature changes can also cause shocks from the failure of the nervous system and also from the failure of physiological functions such as respiration. Tempering the water will reduce the shock effects.

Besides these, other factors like osmotic balance, overexertion and fatigue, parasites, bacterial population, species and life stage will also decide the efficiency of the tank system in the live transportation of the species.

Bag system

The bag handling system consists of placing the organism in plastic bags partially filled with water with the headspace of the bag filled with pure oxygen and sealed. The plastic bags are then placed in cardboard, thermocole boxes for mechanical protection and insulation. The factors affecting the survival of the animals are the same as in tank system. This system is mainly used for the transport of small fishes, bait fishes and fingerlings.

Post harvest handling on land

Post harvest handling of the fish on land involves transportation of the catch, preprocessing the raw material and processing it to the desired product. Handling the fish on land has the same hazards as onboard handling such as autolysis, microbial and chemical spoilage that will affect the quality of the final product. These quality hazards vary linearly with temperature, being twice as fast at 2.5ÚC, as at -1ÚC. At 10ÚC it is four times as at 0ÚC. Hence during handling the temperature of the fish should be kept as low as possible to maintain the quality.

ICAR-CIPHET Method of live fish transportation

A live fish carrier system was developed in ICAR-CIPHET, Ludhiana. Live fish carrier system has two major components Self-Aerating Containers (SAC) and Battery Operated Self-Contained Aerating Vehicle (BOSCAV). Self-Aerating Containers (SAC) are stackable, easy unloading and aerating containers with approximate capacity of 10-20 kg fish/ container. SAC is equipped with aerators, filters and metabolite absorbent to maintain ideal water quality for fish during transportation. SAC facilitates easy loading and unloading of fish, transportation of individual fish species with specific size separately in the same vehicle and also minimizes accident proneness. Battery Operated Self-Contained Aerating Vehicle (BOSCAV) is a carrier developed for short distance transportation of live fish for fish farmers and small vendors and retailers. BOSCAV is operated by rechargeable 4 Lead Acid batteries of 12 Volt 100 A each, equipped with self aerating system with a total carrying capacity of 500 kg. It can run about 60-80 km from a single charge. Driver’s shed and control panel near driver seat provides single man handling facility. Proper braking system for both front and rear wheels provides good stability to the vehicle. It is useful for carrying live fish from farmers’ pond to the auction centers or from auction centers to the retail market with least mortality. Approximate cost of Live Fish Carrier System is Rs.1.75 lakh.

Product Development

There is great demand for seafood/ seafood-based products in ready to eat “convenience” form. A number of such diverse products have already number of such diverse products have already invaded the western markets. One factor responsible for such a situation is more and more women getting educated and taking up employment. Reasonably good expendable income, education, awareness and consciousness towards hygiene and health, increased emphasis on leisure pursuits etc. are some of the other reasons.

A large number of value added and diversified marine products both for export and internal market based on shrimp, lobster, squid, cuttlefish, bivalves, certain species of fish and minced meat from low priced fish have been identified. The technology for their production is readily available. A brief description of such products is given below.

Battered and breaded products

The most prominent among the group of value added products is the battered and breaded products processed out of a variety of fish and shell fish. Battered and breaded seafood offers a convenience food valued widely by the consumer. Battered and breaded items are included in the value added products because the process of coating with batter and breadcrumbs increases the bulk of the product thereby reducing the cost element. The pickup of coating on any product can be increased either by adjusting the viscosity of batter or by repeating the process of battering and breading. As a convention 50% fish portion is expected in any coated product. Fish fingers, fish portions, fish cakes etc. are the staple breaded seafood lines, while breaded shrimp, lobster, oyster, scallops etc. cater to a luxury market and are widely used in restaurant trade.

The production of battered and breaded fish products involves several stages. The method varies with the type of products and pickup desired. In most cases it involves seven steps. They are portioning/ forming, pre-dusting, battering, breading, pre-frying, freezing and, packaging and cold storage.

Portioning/ forming

Portioning is an important stage in the production of coated fishery products. Cutting loss and surface area of the portions are the two important points, which determine the economics of coated products. Cutting loss is negligible when manually done with a band saw, whereas with automatic block cutting machines it is in the range of 5-10 %. Key factors in the production of fish portions are the speed and accuracy with which the frozen fish blocks can be processed at minimum cost.

A recent innovation for the catering sector is forming of skinless and boneless fish fillets into a predetermined shape and size using specially designed forming machines. The shapes vary from conventional fillet shapes to several other imaginative ones.

Pre-dusting

Before a fish portion is battered it usually undergoes a pre-dusting step. The purpose of pre-dusting is to prepare the surface of the portion so that batter can adhere uniformly. Pre-dusting also improves the adhesion of batters to frozen or greasy food surfaces. Pre-dust normally consists of a very fine raw flour type material. A more sophisticated and expensive pre-dust may contain spices and seasonings for both functional and flavouring purposes.

Application of batter

Conventional batters are of low to medium viscosity and hence can be applied with total submersion or overflow batter applicators. Low viscosity batters are normally applied in an overflow configuration. Medium viscosity batters may require a total submersion system depending on the product requirements.

The pre-dusted product is conveyed to the batter applicator and transferred to the next conveyor, which will draw it through the batter. The fish portion is totally submerged in the batter as it is drawn through it. Other applicators may use a pour-on application in addition to the submersion method. Irregular shaped products should be placed on the line with any concave surface upward to prevent air pockets from inhibiting batter pickup.

Line speed is a very critical factor affecting batter pickup. An excessively fast line speed will reduce the batter pickup. Too Iowa line speed also can result in excessive batter adherence. Excess batter, if carried over to the breading section, will cause formation of lumps and this can cause blockages in the breading machine. This will also cause formation of shoulders and tails on the edges of the product and contaminate subsequent breading application. Therefore, to overcome the problems the excess batter is removed by blowing air over the product. The position of the air blower should be as close to the product as possible to control the airflow across the product. Carry over from the pre-dusting operation also is critical. Where pre-dust is carried over, the viscosity of subsequent batter will increase leading to an increase in pickup.

Application of breading

There are many types of breading applicators available and the appropriate machine depends on the ingredients used. The speed of the breading machine is so adjusted to closely match the belt speed of the batter applicator. For soft products the crumb depth should be maintained as thin as possible to avoid product damage when leaving the breading machine; however, frozen or hard products should have a deep bed of crumbs. Pressure rollers are used to apply sufficient force to press crumbs onto the battered product.

Japanese style crumbs with their low bulk density and larger granule sizes make the crumb pickup difficult by the normal batter systems. Special batter formulations, sometimes containing raising agents, may have to be used at medium viscosity for a desired level of pickup of crumbs. Specially designed breading machines are used to apply uniform particle size distribution or granulation to both top and bottom of the product with minimum crumb breakdown. Air blowers are used to remove excess crumb from the product after breading. Excess crumb carried into the fryer can cause unsightly black specks on the product. Filters are used to remove small particles from the oil to prevent this phenomenon.

Pre-frying or flash frying

After coating with batter/bread crumbs many After coating with batter/bread crumbs many products are often flash fried prior to freezing. The purpose of pre-frying is primarily to set the batter/bread coating on the fish portion. Flash frying develops a characteristic crust and gives the product a characteristic fried (oily) appearance and taste.

Therefore the temperature of frying oil and the time of frying are critical. The normal frying temperature is between 180—200°C and the frying time 20-30 seconds. The term pre-frying is used because the final product frying is completed by the consumer for duration of 4-6 minutes depending on the portion size and thickness. The battered/ breaded fish portions enter the frying medium through a conveyor system, the speed of which is adjusted so as to keep the fish portion in the hot vegetable oil for the required time.

Freezing

The fish portion leaves the frying oil with a coating temperature equivalent to that of the oil but still frozen in its center. Although the fish flesh center is frozen the surface flesh may be partially thawed. Therefore a quick and efficient freezing method is very essential to keep the quality of the coated product.

The first step in preparing the fried fish portion for freezing is air-cooling. This is usually accomplished with the use of a fan or a series of fans. This allows the coating temperature to drop, while at the same time allowing the batter coating to recover from the frying shock and also to stabilize itself. The coated fish portions are then fed to the freezer through conveyor belts. Freezing is usually carried out in spiral freezers. Freezing is completed when the internal and external temperature of the fish portion drop to about -10^{o} C

Packing and storage

The coated product may undergo desiccation, discolouration and become rancid during storage. U se of proper packaging can prevent/retard these changes and enhance shelf life. Thermoformed containers are most commonly used for packing coated products. The packaged products are usually stored at -20°C.

Shrimp Products

Breaded shrimp can be prepared both from wild as well as from cultured shrimp in different styles. Shrimp in different forms such as peeled and deveined, butterfly, round tail-on and cooked and peeled are coated with batter and bread crumbs and flash fried for 20 seconds at 180°C in refined vegetable oil. They are then packed in IQF form preferably in thermoformed containers.

Squid products

Squid rings

Cleaned squid tubes are cut in the form of rings followed by cooking in boiling brine (3%) for 1-2 minutes and then cooled, breaded and battered. The battered rings are flash fried at 17 5-180°C for 20 seconds, cooled, packed and frozen.

Stuffed squids

Stuffed squid is prepared from small squid, which are not generally processed for export. The cleaned tubes from such squids are filled with a stuffmg mixture prepared using cooked squid tentacles, potato, fried onion, spices etc. The stuffed squid is then battered, breaded and flash fried.

Clam and Other Related Products

Live clams are depurated and the meat is shucked out after boiling. The meat is blanched in boiling brine, cooled and battered, breaded, flash fried and packed. Other bivalves such as oyster, mussels etc. can also be converted into coated products by the same method.

Fish fillets

Skinless and boneless fillets of fish are brined in dilute brine to improve the colour and taste. The brined and drained fillets are battered and breaded, and flash fried for 30 seconds.

Fish finger or fish portion

Fish fingers, or portions or sticks are regular sized portions cut from rectangular frozen blocks of fish flesh. They are normally coated with batter, and then crumbed before being flash fried and frozen. They may be packed in retail or catering- size packs. The typical British fish finger normally weighs about 1 oz (28 g) of which up to about 50% of the total weight may be batter and crumbs. Food Advisory Committee of the UK government has recommended a minimum fish content of 55% for battered and 60% for the fingers coated with breadcrumbs.

Fish blocks are the most common starting material for battered or breaded fish portions and sticks. Fish blocks are boneless fillets placed together into a frame, compressed slightly and frozen to form a solid block of fixed dimensions. The blocks are convenient to store, ship and handle. A very common 16 $^1/_2$ lbs fish block is 18 $^7/_8$ inches long, 10 inches wide and 2 $^3/_8$ inches thick.

Fish mince and mince-based products

Fish mince is the meat separated from fish in comminuted form free of bones, skin etc. In principle, meat separation process can be applied to any species of fish, but when it is applied to low cost fishes significant value addition will accrue. Fish mince can be used for processing a variety of value added products.

Fish fingers

Fish finger can also be prepared from the skinless and boneless fish mince. The mince is frozen in the form of rectangular slabs. The slabs are sawn into thin fingers and battered and breaded. They are then flash fried for 20 seconds. Alternately, fish fingers are made out of frozen compact slabs of fingers are made out of frozen compact slabs of fish fillets also.

Fish cutlets

Fish cutlets are prepared using cooked fish mince, which is mixed with cooked potato, fried onion and species etc. It is then formed into the desired shape, each weighing approx. 40 g. The formed cutlets are battered, breaded and flash fried for 20 seconds

Fish burgers

More or less similar to fish cutlets, burgers are made out of mince oflean white fish. Cooked mince is mixed with cooked potato and mild spices and formed into round shapes. Burgers are battered, breaded and flash fried for 20 seconds.

Fish sausage

Fish sausage is an analogue of sausage made from pork. The main ingredient is surimi or ground fish meat. Surimi is mixed with salt (3-4%), sugar (2-3%), sodium glutamate (0.3%) starch, and soy protein in a silent cutter. At the end of mixing, lard or shortening (5-10%), polyphosphate (0.2-0.3%) and flavourings are added and the minced meat is placed in a casing tube made from vinylidine chloride. Stuffing is done by an automatic screw stuffer. The casing tube is dosed by metal rings. The tube is heated in hot water at 85-90°C for 40-60 min. After heating, it is cooled down slowly to avoid shrinking of the tube and then stored at refrigerated temperature.

Individually quick frozen products

IQF products fetch better price than conventional block frozen products. However, for the production of IQF products raw-materials of very high quality need to be used, as also the processing has to be carried out under strict hygienic conditions. The products have to be packed in attractive moisture-proof containers and stored at -30°C or below without fluctuation in storage temperature. Thermoform moulded trays have temperature. Thermoform moulded trays have become accepted containers for IQF products in western countries. Utmost care is needed during the transportation of IQF products, as rise in temperature may cause surface melting of the individual pieces causing them to stick together forming lumps. Desiccation leading to weight loss forming lumps. Desiccation leading to weight loss and surface dehydration are other serious problems met with during storage of IQF products.

Some of the IQF products in demand are the following:

Prawn	- whole
	- peeled and deveined
	- cooked
	- headless shell-on
	- butter fly fan tail
Lobster	- cooked whole
	- lobster tails
	- lobster meat
Cuttlefish	- fillets
Clam	- boiled meat
Fish fillets	- skinless boneless fillets of white lean fish

Fish in sauce and fish salads

These are two important groups of ready-to-serve value added products. Fish fillets, tuna steaks, cuttlefish cubes, squid rings, cooked shrimp and boiled clams are suitable for the preparation of such products and sauces used include lemon butter sauce and Spanish tomato sauce. The main ingredients in fish salad are cooked fish (35-40%), salad dressing (25-30%), cooked macaroni (15-200/0) and small quantities of onion, celery, capsicum, pepper and limejuice. These products are preserved by freezing.

Fried fish fillets

Fish fillets of about 1-2 cm thickness are fried in vegetable oil and mixed with fried spices mixture comprised of chilly powder, turmeric powder, ascorbic acid and salt. Fried fillets are then packed in pouches under vacuum. The product has a shelf life of about 16 days at ambient temperature.

Fried thelly prawns

Thelly prawns are dried in sun after treatment with sodium chloride and citric acid. Dried prawns are then fried in refined vegetable oil after removing head and tail and mixed with fried spices and packed in pouches. The product has a shelf life of about 50 days at ambient temperature.

Fried mussel meat

Live mussels are depurated and the meat is shucked after steam cooking. The meat is then fried in vegetable oil to hard texture, mixed with fried spices and packed in pouches. The product has a shelf life of about three months at ambient temperature.

Fish Byproducts

Fish Processing products and by-products

An outline of normal fish processing is given in Figure 1. This flow chart clearly underlines the wastes generated during normal processing. The wastes or the raw-material coming out in different steps of fish processing are

1. By-catch, off-specification product, rubbish etc. after 2nd step.
2. Cuttings, skins, bones, bold, oils, viscera, spoiled material etc. after 3rd step.
3. Off-specification products, spoiled material, trimmings etc. after 4th step.
4. Wastewater, brines, sauces, oils, spoiled material, damaged packaging from 5th and 6th steps.
5. Damaged out of date products, returned products, damaged packaging after final step packaging and despatch.

Therefore, rest raw materials are the by-products of the processing of main product and the by-products as a whole may include rest raw materials plus the fish which are unsuitable for human consumption after catch mostly the by-catch.

Fish processing inevitably results in the generation of by-products, which are the raw materials that are not used in production of the primary product (Figure 2, 3, 4).

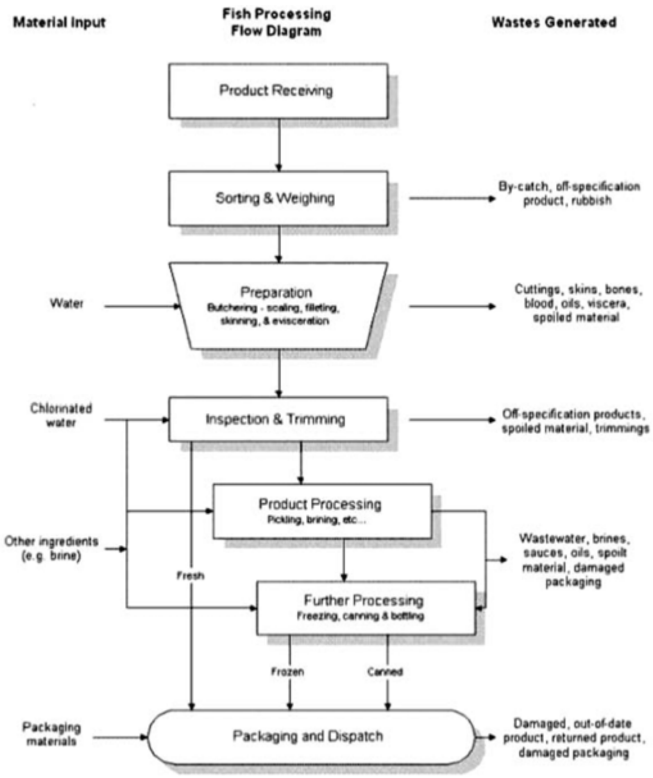

Fig. 1. Outline of basic fish processing line and the wastes of processing

During preservation and processing, some materials of fish and prawn are discarded as waste. Similarly some trash and distasteful fishes are unsuitable for human consumption. These waste material and above fishes become an important source to produce fish by-products, which in turn are used to produce different useful fish by-products. An example about milk fish products and waste is given in Figure 2. The modem trend is not so apparent in various other fish products and by-products.

Some by-products are discussed below

Fish protein *hydrolysates*

Protein hydrolysates have attained an important place in the realms of man’s protein fortified foods and beverages. This is mainly due to their high solubility and digestibility. The technology of production of protein hydrolysates has become cheap and all machineries are available commercially. A variety of methods of production technique are available. The most common among them are listed.

Acid hydrolysis

The whole fish is cleaned well to free of slime and adhering dirt. They are then comminuted and cooked well with 2 to 6 N acid and maintained at about 90 - 100°C for 12 - 24 minutes to get a completely soluble finished product. Disadvantage of this process is that the final finished product will be acidic and has to be neutralized by alkali to bring the pH to 7.

Enzyme hydrolysis

Number of enzymes are used in the industrial production of hydrolysates. The enzymatic production of protein hydrolysates is perhaps the most convenient and cheapest technique. The process is fast and gives hydrolysates without much loss of essential amino acids. However, a suitable enzyme has to be selected for this purpose. The choice of enzyme depends on factors like stability, specificity etc. The important commercially available enzymes are papain, pepsin, bromelain, ficiun and trypsin. Most protein hydrolysates are highly bitter in taste because it contains pepotones, peptides and free aminoacids. Hence,.flavouring agents like cocoa, and jagery are usually added during their fortification in food preparation to mask their bitter taste.

Among the important proteolytic enzymes listed above the widely used ones are bromelain and papain. The industrial methods of production of protein hydrolysates using bromein and papain are given below.

Commercially available enzyme is dissolved in citrate buffer of pH 6. It is centrifuged and the supernatant is taken. This is stable for 3 months.

Preparation of water fat emulsion

Ten parts of hydrogenised fat, antioxidant BHA or BHT(O.Ol %) and 0.15 part of sorbitan mono stearate (emulsifier) are mixed together and heated to *65°C* for about 10 to 15 min. To this, water containing 0.35 part sorbitan monstearate is added (90 parts) and the whole mixture is homogenized in warring blender and then kept overnight. Next day the soluble oil water emulsion is separated from the excess fat and taken separately.

Hydrolysis: Take 100 parts mixed fish meat, 20 parts water and 80 parts oil emulsion and homoginate in a blender for 5 min. To the resulting pasty mass the enzyme stock solution is added (six parts by weight) and the whole mass is transferred into a reaction vessel maintained at 57°C. Hydrolysis is allowed to continue for 15 minutes with continuous stirring. After the reaction is over the mixture is heated to 80°C for 12 min. to deactivate the enzyme. The whole mass is again homogenized in a blender and then rapidly cooled to 5°C. It is filtered and the ftltrate is dried in a spray drier.

Hydrolysis with papain

Enzyme stock solution. About 25g of the enzyme is taken in 100 ml distilled water and centrifuged. The clear ftltrate is taken.

Hydrolysis: Comminuted fish meat is cooked with water (1:1 W IV) for 15 minutes and this process results in sterilization of mixture also. The pH of the mixture is adjusted with acid to 6.5. The mixture is transferred to a reaction vessel maintained at *55°C* and the enzyme is added to this mixture (1 :30, enzyme nitrogen to protein nitrogen). The whole mixture is stirred vigorously and the hydrolysis is continued for half an hour until it is completed. The hydrolysates is filtered and centrifuged, and dried in vacuum to get a fine highly hygroscopic powder.

This can be incorporated in a variety of food preparation like soups, beverages etc as a protein suppliment and there by enhance nutritive value.

Protein hydrolysates incorporated beverages

Protein hydrolysates are bitter in taste and as such unpalatable. One of the best ways to make the hydrolysates tasty is to add malt, cocoa, sugar and fat to the hydrolysates and the fortified mass is spray dried to make it a fine powder which is highly hydroscopic and soluble in water. One such formula is given below:

Recipe

Composition by weight %

Fish protein hydrolysate	30
Malt	20
Sugar	20
Milk powder	10
Fat	10
Cocoa	10

This product is found highly acceptable to consumers and acceptability with respect to taste, flavour and odour is over 90%. The protein efficiency ratio of the product is 22 compared to casein (37) at 10% level of protein.

Ambergris

Ambergris is a compound obtained accidentally from the sea and is valued fabulously because of its use in perfumery. Its rarity, uniqueness in chemical composition and high commercial value attributed to some real and certain unimaginative properties, make it one of the most priceless gift of animal kingdom to man. It is often used in the East as an aphorodisiac although this particular property is not scientifically supported. It has a characteristic musk odour. It is used in blending of a large number of exotic perfumes. Ambergris is collected either from open sea or from seashores. It is often spotted in tropical and subtropical seashore of many countries like Australia, New Zealand, India and Bahamas. Eighty percent of ambergris is cholesterol. A fatty oil called ambergris , benzoic acid, some other steroids and hydrocarbons are also reported as its constitutes.

Ambergris is now considered as a morbid concretion from the intestinal tract of sperm whale *(Pyster catadon,* L *physteridae)* and probably only of male whale. It comes from the stomach of dead whale. This is based on the enormous size of ambergris cited in the past. A mass weighing 184 kg and 150 cm in girth and another weighing upto 418 kg were recorded in the past. This wouldhave come from very big animal like whale. When sperm whale feeds on cuttlefish due to some injury or un known reason the ambergris is formed in the insteines. This is based on the findings that small fragments of cuttlefish are seen in the ambergris when it is freshly collected.

Ambergris is normally jettisoned from the intestines when the whale dies. By constant exposure to sun and seawater ambergris hardens and develops a pleasant scent. A good quality ambergris soft, waxy and gray in color.

Black ambergris is of poorest quality. Although it is sticky it can be kneaded with the fingers. A good quality and aged ambergris is found to have a concentric layered structure resembling that of onions.

Properties: It is grey to black waxy mass with characteristic odour.

Density - 0.8 to 0.92, Melting point 60 to 65°C, Softening point 45 - 65°C

It is inflammable and almost volatile by heat. It is insoluble in water or alkali but soluble in hot alcohol, chloroform, ether, fats and volatile oils. It bums with a pale blue flame with characteristic musky odour (resembling the burning smell of rubber) without leaning scum or ash. It also floats on fresh and salt water.

Uses: it is widely used in perfumery on tincture and essence for fixing delicate odours. A good quality ambergris has commercial value ranging from $ 1000 to 2000 depending on its quality. Ambergris is usually found adulterated with whale fat.

Beche-de-mer

Holothurians or sea cucumbers belong to the class Holothuridae. They are entirely marine and distributed in all seas at all depths. They live in large numbers, coral reefs in seas around India, about 200 species of holothurians are known. In these about 13 species are of commercial importance. For processing into beche-de-mer holothurians which are large in size and having thicker body wall are used.

Some important commercially exploited species of holothurians available in Indian waters and are used for processing into Beche-de-mer are:

Scientific Name	Common Name
Holothuria Seabra	Sand fish
H.Spiqiifera/ H.Atra	Lolly fish
Bohadsehia marmerata	Chalky fish
B. argus	Leopard or Tiger fish
Actinopyga mavritana	Surfred fish.

In India the industry is mostly dependent on a single species *Holotburia scabra (sand fish)* at present. Considering the extensive exploitation and commercial importance it is worthwhile to note the characteristics of *Holothuria sea bra* which is at present almost exclusively used for processing.

Caviar

Salmon eggs are processed in to caviar (smaller eggs). Roe of sturgeon (black carviar) or other fish (eg bream, carp, catfish or paddle fish, coalfish, cod fish, haddock, hake, herring, lumpsucker, mullet, pike, salmon (red caviar), spoan bill, tuna or white fish) is prepared bya special process called maturation and salting (mild 3 to 4%,heavy 10%) and should be labeled by the type of fish. The salmon eggs are removed from the body cavity with viscera and separated from it by hand. The salmon eggs are subsequently preserved by freezing, salting or by a chemical treatment. In the salting process the eggs are washed in salt water and placed in saturated salt brine containing added colour for 20 min. The caviar is then placed in boxes with salt added between the layers and allowed to cure for 1 week and subsequently stored at 5°C. Milt is separated from the viscera and each gallous is treated with 0.13 gallon of caustic soda solution 600g/1 which is a preservative and is the first step in processing.

In addition to salting, salted dried roe can be produced by salting for 20 h., washing, draining and pressing and air drying for 20 days, during which the oil is spread on the surface. The roe is blanched by dipping for 3 minutes at 80°C water and packed for storage for upto 9 week. Dried roe has a composition of 16% moisture, 43% protein, 40% fat and 1 % ash.The composition of salmon eggs is 13% fat, 6.2% phospholipids and 0.4 cholesterol. The fat has 3% cholesterol, iodine number of 200 and 6% unsaponfiable. 53% of the unsaponifiable are cholesterol.

The protein of salmon eggs is high in lysine, methionine and isoleucine.

Seaweeds and products

From time immemorial man has utilizing seaweeds as food. Agar, alginic acid and carrageenan are the most important phycocolliod prepared from seaweeds.

Agar is prepared from the *agarophytes Gelidiella acerosa, Gelidiella indica, Gelidicus PI/silllm, Gracialaria edulis, Gracialaria uemcosa, Gracilaria corticata* and *Gracitaria crassa.*

The harvested or collected seaweeds should be thoroughly washed in seawater to remove the sand and other foreign materials. For keeping it for long period, seaweeds are to be dipped in 2% formalin. A cottage industrial method for the extraction of agar is' as follows:

Sun bleached sea weeds are washed in fresh water and wet grinded in a stone mortar to remove impurities and other foreign materials. Sea weeds are boiled with dilute mineral acids for few minutes. Agar gel obtained is filtered using a cloth filter; Gel is allowed to cool at temperature 0ÚC to 5ÚC. When it is thawed at room temperature water is removed. Freezing and thawing are repeated several times. By this method impurities and water are separated. The gel obtained is bleached and dried. After drying it is powdered and packed. The quality of the agar obtained is not very high in this method. By adopting alkali treatment method (treating seaweeds with O.5N sodium carbonate or sodium hydroxide, prior to extraction very good quality agar can be prepared.

Uses of agar

Agar was the first phycocolloid used in food industry. In human food industry, agar is used mainly as a gelling agent and in a secondary way as a stabilizing agent for controlling viscosity. It is also used as an additive. Usually 1 to 1.5 % solution is used for all purposes.

In confectionary to prepare jellies, marmalades, marshmall and fillers and candies or candy fillers. In marmalade production, agar is used as a thickening and gelling agent. In bakery it is used to cover cakes and icing. It is also used for dehydraction of the confectionary. It is also used in gelly preparation and yogurt. Meat industry it is useful for sausage preparation. It is prepared for tissue culturing of plants, and as a bacterial medium and is also used for pharmaceutical purpose as a thickening agent.

Alginates

Most of the brown seaweeds are potential sources of alginates. The properties of alginates vary from one species to another. The main commercial sources are Ascophyllum, Drvillaea, Eckmer, Laminaria, Lessonia, Marcrocystis, Sargassm and Turbinaria, Of these the most important are Laminaria macrocystes and Ascophythus. In India, sargassm and turbinaria are the two species of seaweed used for the production of alginic acid.

Indian alginate industry depends on the sargassum grown in Tarnil Nadu coast, Kerala and Gujarat Coast. The species growing in Gujarat coast gives low viscosity alginates which are unsuitable for the main Indian market of textile printing. Sargassum found in Philippines is exported to Japan for use in animal feeds and fertilizers.

Extraction of alginic acid

The processes used to make sodium alginate from brown seeds are relatively simple. The difficulties of the process arise from the physical separation of residue, from viscous solutions to separate gelatinous precipitate which hold large amount of liquid. The method of preparation of alginic acid and alginates are given in the flow diargram (Fig. 3).

Uses of alginates

It is used for film formation, filament formation, food additive, some salts, alginic acid are considered as safe

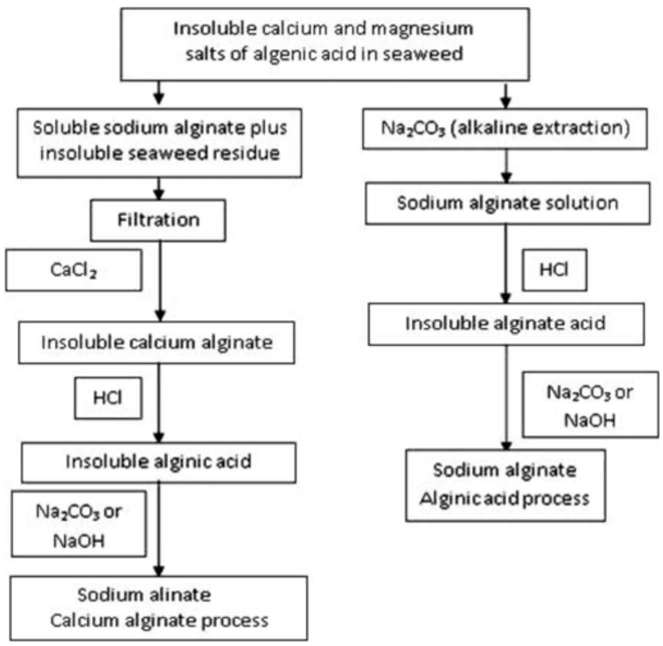

Fig. 3. Preparation of alginic acid/ sodium alginate from seaweed

as food. It is used as a thickening gelling and general colloidal properties. It is used as a immobilized bio-catalyst.

Surface sizing of the paper is the main use of alginates in paper industry. It is also used in welding industry to coat welding rods.

It is also used in pharmaceutical industry. It is added to increase the viscosity of the medicine, other uses are in medical dressing. It can be used in fish feed as a binder. Alginate gel finds small use in confectionary

Carrageenans

Carrageenans contribute the third most important hydrocolloid after starch and gelatin. They are extracted from the main plants, carrageenophytes. They serve a structure of function analogue to that of cellulose in land plants.

Philippines is the world's largest producer of carrageen. Irishmoss is also known as carrageenan. Important species of seaweeds used for the production of carrageenan are *Chondrus crispis*, and other chondrus species *Euehema eottoni, Fureel/aria farliligita* and Hypnea species of all these species only few species are commercially exploited and used for the manufacture of carrageenans.

When carrageenans are fractionated with potassium chloride two fractions, kappa and lamda carrageenans are obtained. Kappa was the fraction which was precipitated by potassium chloride and lamda was the fraction which remained in the solution. It was also reported that small quantities of iota and theta and Xi carrageenan are obtained from some species of carrageenophytes.

Extraction of carrageenan

In the Philippines carrageenan is processed into three grades: 1. PNG 2. Semi refined carrageneen and 3. Refined carrageenan.

Process: The carrageenophytes are washed, cleaned and digested with 5 M KOH. The alkali is drained off and residue is washed free of alkali, dried, powdered and packed. The product is called semi-refined carrageenan. It is used directly as food additive. The flow diagram is given below

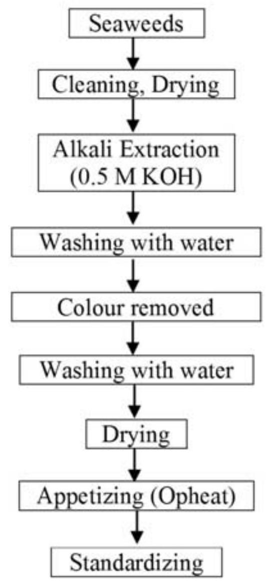

Fig. 4. Extraction of carrageenan

A pure carrageenan solution will not gel even if it is cooled to the freezing point. Since agar and carrageenan do not have the same properties, they have different uses. Carrageenans usually used for water thickening application are difficult types or the sodium salt of mixed lamda and kappa. They dissolve in either cold or hot water to form viscous solution.

Uses of carrageenans

Food - clarification of liquors/beverages, chocolate/milk drinks or shakes, icecreams, desserts, and processed food.

Meat industry: Beef patty, poultry and ham, Non food- pet food, toothpaste and freshness materials.

Processing and Value Addition of Millets

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Millets, the small-seeded cereal crop of the Graminae family, are harvested for human food or animal feed. Millets include small seeded annual grasses, belonging to species under the five genera in the tribe *Paniceae*, namely *Panicum*, *Setaria*, *Echinochloa*, *Pennisetum* and *Paspalum*, and one genus, *Eleusine*, in the tribe *Chlorideae* (FAO, 1972). The most prominent and well known millets are the sorghum *(Sorghum vulgare)* and pearl millet (*Pennisetum glaucum*). These two taxa account for the majority of millet grain produced around the world. The rest of the millets, often referred to as the small or minor millets include finger millet (*Eleusine coracana)*, barnyard millet (*Echinochola colona*), foxtail (*Setaria italica*), proso (*Panicum miliaceum*), kodo or ditch millet (*Paspalum scrobiculatum*) and little millet (*Panicum sumatrense*). Among these, kodo, foxtail, proso (common millet), little and barnyard millets are the smallest one (Rao, 1989). Essential similarities of the members of this group of species are the resilience and ability to thrive in harsh environments, along with nutritious seed content. The percentage of millet used for domestic food consumption is rising steadily in Africa, but the vast and still expanding millet areas continue to produce low, but steady, yields with very few fertilizer inputs. In Asia, millet is restricted almost exclusively to two countries, India and China, although Myanmar, Nepal and Pakistan also produce small quantities. India is the largest producer of millets in the world with an annual production of 334500 tons (43.85%) (FAO 2012). In India, millet cultivation is the mainstay of rain-fed farming on which 60% of Indian farmers depend. At present millets are consumed conventionally as a major food component, in various traditional foods and beverages, such as bread (fermented or unfermented), porridges, and snack foods. Moreover, as an ingredient in multigrain and gluten-free cereal products their importance has been highlighted.

Nutritional significance

The nutritional composition of these minor millets is comparable to and even higher than the wheat and rice (Table 1) and hence these are rightly termed as ‘nutricereals’. Their high fibre content with its health benefit such as good bowel movement, and reduction in blood cholesterol and sugar has also contributed to their increasing demand. Besides fibre, millets are also rich in health-promoting phytochemicals like polyphenols, lignans, phytosterols, phyto-oestrogens, phytocyanins. These function as antioxidants, immune modulators, detoxifying agents etc. and hence protect against age-related degenerative diseases like cardiovascular diseases (CVD), diabetes, cancer etc. (Rao *et al*. 2011).

Table 1. Nutritional composition of millets (per 100 g edible portion; 12% moisture, on dry basis)

Millet	Protein* (g)	Fat (g)	Minerals (g)	Crude fibre (g)	Carbohydrates (g)	Energy (kcal)	Calcium (mg)	Iron (mg)
Finger millet	7.7	1.5	2.6	3.6	72.6	336	350	3.9
Common millet	12.5	3.5	3.1	5.2	63.8	364	8	2.9
Foxtail millet	11.2	4.0	3.3	6.7	63.2	351	31	2.8
Little millet	9.7	5.2	5.4	7.6	60.9	329	17	9.3
Kodo millet	9.8	3.6	3.3	5.2	66.6	353	35	1.7
Barnyard millet	11.0	3.9	4.5	13.6	55.0	300	22	18.6
Rice	7.9	2.7	1.3	1.0	76.0	362	33	1.8
Wheat	11.6	2.0	1.6	2.0	71.0	348	30	3.5

* Wet basis; Table adapted from-Saleh *et al* (2013)

The presence of all the required nutrients in the millets makes them suitable for large-scale utilization in the manufacture of various food products, e.g. bakery products, baby foods, snack foods, dietary foods, etc. in both grain and flour form. The millets lack gluten and hence can be utilized in health foods for celiac disease patients in form of gluten free products. Despite these attributes, millets are losing their pride of place in production and consumption in India. In recent years, there has been some effort towards reviving millets.

Primary processing

The primary processing of millets includes harvesting, threshing, winnowing followed by storage (Harvey and Fuller 2005; Seetharam *et al* 1989). The large millets are often cut at the top of the stalk while the smaller/ minor millets are cut at the base (Reddy 1997; Harvey and Fuller 2005). As a result, minor millets require more intensive labor for processing and more processing stages. The processing of these millets is also influenced by the utilization pattern of millets and these uses in turn are influences by cultural traditions of food consumption and taste. Milling is the primary processing of food grains. Milling to remove the outer bran (pericarp) of the grain is the most common way of processing of millets. A technique similar to those seen with rice, which serves to lighten the color and lead to faster cooking of softer products (Malleshi 1989). Co-milling of small millets with wheat and other cereals to produce composite flours has also been extensively studied.

Conventional millet products

Roti (unleavened pan cake), mudde (dumpling) and porridge are the main food products prepared from millets. For preparing roti, millet flour is mixed with hot water to partially gelatinize the starch. This imparts the necessary binding of particles and helps to roll the dough into thin sheets. The flattened dough is baked on a hot plate. Roti resembles wheat chapathi or maize tortilla. Mudde from millet flour is prepared by steaming the dough and making it into balls.

Non-conventional processing

The minor millets are also processed into different products by applying different processing techniques as follows:

1) ***Popping:*** Popping also called as puffing is a processing technique of cereals to prepare ready to eat products which are crunchy, porous and precooked. This technique improves the taste and flavor of the product. Popped grains can be consumed in many ways as snack.
2) ***Flaking:*** For making flaked products, the Pearled grains are soaked in water, steamed or cooked under pressure to effect complete gelatinisation of the starch, dried to about 18 per cent moisture and then pressed to requisite thickness between heavy duty rollers. These are then dried to prepare flakes. Flakes hydrate quickly when added to warm water or milk and are used to prepare sweet or savoury dishes.
3) ***Extrusion technique:*** Extrusion technique is used for making kurkure and noodle like products by hot extrusion and cold extrusion, respectively.
4) ***Parboiling:*** Millets can be parboiled such as finger millet that results into the hardening the endosperm, enables the production of grits, and reduces the sliminess of the kodo millet for improving the milling quality (Desikachar, 1976 and Shreshta, 1972).
5) ***Malting:*** Millets also find application in malted form in weaning foods and can rduce the dependency on barley malt.
6) ***Baking:*** Baking technique is currently being employed for making numerous millet based bakery products viz. bread, biscuits, cakes etc.

Baking Technique for value addition of Minor millets

Baking is the technique of prolonged cooking of food by dry heat acting by convection, and not by radiation, normally in an oven, but also in hot ashes, or on hot stones. The term ‘baking’ applies not only to the production of bread, but to all food products in which flour is the basic material and to which heat is applied directly by radiations from the walls and/or top and bottom of an oven or heating appliance. More particularly, it is primarily used for the preparation of bread, cakes, pastries and pies, tarts, quiches, cookies and crackers where flour is the essential and principal ingredient for the base product. Baking also includes the toppings, frosting, fillings etc that finish the baked product. The bakery industry in India occupies a significant place in the industrial sector and is the largest of the food industries with an annual turnover of about Rs. 3000 crores.

Bakery products are ready to eat convenience foods and offer comparatively higher shelf life and are an important source of nutrients viz. energy, protein, iron, calcium and several vitamins. These can be classified in to two categories- dry and moist bakery products. Biscuits such as soft biscuits, hard biscuits, cookies, crackers, fancy biscuits and cream wafer biscuits come under the category of dry bakery products whereas bread (Sweet bread, Milk bread, Masala bread, Garlic bread, Fruit bread etc) and buns (Fruit buns, hamburger buns, dinner rolls, crisp bread, pizza) come under the category of Moist bakery products. Generally, commercial bread and biscuits contain around 7.5 and 7-8% protein, respectively. Most bakery products can easily be enriched and fortified at a low cost with proteins, various vitamins and minerals to meet the specific needs of the target groups and vulnerable sections of the population, who are undernourished and malnourished. Bakery products can also be engineered in such a fashion that they meet the specific therapeutic needs of consumers.

Millet utilization as Composite flour in bakery products

Composite flour technology initially referred to the process of mixing wheat flour with cereal and legume flours for making bread and biscuits. However, the term can also be used in regard to mixing of non-wheat flours, roots and tubers, legumes or other raw materials. The protein quality of wheat is inferior to that of most cereals because it is deficient in lysine and threonine. To improve the nutritional quality of baked products, the use of single flour is replaced by the composite flour. Use of non-wheat flours for extending wheat supplies has been investigated with composite flours in bakery products. Diluting wheat flour with locally available cereals and root crops was found to be desirable to encourage the agricultural sector and reduce wheat imports in many developing countries. In Africa there has been an ever-increasing demand for wheat products such as bread. Africa is not a major wheat-growing region, but it produces large quantities of other cereals such as sorghum and millets. Thus composite flour technology holds excellent promise for developing countries. Although actual consumer trials have been rare, products made with composite flour have been well accepted in Colombia, Kenya, Nigeria, Senegal, Sri Lanka and the Sudan (Dendy, 1992). Bread could be produced from composite flour made by co-milling wheat with pearl, prove, barnyard or finger millets. The proportion of millet in the flour can be up to 15 percent. Potassium bromate treatment of the dough tends to improve the loaf volume. Breads with up to 15 percent proso millet were acceptable and comparable to white wheat bread (Lorenz and Dilsaver, 1980). When millets are used for bread-making, addition of bread improvers or modification of the bread-making process is needed. For the production of biscuits from composite flours, the fat content of the non-wheat flour should be kept as low as possible to promote a longer shelf-life. A combination of 80 percent non-wheat cereal and 20 percent wheat can be used to produce biscuits with acceptable quality. Proso millet was found suitable for making biscuits; biscuit spread and quality score increased with increased levels of prove millet flour because of its high fat content (Lorenz and Dilsaver, 1980). Millet flour imparted a slight grittiness, however. In Senegal, traditional foods such as faux, conus and beignets (fritters) are prepared by mixing millet flour with rice, maize or wheat flour (Thiam, 1981). De Ruiter (1972) discussed the use of non-wheat flour in bakery products and published formulae for cookies (literally soft cakes) with sorghum flour and biscuits (literally hard cakes) using millet flour. Vaidehi *et al.* (1985) prepared high protein biscuits with malted finger millet flour and oilseeds flour blend in 70:30. Sensory evaluation result indicated that malted brown finger millet flour and white flour blended with full fat peanut flour gave the best acceptable biscuits.

Millet utilization for gluten free bakery products

Gluten-free bread (GFB), obtained from native starchy flours from developing countries, could represent the offer of lower cost products and serve as a source of energy for celiac patients, who present permanent intolerance to gliadin and other similar proteins contained in a diet based on wheat, oats, barley, rice and triticale. GFB does not show the same characteristics of volume and texture as wheat bread (Clerici and El-Dash, 2006). When gluten-free flour is mixed to form dough, it does not form a continuous phase or dough structure, and therefore fails to produce good quality bread (Ranhotra, Loewe, & Puyat, 1975), one of the main characteristics of GFB being a firm, sticky crumb (Ylimaki, Hawarysh, Hardin, & Thomson, 1988). Many researchers have tried using additives in order to improve the quality of GFB, such as gums, emulsifiers, gelatinized flours or starches (Clerici and El-Dash, 2006), or the joint use of gums and enzymes to strengthen the rice protein network (Lorenz & Jansen, 1980). Probably due to the formation of hydrogen bonds, gelatinized rice has been shown to be capable of forming a three-dimensional network that retains gases and expands during the fermentation and baking of GFB.

Pre-gelatinized starch is capable of instantly forming numerous hydrogen bonds with water, and the acid modification of gelatinized starch could increase the number of these bonds by reducing the molecular size of the starch. In a study conducted by Raghua K S and Bhattacharya Sila (2010) the effect of bacterial á-amylase on the rheological (maximum force, firmness and compression energy), physicochemical (degree of gelatinization, viscosity of soluble fraction and total amylose content) and sensory attributes (hardness and stickiness) of finger millet dough revealed that an increase in the concentration of enzyme and time of treatment markedly increases the sensory stickiness, while maximum force, firmness and compression energy decreases.

Barnyard millet based gluten free muffins

Barnyard millet, commonly grown in Uttaranchal, Tamil Nadu, Andhra Pradesh, Karnataka and Chhattisgarh state of India, is the richest source of dietary fibre**.** It is low in phytic acid and rich in iron and calcium. This millet lacks gluten, a major protein component of some cereals like wheat which is responsible for flour processing characteristics in bakery industry. However, it is also responsible for an increasingly recognized disorder called celiac disease or celiac sprue. This disease is due to a permanent intolerance to gluten in genetically susceptible individuals. The ingestion of 70% ethanol soluble prolamin fraction of protein present in wheat (gliadin), barley (hordein) and rye (secalin) triggers the immune response in celiac patients. Due to this disease maldigestion and malabsorption of nutrients, vitamins, and minerals in the gastrointestinal tract occurs that further aggravates the conditions. Around 1% of world population is suffering from this disease and the prevalence of celiac disease increased sharply in recent years because of better recognition of the disease and its associated disorders. A strict lifelong adherence to a gluten-free diet is the only scientifically proven treatment for celiac disease. For making gluten free muffins the formulation contains 26 % millet flour, 26 % sugar, 21 % egg, 13 % full fat milk, 12 % oil, sodium bicarbonate (1.1%), citric acid (0.8%) and 0.1 % salt. The process protocol for making the gluten free muffins from barnyard millet is as follows:

Whipping of egg white (2 min, high speed)
↓
Sugar addition and mixing (30 s, high speed)
↓
Addition of egg yolk, citric acid and half of milk (6.5%) and mixing (1 min, medium speed)
↓
Wheat flour/millet flour blend, sodium bicarbonate and salt addition and mixing (1 min, medium speed)
↓
Oil and remaining milk were added and mixed (3 min, medium)
↓
Muffin batter
↓
Filling the batter in paper muffin cup of about 50-mm diameter (30 g of batter)
↓
Placing of the filled paper muffin cup in a silicone mould on a baking tray
↓
Baking in a conventional oven (at 200^{o}C for 6 min and further at 175^{o}C for another 6 min)
↓
Cooling (room temperature)
↓
Barnyard millet based muffins

Fig. 1. Process flow chart for making muffin

Conclusion

Today, millets are seen as minor crops that are often used as a food for the poor or fodder for animals. Europeans and American are most familiar with millets in bird seed. However, several initiatives and schemes has contributed in making the world aware of their importance and enormous nutritional potential due to which these are increasingly making their own deman among consumers. The improved processing techniques and diversified health food and functional foods made therof has opened there opportunities for more utilization in food processing sector. There is still need to further popularize these nutricereals and increase their demand by various ways viz. (i) Creating awareness regarding their environmental sustainability, nutritional and other health benefits, (ii) Making them available through PDS, (iii) Value addition, and (iv) Inclusion under feeding programmes like mid-day meal etc.

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Modified Atmosphere Packaging Design for Fruits and Vegetables

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Modified atmosphere packaging (MAP) of fresh fruits and vegetables relies on modification of the atmosphere inside the package, achieved by the natural interplay between two processes, the respiration of the product and the transfer of gases through the packaging, that leads to an atmosphere richer in CO_2 and poorer in O_2. This atmosphere can potentially reduce respiration rate, ethylene sensitivity and production, decay and physiological changes, namely, oxidation (Kader, Zagory & Kerbel, 1989; Saltveit, 1993). Produce physiology, more specifically, postharvest produce physiology, including respiration, senescence, transpiration (or water loss), and environmental stress responses, as well as produce biochemistry, such as ethylene synthesis, enzymatic browning, chlorophyll degradation, metabolism of aroma-active volatiles, and nutrient degradation, directly determine the shelf life and quality of fresh-cut fruits and vegetables stored under modified atmosphere packaging (MAP). Respiration is an essential physiological process that keeps the cells and organism alive or fresh for produce after being freshly cut. In addition, respiration has been hypothesized to be responsible for senescence and/or deterioration of postharvest fruits and vegetables (Kader 1986). In climacteric fruits, the increase in respiration (or CO_2 production) rates coincides with ripening, softening, and/or color changing. During postharvest storage of fruits and vegetables, there generally is an inverse relationship between respiration rate and shelf life. For fresh-cut products either under MAP or air, respiration is the mostly measured physiological activity noted in the research. There have been tremendous efforts in the literature to use respiration rates of fresh-cut products for indicating quality changes, selecting packaging materials, and predicting equilibrium and beneficial headspace O2 and CO_2 contents (Jacxsens et al., 2000,). The plant hormone ethylene has different physiological effects on postharvest fruit and vegetable quality. It accelerates ripening of many fruits, senescence of leaves and flowers, rates of respiration, and changes of leaf and fruit pigments, such as banana, tomato, and broccoli.

Methods of Modified atmosphere packaging

Methods of atmosphere modification within a packaged food product can be sub-divided into two main categories: Active modification & passive modification. Several methods can be used to actively modify the gas atmosphere within the packaged product. This includes vacuum packaging, MAP, the use of gas or scavenger of oxygen, moisture absorbers, or CO_2 and ethanol emitters and of gas injection. In commodity-generated or passive modification, the product is modified as a result of the consumption of O_2 and generation of CO_2 through respiration of the product. Passive modification is commonly used to modify the gas atmosphere of packaged fruits and vegetables. However, in order to maintain the correct gas mixture within the packaged product, the gas permeability of the packaging films must be equal to rate of respiration of product, which allows O_2 to enter the package at a similar rate as respiration of product. This process is also known as equlibrium modified atmosphere packaging EMA. Similarly, CO_2 must be vented from the package to offset the production of CO_2 by the product. Failure to accomplish this gas balance might result in a depletion of O_2 and a buildup of CO_2 resulting in spoilage of products. MAP is simply as extension of vacuum packaging technology, which involves the evacuation of air followed by the injection of the appropriate gas mixture.

The objective of MAP design is to define conditions that will create the atmosphere best suited for the extended storage of a given produce and to minimize the period of time to achieve this atmosphere. A MAP system not properly designed may be ineffective or even shorten the storage life of a product. If the desired atmosphere is not established rapidly, the package has no benefit. For example, high perishable products may deteriorate before the recommended atmosphere is attained. If O_2 and/or CO_2 levels are not within the recommended ranges of O_2 and CO_2 concentrations the product may experience serious alterations and its storage life is shortened. It may even induce anaerobiosis, with the possible growth of pathogens and concomitant effects on product safety.

Respiration rate

Control of respiration is an important effect of atmosphere modification on post-harvest life of fruits and vegetables. High respiration rates are associated with rapid deterioration of the product. There are three methods for measuring respiration rates: the flow-through system, the closed system, and the permeable system. Design of a MAP system that will prolong the storage or shelf life of fresh product requires the mathematical equation for predicting the respiration rate at the various influencing factors. Thus, the respiration rate model is central to the design of MAP for fresh fruits and vegetables The live tissue of fresh fruits and vegetables respires and transpires. The respiration rate varies greatly among different species, and depends heavily on temperature. As a result, MAP of fresh produce requires a different approach as compared to other products. The main goal of modified atmosphere applied to fruits and vegetables is to minimize the respiration rate of the product. This includes suppressing the production of ethylene, a gas responsible for accelerating ripening and deterioration, and hastening the onset of senescence in fruits and vegetables.

On the other hand, the use of MAP techniques with fresh produce, especially fruits, has a few potential hazards. The complete elimination of oxygen from the package quickly results in anaerobic respiration, the production of ethylene, and, subsequently, a fast and dramatic deterioration of the product quality. This is normally due to the accumulation of acetaldehyde, ethanol, and organic acids, the development of off flavours, and, finally, the discoloration and the softening of the tissue.

The closed system method is more efficient for measuring respiration rates as a function of gas concentrations. This method involve monitoring the O_2 and CO_2 concentrations inside a closed jar contain in the product as a function of time (Haggar et al., 1992). The initial gas concentrations inside the jar are usually those of air, but other gas concentrations may also be used. As the product respires, the gas concentrations in the jar change with time - from high O_2 and CO_2 now CO_2 concentrations at the beginning to low O_2/high CO_2 concentrations toward the end.

Modified atmosphere package design methodology

Fruits and vegetables being respiring produce when stored in a package comprised of a plastic film, it serves as the regulator of O_2 flow into the package and the flow of CO_2 out. Assuming that there is no gas stratification inside the package and that the total pressure is constant, the differential equations of mass balance for O2 and CO2 in MAP containing a respiring product are (balance with N2):

These two first-order linear differential equations are useful in describing the unsteady state behaviour in passive MAP. When the accumulated term is zero, the above Equations1 and 2 are reduced to the steady state as

$$V_f \times \frac{d(y_{O_2})}{dt} = \frac{P_{O_2}}{e} \times A \times (y^e_{O_2} - y_{O_2}) - R_{O_2} \times M \quad \text{Eq. 1}$$

$$y^e_{O_2} = y_{O_2} + \frac{R_{O_2} \times e \times M}{P_{O_2} \times A} \quad \text{Eq. 3}$$

$$V_f \times \frac{d(y_{CO_2})}{dt} = \frac{P_{CO_2}}{e} \times A \times (y^e_{CO_2} - y_{CO_2}) + R_{CO_2} \times M \quad \text{Eq. 2}$$

$$y^e_{CO_2} = y_{CO_2} - \frac{R_{CO_2} \times e \times M}{P_{CO_2} \times A} \quad \text{Eq. 4}$$

The above equations describe the dynamic equilibrium behaviour of the MAP system, when the CO_2 evolution rate equals the efflux rate of CO_2 through the package and the O_2 consumption rate equals the influx rate of O_2 through the package. In most commercial package situations, steady state or dynamic equilibrium is approached within two days. For long storage of the product, the dynamic equilibrium behaviour is more important than the unsteady state behaviour. To use Equations 3 and4 as design equations, it is necessary to keep track of how many independent or design variables are available. As per Table1, there are a total of 11 variables: there are a total of 11 variables: RO_2, RCO_2 and M are associated with the product; PO_2 , PCO_2 are associated with the package; e and A are associated with the environment. Once the product and the temperature are selected, six out of the 11 variables are already decided: RO_2, RCO_2 from the respiration rate model as reported in the literature; yO2 and yCO_2 are assumed to be the optimum O_2 and CO_2 concentrations and y^eO_2 and y^eCO_2 are constant, i.e., 0.21 atm and 0.0003 atm, respectively. With six variables fixed and two equations to satisfy, there are only (11-6-2) = 3 design variables. That is, only three out of the remaining five variables (M, e, A, PO_2 and PCO_2) can be specified arbitrarily. Combining Equations 3 and 4 we get:

$$\frac{y^e_{CO_2} - y_{CO_2}}{y^e_{O_2} - y_{O_2}} = -\frac{RQ}{\beta}$$

Table 1. Variables used in designing modified atmospheric package

	Surrounding-related	y^e O2, y^e CO_2
Input variables	Package- related	A, e
	Commodity- related	M
Calculated variables	Package-related	PO_2 and PCO_2
	Commodity-related	RO_2 RCO_2
Response variables	System-related	yO_2, yCO_2

Where, RQ is the respiratory quotient and â is the permeability ratio, defined as RCO_2 /RO_2 and PCO_2/PO_2, respectively. For any packaging design, the product characteristics such as its weight, respiration rate, density and the optimum conditions for the best shelf life are needed for the mathematical calculations.

The appropriate final atmosphere is formed by the interplay between the respiration of the product (for respiring products), the initial atmosphere (air or gas mixture) and the gas transfer through the packaging material. The choice of an adequate packaging material is the key to achieve that appropriate atmosphere, and this will be dependent on:

1. gas and water vapour permeability
2. thickness of the packaging film
3. package surface area

$$\beta = \left(P_{CO_2} / P_{O_2} \right)$$

The permeability ratio (β) of a film is the ratio of its permeabilities to CO_2 and O_2. The β value of a film is a predictor of the relative amounts of CO_2 and O_2 that will accumulate in the package.

i. Films with a high β value will allow CO_2 to escape the package relatively quickly, resulting in an atmosphere with low CO_2 and O_2 levels.

ii. Films with a low β values will not allow CO_2 to escape the package relatively quickly, resulting in an atmosphere with high CO_2 and low O_2 levels.

Most of the commercially available films have β values ranging from 3 to 6. A β value of 3 means that the film will allow CO_2 to exit the package 3 times faster than O_2 enters the package. Since polymeric films commonly have much higher CO_2 permeability than O_2 permeability (Table 2), the level of CO_2 that may be obtained inside the package is limited by the O_2 concentration. An important factor in determining the correct packaging material is the oxygen transmission rate (OTR). Packaging materials are classified according to their barrier properties to oxygen in to:

Table 2. permeability ratio (â) of different types of packaging film

Packaging Film	β value
Low density polyethylene, LDPE	6.3
Linear low density polyethylene, LLDPE	5.2
High density polyethylene, HDPE	6.0
Polypropylene, PP	5.6
Bi-oriented polypropylene, BOPP	5.4
Polyvinyl chloride, PVC	6.1
Polyvinyl chloride, PVDC	4.8
Polyethylene terephthalate, PET	
Unoriented	5.1
Oriented	4.9
Nylon 6	4.2
Nylon 11	4
Ethylene vinyl alcohol, EVOH	
32 mol % ethylene	31.0
44 mol% ethylene	30.0

1. low barrier (> 300 cc/m^2 day atm.)
2. medium barrier (50-300 cc/m^2 day atm.)
3. high barrier (10-50 cc/m^2 day atm.)
4. ultra high barrier (< 10 cc/m^2 day atm.)

Polymeric films used for MAP of fresh fruits and vegetables

Many of the films used in MAP, singly do not offer all the properties required for a modified atmosphere pack. To provide packaging films with a wide range of physical properties, many of these individual films are combined through processes like lamination and co-extrusion. There are several groupings in MAP films. Polyethylene is most commonly used to provide a hermetic seal and also as a medium of control for characteristics like anti-fogging abilities, peelability and ability to seal. Using polymeric films, MA packaging systems for products with low to medium respiration rates have to some extent been successfully developed. Products such as broccoli, mushrooms, leeks, etc exhibit very high rates of respiration such that conventional films can potentially over modify the pack atmosphere and thus result in fermentation. Accordingly, there has been a lot ofcommercial interest to develop films with high gas transmission. Films that have improved rates of gas transmission by virtue of their polymeric nature are usually blends of two or three different polymers, where each polymer of a blend performs a specific function such as strength, transparency and improved gas transmission to meet certain product descriptions. Furthermore, films can be laminated to achieve needed properties. Among this class are high (6–18%) ethylene–vinyl acetate content, low-density polyethylene (Elvax, DuPont, Wilmington, DE), oriented polypropylene laminates (OPP, BP Amoco, Lisle, IL), styrene butadiene block copolymer films (K-Resin, Phillips Chemical Company, Houston, TX) and ultra low-density ethylene octene copolymer films (Attane series, Dow Chemical Company, Midland, MI) and polyolefin plastomer octene copolymer films (Affinity series, DowChemical Company, Midland, MI).

Modified atmospheric packaging on different fruits and vegetables

Many plastic films have been in use for modified atmosphere packaging of varieties of produce (Table 3).

Micro-perforations for achieving optimal atmospheric conditions

Most commercial films do not provide adequate permeability to CO_2 to O_2 to achieve optimal concentrations inside typical packages for MA for fruits and vegetables. Atmospheres for products with high CO_2 and low O_2 requirements such as fruits and vegetables can be reached by using micro-perforated films. In micro-perforated films the micro-perforations are the primary route of gas exchange while in continuous films the polymeric material restricts the gaseous movement into or out of the package. Micro-perforated films can provide high OTRs since the ratio of CO_2 to O_2 is roughly 1, and they can mitigate the high/low concentrations of CO_2/O_2, respectively, which might occur in a continuous film packaging system for high respiration rate products. Increased weight loss is expected during postharvest storage for respiring products packaged in the currently available micro-perforated systems. The number, position, area and length of the micro-perforations will control the atmosphere inside the container. Micro-perforations can prevent condensation inside of the package and therefore, conditions favorable for microbiological growth and decay of the produce. Several methods can be used to microperforate packaging materials:

1. Cold and hot needle mechanical punches,
2. Electric spark and
3. Lasers.

Produce requirements are determined by laboratory testing produce packed in a variety of perforated films. The total flux needed by a fresh produce package to maintain a desired O_2 and CO_2 internal atmosphere is based on:

1. The respiration rate of the specific product,
2. The weight of the product,
3. The surface area of the package,
4. The storage temperature.

Table 3 Summary of the type of product, type of plastic, atmosphere composition, temperature of storage during MAP

Type of product	Type of plastic	Atmospheric composition		Temperature of storage (°C)	Storage period under MAP
		% O_2	% CO_2		
Apple (cv. Bravo de Esmolfe)	Polypropylene	5	3	2	6.5 months
Apple (cv. 'Cox's Orange Pippin')	LDPE	3	3	4	5 weeks
Apple (cv. Bramley's Seedling and Cox's Orange Pippin apples)	Cardboard cases lined with LDPE	7	5	15	4 week
Apples (cv Fuji)	Polypropylene, PVC	5	4	10	7 months
Guava (cv. Kumagai)	Multilayer coextruded polyethylene	1.5	4.5	10	3 weeks
Guava (cv. Kumagai)	LDPEm	3	4.5	10	2 week
Guava (cv. Kumagai)	PET	4	5	5	24 days
Banana	LDPE	3	5	15	15 days
Autumn seedless table Grape	Polypropylene	15	10	0	60 days
Table grapes (cv. Autumn Royal)	Oriented polypropylene	8	2.5	1	56 days
Litchi (cv. Mauritius)	BOPP	17	6	2	34 days
Litchi (cv Heiye)	Polyethylene	15	4	3	42 days
Litchi	Laminated polyethylene	15	5	1.5	4 weeks
Litchi (cv. McLean's Red)	BOPP	16	6	2	18 days
Sapota (cv.'Jantung)	LDPE	–	–	5, 10, 15	4 weeks at 10°C and 3 weeks at 15°C, a experienced chillin injury
Strawberries (cv. Camarosa)	PVC, LDPE, PP	6	8	2°C (4 days), followed by 10°C (2 days) and by 18°C (2 days)	8 days Simulated condition of MAP (transport, distribut and retail sale)
Strawberries and raspberries	LDPE, PVC	3	5	7	1 week
Sweet cherry (cv. Sams)	LDPE	0.11, 0.18, 0.04, 0.016, 0.28, 0.13	9.2, 11.5, 12.4, 15.2, 20.3, 20.3	0, 5, 10, 15, 20, 25	3 weeks
Sweet cherries	LDPE	5	14	34°F	14 days
Broccoli (cv. Marathon)	LDPE	1.5	6	15	2 weeks
Broccoli heads	Macroperforated, microperforated and non-perforated PP	3	5	1	28 days
Broccoli	OPP, PVC, LDPE	5	7	10	1 week
Broccoli (cv. Acadi)	Plastic containers (4-L) fitted with diffusion windows for gas exchange	3	8	3	30 days
Mushrooms (U3 Sylvan 381)	Plastic containers (26-L) fitted with diffusion	5	10	4	12 days

Types of modified atmosphere packaging machines for packaging of fresh fruits vegetables and minimally processed fruits and fresh cut vegetables

Horizontal Form-fill-seal (HFFS): The flow-pack machines are capable of making flexible pillow-pack pouches from only one reel of film. HFFS machines can also overwrap a prefilled tray of a product. The air from the package is removed by continuous gas flushing, but gas mixtures containing levels of O_2 > 21% cannot be used due to the use of hot sealing jaws at the end of the machine. For certain very porous products (e.g. some bakery goods), gas flushing is not capable of reducing the residual O_2 within the package enough to low levels. In such cases, a gas injection station can be fitted to the machine infeed so that the product itself is purged with gas immediately prior to packaging. Figure below illustrates a diagrammatic representation of an HFFS machine**.**

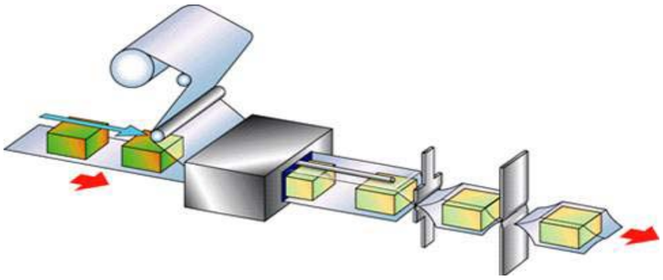

Figure. Horizontal Form-fill-seal (HFFS)

Vertical Form-fill-seal VFFS machines: Similar to HFFS machines, VFFS machines are capable of making flexible pillow-pack pouches from only one reel of film. Also, the air from the package is removed by continuous gas flushing so long as the gas mixture does not contain levels of O_2 > 21%. In VFFS machines, gas flushed packages are gravity fed by loose product which has been pre-weighed on a multihead weigher. Pre-flushing with gas may be necessary for porous products. Figure at left illustrates a diagrammatic representation of a VFFS machine.

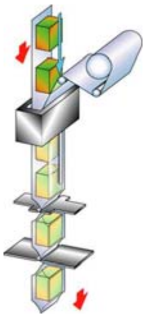

Figure. Vertical Form-fill-seal VFFS machines

Thermoform-fill-seal (TFFS): TFFS machines produce packages consisting of a thermoformed semi-rigid tray, which is hermetically sealed to a flexible lidding material. Rollstock film (typically PVC/PE) is automatically conveyed into a thermoforming section where a vacuum or compressed air is used to draw the film into dies, giving the trays their desired shape. The product is then manually or automatically loaded into the trays before evacuation, back flushing with the desired gas mixture, and heat-sealing with lidding material. The hermetically sealed packages are then finally separated by cross-cutting and longitudinal cutting units. Figure above illustrates a diagrammatic representation of a TFFS machine.

Preformed Tray and Lidding Film (PTLF): PTLF machines are essentially the same as TFFS machines (see below), except that preformed trays are used instead of thermoformed semi-rigid trays.

Three-web Thermoform-fill-seal (TWTFFS): TWTFFS machines are essentially similar to TFFS machines (see below), except that the product to be packed is first held in position with a permeable top web skin. After this process, the product enters a second sealing section where a lidding film is placed on top of the thermoformed tray. The space between the top web skin film and the lidding film is gas flushed. TWTFFS machines enable packs to be produced, which combine the advantages of MAP with vacuum skin packaging (VSP). VSP prevents product movement, pack integrity is maximised, juice exudation is limited, and vertical retail display is possible.

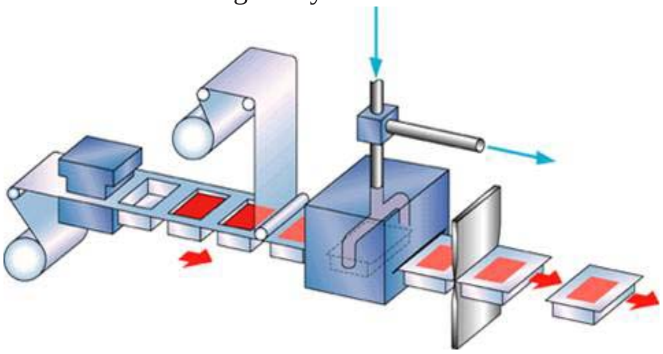

Figure. Three-web Thermoform-fill-seal (TWTFFS)

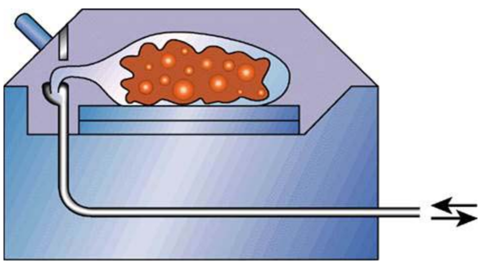

Figure. Vacuum Chamber (VC)

Vacuum Chamber (VC): These machines use preformed bags and utilise the compensated vacuum technique to replace air. Preformed plastic bags are manually placed within the chamber before evacuation, back flushing with the desired gas mixture, and heat sealing. These machines can be used for small-scale production of vacuum or gas flushed catering packs. The figure below illustrates a diagrammatic representation of a VC machine.

Snorkel Type (ST): These machines use the compensated vacuum technique to produce bulk MA catering bag-in-box packs. Alternatively, they can gas flush conventionally packaged retail products, such as over wrapped packs of red meat, into large master packs. In these machines, preformed plastic bags are positioned on a heat seal mandrel and retractable snorkels pull a vacuum and then back-flush with a desired gas mixture before heat sealing.

Conclusion

The recommended percentage of O_2 in a modified atmosphere for fruits and vegetables for both safety and quality falls between 1 and 5%, although the oxygen level will realistically each levels below 1% in MAP produce. The greatest extension of shelf life occurs at the lowest possible oxygen concentration before anaerobic respiration is initiated. It is generally believed that with the use of permeable films, spoilage will occur before toxin production is an issue; MAP of produce, however, should always incorporate packaging materials that will not lead to an anoxic package environment when the product is stored at the intended temperature. The polymeric films of recommended gas transmission rates and other characteristics (strong, flexible, trans- parent, durable and food grade) required for MAP for all commodities should be produced commercially either as single polymer/coextruded/laminated for thesuccess and popularization of MAP technology. Successful control of both product respiration and ethylene production and perception by MAP can result in a fruit or vegetable product of high organoleptic quality; however, control of these processes is dependent on temperature control. Along the whole food continuum, that is, processing, storage, transportation and retailing, one needs to maintain optimum temperatures. Maintaining proper storage temperatures is often most difficult at retail level. Oxygen, CO_2, and N_2, are most often used in MAP/CAS. Among them, CO_2 is the only one with a direct antimicrobial effect, resulting in an increased lag phase and generation time during the logarithmic phase of growth. Although other gases such as nitrous and nitric oxides, sulphur dioxide, ethylene, chlorine, as well as ozone and propylene oxide have been investigated, they have not been applied commercially due to safety, regulatory, and cost considerations. As fruits and vegetables are more sensitive to environmental conditions, the conditions have to be controlled precisely to achieve superior product quality and the development of models for diûerent fruits and vegetables is a pre-requisite. Research is also needed in integrating active packaging with MAP to make this technology economically viable. Current ethylene removing techniques (catalytic or chemical oxidation) are not commercially successful. Active packaging involving ethylene-absorbing substances should be studied. It is an exciting time within the MAP industry. There are emerging technologies and opportunities that will have far reaching impact on the marketplace. Issues such as sustainability in packaging and the impact that packaging has on current food safety issues are already providing both tremendous challenges and opportunities. The challenge will be how to incorporate all of the desired requirements into MAP without diluting its fundamental purpose. A package that tries to become all things to all applications becomes mediocre at best with respect to any one requirement.

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Microcontrollers and Sensors in Post-Harvest Application of Agricultural Commodity: Sorting/Grading and Storage

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Now days, there is general trend of industrial automation which is nothing but the process of handling different industrial processes automatically with the help of various machines such as computers and robots i.e. with the help of microcontrollers and sensors. This approach increases efficiency, productivity and decreases the human efforts and labour cost. Food industry is also incorporating this same approach of industrial automation in processing techniques to reduce production time and labour cost for enhancing quality of the produce and profit. There are many processing techniques such as sorting, grading, screening, dehulling and storage which required to be done in food industry for obtaining uniformity in products for further processing. Automatic sorting mechanism is a basic need in agricultural fields or in food industries. Sorting of any raw material can be depend on color, size, shape and weight of the commodity. In case of storage of the commodity, it is very difficult to monitor and control the storage parameters by manually, so with the interventions of sensors, actuators and microcontrollers one can easily control the real time storage conditions automatically with better precision and accuracy.

Automatic Sorter Based on color

Automatic color sorters are used in food industry for basic classification. Color sorter is a machine that separate objects in different sets depending on its color. In agricultural industries, there are many categories of color sorters used like rice sorter, beans sorter, peanut sorter, fruit sorter, seeds sorter, etc. Also, in other industries there are several sorters like gear sorter, plastic granule sorter, etc. Poojary et al. (2017) designed an automated fruit and vegetable sorter based on colour detection. The proposed method uses Open CV library for Colour detection. Entire algorithm is programmed using Python 2.7 IDE. Sheela et al. (2016) studied automatic sorting of objects using raspberry pi 3. Authors proposed a highly automated system which uses Raspberry pi 3 for detecting the presence of objects and their color and allows only those objects which are of desired color to pass through conveyor belt and rejecting those colored objects which are undesirable away from the belt. A linear actuator is activated by passing a high signal when the color is undesirable which pushes away the objects using PYTHON code with Raspberry pi 3 support. Gaikar et al. (2016) sorted objects using color sensor, arduino (controller) and shading sensor. Shading sensor distinguishes shading and gives serial yield of RBG. The distinguished shading is recognized as measure of three essential shading values to be specific Red, Green and Blue with 8 bit exactness for every essential shading. Shading can be isolated or consolidated into three essential hues red, green and blue utilizing the RBG values. Shen et al. (2015) designed a color sorting robot with Arduino Uno microcontroller, TCS3200D Color Sensor, SG90 Tower Pro Servo Motor and other electronic components. The system has the ability to sort the object according to their color into respective color station in minimum time.

The following components are required for development of color sorter model

1. Ardiuno board
2. Servo motors
3. Color sensor
4. Jumper wires
5. Color balls/ Cadbury gems

Fig. 1. Arduino Mega Board

Arduino Mega 2560 is used as microcontroller unit. The Arduino Mega 2560 is an open source hardware, based on ATmega 2560. It has 54 digital input/output pins, 16 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack and a reset button. It is used for building digital devices and interactive objects that can sense and control objects in the physical and digital world. (https://www.arduino.cc/)

Servo motor: The servo motor is controlled with an electric signal which determines the amount of movement of the shaft. Servo motor has some special arrangement which makes the motor to rotate a certain angle for a given electrical input (signal). Servo motors are controlled by sending an electrical pulse of variable width, or pulse width modulation (PWM), through the control wire.

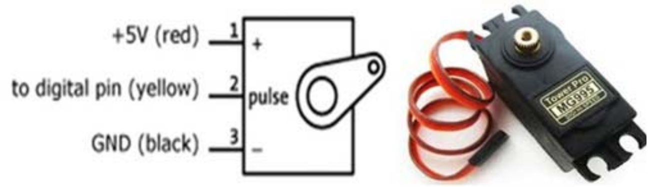

Fig. 2. Servo motor

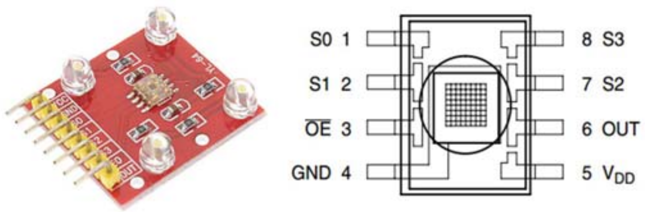

Fig. 3. TCS3200 Color Sensor Module

Color sensor: TCS3200 color sensor module (shown in figure) is used for color sensing. The TCS3200 color sensor is a module that includes RGB sensor chip and 4 white LEDs. It senses color with the help of photodiode array and then using a current-to-frequency converter, the readings from the photodiodes are converted into a square wave with a frequency directly proportional to the light intensity.

As shown in figure, sensor has 8 x 8 array of photodiodes. Sixteen photodiodes have blue filters, 16 photodiodes have green filters, 16 photodiodes have red filters, and 16 photodiodes are clear with no filters. Each 16 photodiodes are connected in parallel, so using the two control pins S2 and S3 we can select which of them will be used for reading specific color.

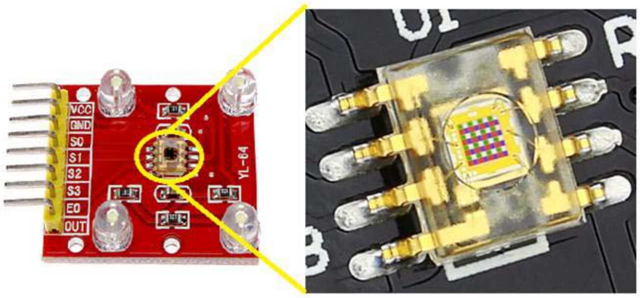

Fig. 4. Photodiode array

Table: Photodiode colors of TCS3200

S2	S3	Photodiode type
0	0	Red
0	1	Blue
1	0	No Color
1	1	Green

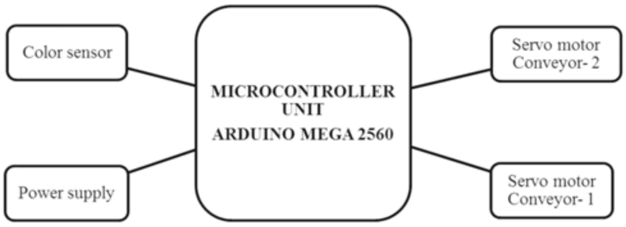

Fig. 5. Block Diagram of System

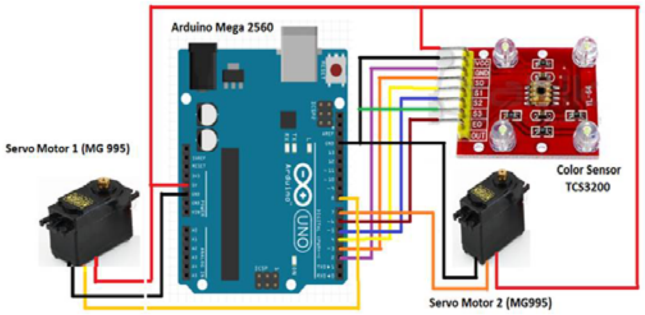

Fig. 6. Connection set up for the Color Sorter

Process flow description:

1. Microcontroller unit is programmed using Arduino Integrated Development Environment (IDE) such that, first it initializes all peripherals i.e., both servo motors and color sensor. Initialization of color sensor includes selection of pins of microcontroller as output pins for selecting lines of color sensor (S0, S1, S2, and S3) and as input pin for output of color sensor (OUT). Also, microcontroller selects output frequency scaling using S0 and S1 control pins in initialization routine.

2. Program is written in a loop so that top servo motor continuously rotates the conveyor plate having circular hole for ball i.e. from position at bottom of the hopper to position at below the color sensor and from position at below the color sensor to the hole from which the conveyor tube starts.
3. When top servo brings the conveyor plate below the color sensor and waits for fraction of time then color sensor measures the color frequencies in R, G and B channel.
4. The color sensor reads the colors in red, green and in blue channels and sends it to the microcontroller unit, then on the basis of color value, microcontroller sends the signal to the bottom servo motor to rotate the conveyor tube in specified degree as per values of colors.
5. This process will continue in loop till objects to be sorted are finished.

Model of color sorter worked well for sorting of color balls with diameter 7 cm. Six different type of color balls sorted through sorter using color properties. This model has a limitations that it requires a uniform color of the object, it will be a good solution for food industry which is producing a products like Cadbury Gems or toffies with uniform color. Model have a bright future perspective and it will give a way to small scale fruit and vegetable sorting automated machines with some advanced sensors like camera and actuators.

Automatic Sorter Based on Weight

In India, highest post-harvest loss was recorded for tomato (12.44%), highest loss of tomato (18.34%) was observed in western plateaus and hills region, Maharashtra (Jha et al., 2015). The severe post-harvest loss occurs during handling and transportation and ultimately, gives adverse result during marketing. In order to address these challenges and for well managed handling, transportation and marketing, grading and sorting of fruits and vegetables is necessary.

Generally, sorting of fruits and vegetables is done according to their geometry and shape either by visual inspection or using image processing technology. Since size of fruits depends on cell division and cell expansion while weight of fruit depends on total solid (water soluble and insoluble) content present in it. So, there is lack of precision in sorting of fruits and vegetables on weight basis by considering only their geometry and shape.

Shendage and Narawade (2015) developed automated weight based fruits sorting system as an economical sorting solution. Rautu et al., (2017) conducted study on sorting of objects based on color, weight and type on a conveyor line using programmable logic controller to sort objects depending upon the color and to analyse the quality of the object. Vashistha et al., (2017) conducted study on design and implementation of weight based object sorting system to eliminate monotonous work done by human and to achieve accuracy and speed of work. Bhausaheb et al., (2017) developed automation (load cell) technique using programmable logic controller to sort object on weight basis.

Materials used: The following components are required for development of weight sorter model

1. Ardiuno board
2. Servo motors
3. Weight sensor amplifier
4. Weight sensor/load cell
5. Jumper wires

HX711 weight sensor amplifier

As load cell output value ranges in mV that doesn't give significant change in displayed output while changing load. So, there is need to amplify output data obtained from load cell. HX711 weight sensor amplifier was used to amplify data obtained from load cell.

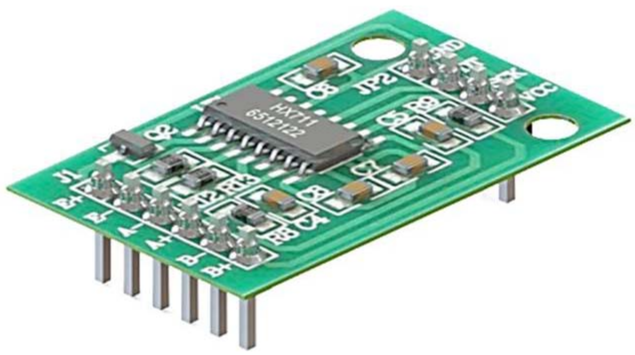

Fig. 7. HX711 weight sensor amplifier

Load cell

Load cell is a weight sensing device. A 5 kg strain-gauge type load cell was used. It works on the principle that when a one end mounted thin elastic wire is subjected to load at its other end then either it gets stretched or compressed and this change in length or diameter causes change in resistance of wire and ultimately change in potential difference along the wire. One end of load cell is mounted and the other end at which load is sensed is kept free.

Fig. 8. Load cell

Working principle of the system

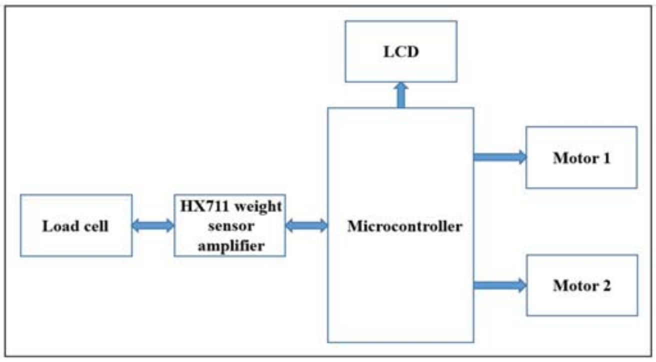

Fig. 9. Block diagram of whole system

"When any sensor senses, it can transfer what it sensed and can be able to operate other actuator". The model for automatic sorter on weight basis for tomato mainly consists of three section viz., electronic control section, weighing section and conveying mechanism. The electronic control section consists of arduino UNO and HX711 weight sensor amplifier, weighing section consists of load cell and conveying mechanism is combination of product dropping and collection mechanism.

At first Arduino software and HX711 library was installed to control whole electronic control segment. Microcontroller, HX711 weight sensor amplifier, load cell and servo motor were used as electronic control segment. Tomatoes of different weight were sorted in five grade. By using statistical analysis (K-means clustering) range of weight for grading was determined for different grades, like more than 150g (1st grade), 110-150g (2nd grade), 80-110g (3rd grade), 50-80g (4th grade) and less than 50g (5th grade). With the help of two servo motor, tomatoes were dropped in their respective compartment according to their weight.

The model gives precision in sorting on weight basis that can't be obtained only by considering shape and geometry of fruits and vegetable but by considering the actual weight of the produce. Error of about ±3g also appears but it doesn't take significant role because range of weight is considered while sorting. It also speeds up time of sorting and thereby processing. In addition to design, a conveyor can also be joined as extended part which will convey material to weighing part and stop till weight will sensed and dropping of material in their respective compartment will take place. This will result in drudgery reduction and also speed up time of processing. With inclusion of advance sensors and microcontroller this model will be good asset for large capacity automatic sorting operation.

Development of low cost real time automatic data-logger for measuring temperature and humidity

Pertinent information about the temperature and humidity during a certain time period is very important in the scientific, medical and industrial fields. For retrieval of this information, various methods can be used. Either it can be done manually, or devices such as chart recorders or data loggers can be used. Data logger can be considered as a self-sufficient tool to collect data, having the ability to clearly present real-time data with sensors and probes able to respond to parameters that are beyond the normal range available from the most traditional equipment. A data logger or a data recorder is an electronic measuring device, logs the data over a period of time with a sensor, built in instrument or via external instruments. The data logger measurements may include: temperature and humidity of air, alternating and direct current and voltage, air pressure, room occupancy, intensity of light, temperature of water, level of water, water content in soil, dissolved oxygen, measurement of rain, motion of wind and its path, pulse signals, leaf wetness etc. These are widely used inside the building, outside the building and in submarine circumstances where the data is required. The purpose of having data loggers is its capacity to spontaneously collecting data for 24 hours cycle continuously without a break. After activating, the data loggers are left not attending to measure and log data for the particular date and time. This permits exact and complete image of the atmospheric conditions which are being observed such as temperature of air, moisture content in the air, and many more parameters.

We have tried to build a low cost, automatic, real time embedded arduino based data-logger to meet the purpose (i.e. read temperature and humidity with respect to time). The arduino microcontroller board is used which has an inbuilt ADC and other peripheral circuit components (i.e. DHT 22, 16*2 LCD I2C Display, SD card and RTC module) necessary for its working. The physical parameters are sensed by the sensor and then are converted to analog signal. This analog signal is then fed into the arduino board ADC pins which is then converted to an equivalent digital quantity. The processed signal from the microcontroller can then directly be displayed on the serial monitor or recorded on the LCD screen or it can be saved to the SD card for further research. Lakooju et al. (2011) stated that ATmega 2560 contributes incredibly in electronics control applications such as data logging, data acquisition system and many more as it is well known for its economical and greatly flexible chip amongst electrical circuit designer. Apart from that, the chip is always referred as a high-performance microcontroller and it was totally supported by many other researchers to have a great performance microcontroller in their researches.

The block diagram is shown below:

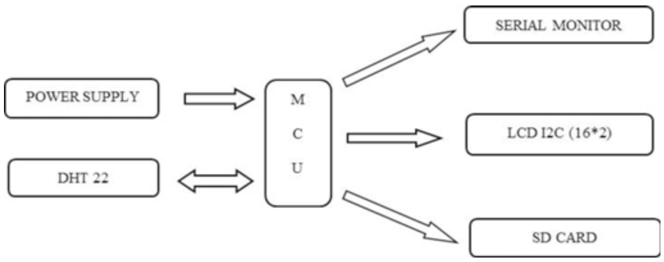

Fig. 10. Block Diagram of Data-Logger

SYSTEM COMPONENTS:

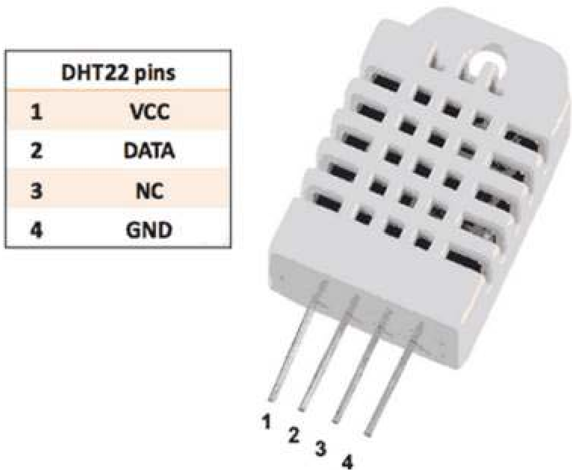

Fig. 11. DHT 22 Sensor

Data logger consists of the following components:

1. Sensors (DHT 22)
2. Arduino Mega 2560
3. LCD Display (16*2)
4. SD Card with module
5. Real time clock module
6. Jumper wires

The DHT 22 sensor is used in this project can be described as follows:

AM2302 capacitive humidity sensing digital temperature and humidity module is one that contains the compound which has been calibrated to digital signal output of the temperature and humidity.

For Relative Humidity:

Parameter	Specification	Unit
Resolution	0.1	%RH
Range	0-99.9	%RH
Accuracy	±2	%RH
Response	<5	S

For Temperature:

Parameter	Specification	Unit
Resolution	0.1	
Range	-40-80	
Accuracy	±1	
Response	<10	S

After setting up the connection and performing experiment, the results were summarised as:

Fig. 12. Overall setup of the designed data- logger

OUTPUT OBTAINED:

The signal out of the microcontroller as the required output can simultaneously be displayed and recorded in the following:

1. LCD Display
2. Serial monitor
3. SD Card/Memory card

Developed data logger is calibrated by comparing it with standard measuring instruments. The variation of measured parameters is studied. We can change the time interval between two readings as per user requirement. Also we can add more sensors in data logger so that one can take reading of different parameters from different locations within permissible range. These measured parameters are displayed in real time on the LCD of the data logger and as well as logged on the serial monitor and saved to the memory card for further analysis.

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Newer Approaches in Co-Products and By-Products Utilization for Development of Functional Foods

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A co-product is defined as a product which is produced along with the main product and carries equal importance as main product. However, a by-product is defined as a substance or product, resulting from a production process, the primary aim of which is not the production of that item. Main difference between these two is costing, a co-product generally fetch a reasonable price while a by-product has low or minimal market value. In food processing sector co-products are of more importance than by-products owing to their high nutritional quality as compared to that of by-product that are mainly used for animal feed; because a by-product is more or like a waste material resulted while processing of main product (after obtaining of co-product) however, with increased technological interventions, the utilization of by-products by extracting bioactives, biofuels, enzymes, biodegradable plastics and nanoparticles opens new avenues in management of food supply chain waste. Prompt urbanization along with slow progress in the development of effective waste management strategies leads to the accumulation of food waste. A study published by the EU in 2010 revealed that almost 90 million tonnes of food waste are expelled from the food manufacturing industry every year. Food waste, being high in nutritional content, putrefies on accumulation, providing breeding grounds for disease causing organisms. Food industry waste is mostly lignocellulosic in nature, with high cellulose and lignin content (except animal-derived food waste). Many studies have reported on various technologies for the conversion of food waste such as fruits/vegetable pomace and brewers' spent grain into biofuel. Cellulose and hemicelluloses on enzymatic breakdown release glucose and xylose, which can be converted into ethanol by fermentative microorganisms. Furthermore, lignin on pyrolysis and anaerobic digestion yields H_2 and CH_4. Also, food waste is a reservoir of other value-added chemicals (bioactive compounds, enzymes, organic acids etc.). Biorefinery is an emerging concept in the field of biomass waste management suggesting that all kinds of biomass-derived material can be converted into different types of biofuels and chemicals through various conversion processes.

Utilization of Food Industry Waste

The value/effectiveness of the biomass conversion process is determined by the operational cost and the value of the target products. It is therefore necessary to evaluate the current trends and recent development of technology in the conversion of food supply chain waste. A large range of commercially important products such as biofuels, enzymes, organic acids, biopolymers, nutraceuticals and dietary fibres have been developed from the bioconversion of food industry waste.

Biofuels

Plant biomass has been used for the production of biofuels (bioethanol, biodiesel, biohydrogen, biobutanol, bioether, biogas and syngas) for almost a century. In recent developments, bioethanol was produced from food waste using carbohydrases and Saccharomyces cerevisiae as the fermentative microorganism. The two modes of fermentation viz. separate hydrolysis and fermentation (SHF) and simultaneous hydrolysis and fermentation (SSF) were able to obtain ethanol yields of 0.43 g/g and 0.31 g/g, respectively. The quality of cooking oil degrades over repeated use making it unfit for human consumption therefore, the production of biodiseal from cooking oil waste was attempted by many researchers. Biodiesel is

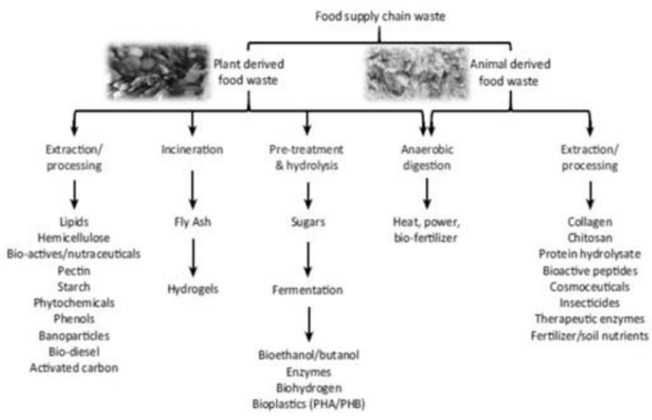

Fig. 1. Possible commercial products from food waste management

a value-added product of cooking oil waste. Soy bean oil, canola oil, and cooking oil waste have been successfully converted into biodiesel by various methods. Lipolytic enzymes such as Lipozyme TL IM and Novozym 435 are employed in the transesterification process to convert cooking oil into biodiesel. Biohydrogen has been produced using oil palm fruit bunch, sweet sorghum and wheat straw in separate studies. In studies, it has been observed that genetic enhancement of the fermentative organism resulted in better yields. Enterobacter, Bacillus and Clostridium are the most popular microorganisms used for biohydrogen production.

Industrial enzymes

Food waste has been preferred as an ideal substrate for cost-effective enzyme production and therefore several food supply chain wastes have been used for the production of commercially important enzymes. Oxidative enzymes such as cellulase, laccase, amylase, xylanase, phytase and lipase have been the focus of production using organic food waste residues. Commercial enzyme production is a cost-intensive process, with almost 28% of the operational cost dedicated to raw material procurement. Therefore, several research investigations have focused on the utilization of lignocellulosic food waste as a raw material for enzyme production. Microbial strains are capable of degrading the complex polymers in plant biomass and utilize the sugars released for their nourishment hence, food processing industry waste as a raw material for enzyme production possesses additional advantages. Furthermore, high enzyme activity can be achieved by using media optimization techniques and genetically superior enzyme-producing microbes. The solid state fermentation mode is preferred over submerged fermentation due to its low operational cost. According to researchers, the operational cost of solid state fermentation is one-tenth of that of submerged fermentation. Also, solid state fermentation replicates the natural environment for enzyme production in a bioreactor, which has been proved to increase enzyme yield. Food waste is naturally heterogeneous in nature and therefore can cause problems in downstream processing resulting in increased costs for enzyme isolation and purification. However, these drawbacks can be overcome by innovative enzyme recovery processes such as one step purification and immobilisation of enzymes.

High-value compounds from food waste

Food wastes account as a source of valuable nutraceuticals and deal with the prospects of satisfying nutritional requirements of fast growing population in 21st century. For this reason, the term “food by-products” is increasingly used among the food scientists in order to inform that “food wastes” are ultimate substrates for the recapture of functional compounds and the development of new food products with health promoting components. For example, phenols and carotenoids from fruit by-products could be applied as natural food or beverage preservatives since they extend the shelf-life of the product by acting as antioxidants (delaying the formation of off-flavors and rancidity).

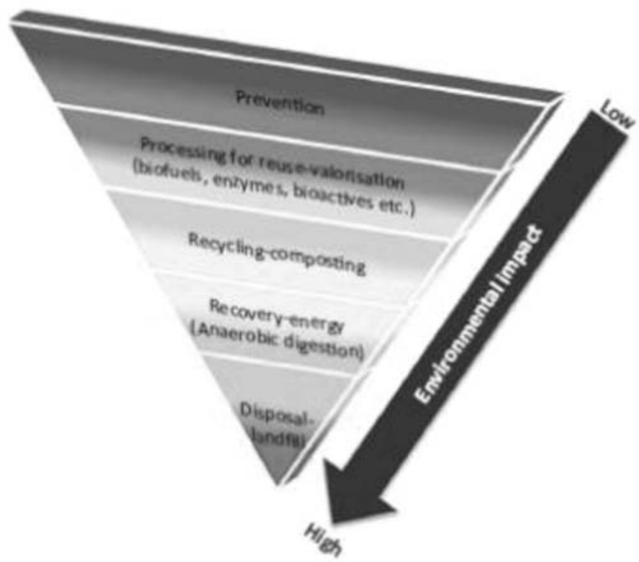

Fig. 2. Hierarchy for waste processing

Pectin could be utilized as gelling agent in jams, jellies, fruit juices and confectionary or as fat replacers in processed bakery and meat products. Generally, fruits and vegetables processing wastes are the most widely investigated substrates for the extraction of several types of antioxidants and dietary fibers. Citrus is among the largest fruit crop worldwide and substrates like lemon by-products have been applied for the production of pectin and flavonoids. Orange peel has also been utilized for the recovery of flavonoids (i.e. hesperidin), essential oils and carotenoids. The latest compounds have been delivered from carrot peels, tomato pomace and skin, too. Among the several roots and tubers, potato and cassava are the largest crop worldwide. Processing of potatoes is conducted mainly for the production of chips or French fries and corresponding solid wastes consist of peels or cull potatoes. Potato peels and processing wastewater have been thoroughly investigated for the extraction of phenols by several researchers. Nevertheless, cassava peel has only been studied as a substrate for microbial protein enrichment. Water insoluble fibers (i.e. hemicelluloses) are able to improve intestinal regulation and thereby are destined to supplement food products or ready meals. Animal originated wastes contain high amount of proteins that are too valuable to be discharged on the environment. Cheese whey is one of the most popular substrates for the extraction of proteins and saccharides, as it is massively produced during cheese manufacture and possesses a very high ratio of mass per product mass the so-called specific waste index. Cheese processing whey is an abundant source of lactose and proteins, and thus it is designated for the delivery of monosaccharides and oligopeptides in nutritional supplements and soft drinks, respectively. Protein hydrolyzates from deoiled meals and fish by-products have also been proposed as flavor enhancers. Grain milling generates by-products like bran or straw, which are rich in high nutritional proteins, dietary fibers and particularly glucuronoarabinoxylans. Oat mill waste (originated from rolled oat grains) has been suggested for the extraction of beta-glucan with advanced gelling properties. In the case of oilseeds and pulses, sunflower and soybean seeds are destined to the extraction of phytosterols. Olive is a very popular oil crop in the Mediterranean region that can also be considered in the fruits' group. Olive mill pomace and wastewater have been widely valorized as a source of bioactive phenols and more recently pectin. Despite the omnipresence of hypothetic scenarios, high quality studies and patented methodologies, the labeled products derived from food waste are today rather limited and concern mainly whey protein isolates.

Technologies for extraction, fractionation and isolation of high added-value compounds from food wastes

The extraction, fractionation and isolation of high added-value compounds from food wastes usually follow the principles of analytical chemistry. Thereafter, modifications are accordingly applied into the methodology depending on the objective or target component to be extracted with an ultimate goal of:

(a) maximizing the yield of the target compounds,

(b) suiting the demands of industrial processing,

(c) clarifying the high added-value ingredients from impurities and toxic compounds,

(d) avoiding deterioration and loss of functionality during processing and

(e) ensuring the food grade nature of the final product.

Among the numerous methodologies found in literature, five distinct recovery stages can principally be observed, although steps are sometimes eliminated or oversubscribe each other. Processing starts from the macroscopic to the macromolecular level and afterwards to the extraction of specific micro-molecules followed by purification and encapsulation.

This downstream scheme is selected if two different ingredients are recovered or the valuable component is a micromolecule (i.e. antioxidant). In reverse, when the target compound is a macromolecule (i.e. protein), the second stage may be omitted. The macroscopic pre-treatment aims the adjustment of the food waste matrix according to the water content, enzymatic activity and permeability of the bioresource tissues. This stage includes only one process that is depended on the nature and the structure of the substrate (i.e. solid, sludge or wastewater). If the substrate is solid for example fruit or vegetable by-product, a wet milling step is necessary to facilitate and improve the yield of the following separation and extraction stages, if the substrate is a wastewater (i.e. of olive oil industry), concentration (thermal or vacuum) is utilized with a final purpose of removing water and increasing content of valuable components alternatively dewatering may be conducted with mechanical pressing in order to avoid thermal-induced yield reduction and loss of functionality. In second recovery stage, alcohol precipitation is the most popular method for the separation of smaller compounds (i.e. antioxidants, acids or ions) from macromolecules (i.e. pectin, dietary fibers or hydrocolloids). Isoelectric solubilization /precipitation allows the selective solubility of proteins from meat, fish or marine by-products with concurrent removal of lipids, bones or skin. The third step involves extraction which is the most important stage of downstream processing, is achieved by different methodologies employed towards the target molecules and their physicochemical characteristics. Solvent extraction is very convenient, since the solvent provides a physical carrier to transfer the target molecules between different phases (i.e. solid, liquid and vapor). Phenols are easily solubilized in polar protic mediums like hydroalcoholic mixtures, while corresponding fractions can be obtained on the basis of polarity by varying alcohol concentration. Ethanol is most preferable polar solvent used for extraction due to its cost and "GRAS" status (Generally-Recognized-As-Safe) status. Liposoluble components such as carotenoids such as tomato lycopene are extracted by using non-polar solvents i.e. acetone or ethyl acetate. At this stage, the solvent should be removed completely from the extract prior its re-utilization in food products.

To facilitate extraction or to increase the yield of extracted components several assisted technologies have been employed. For example extraction of phenols, carotenoids and flavorings in combination with pressurized and distillation processes, accelerates the process and increase the yield of extracted volatile compounds. Microwave-assisted extraction raised interest over the last years, as microwave energy is able to heat solvents rapidly and thus accelerating transfer of analytes from the sample matrix into the solvent. This technique is easy to handle, requires moderate solvent and has recently been applied for the extraction of pectin and phenols from apple pomace and potato by-products, respectively. Another effective technique is ultrasound assisted extraction (UAE) that has also reported to enhance the efficiency of a conventional system. In a solvent extraction unit, an ultrasound device is placed in an appropriate position to enhance the extraction efficiency. The advantages of UAE include reduction in extraction time, energy and use of solvent. Ultrasound energy for extraction also facilitates more effective mixing, faster energy transfer, reduced thermal gradients and extraction temperature, selective extraction, reduced equipment size, faster response to process extraction control, quick start-up, increased production and eliminates process steps. UAE is reported to be an effective extraction technique for bioactive compounds extraction from herbal plants. The non-thermal processing technologies such as pulsed electric field (PEF) treatment and pressurized liquid extraction (PLE) were recognized as useful technique for improving the extraction and diffusion processes during recent times. PEF can increase mass transfer during extraction by destroying membrane structure of plant materials for enhancing extraction and decreasing extraction time. PEF has been applied to improve release of intracellular compounds from plant tissue with the help of increasing cell membrane permeability. PEF treatment at a moderate electric field (500 and 1000 V/cm; for 10^{-4}–10^{-2} s) is found to damage cell membrane of plant tissue with little temperature increase and hence minimize the degradation of heat sensitive compounds. PEF is also applicable on plant materials as a pretreatment process prior to conventional extraction to lower extraction effort. PEF treatment (at 1 kV/cm with low energy consumption of 7 kJ/kg) in a solid liquid extraction process for extraction of betanin from beetroots showed highest degree of extraction compared with freezing and mechanical pressing. bioactives extraction from grape by-product using PEF resulted in better extraction of anthocyanin monoglucosides. High pressure facilitates the extraction process. Automation techniques are the main reason for the greater development of PLE-based techniques along with the decreased extraction time and solvents requirement. PLE technique requires small amounts of solvents because of the combination of high pressure and temperatures which provides faster extraction. The higher extraction temperature can promote higher analyte solubility by increasing both solubility and mass transfer rate and, also decrease the viscosity and surface tension of solvents, thus improving extraction rate.

Some phytochemicals in the plant matrices are dispersed in cell cytoplasm and some compounds are retained in the polysaccharide- lignin network by hydrogen or hydrophobic bonding, which are not accessible with a solvent in a routine extraction process. Enzymatic pre-treatment has been considered as a novel and an effective way to release bounded compounds and increase overall yield (Rosenthal et al., 1996). The addition of specific enzymes like cellulase, a-amylase and pectinase during extraction enhances recovery by breaking the cell wall and hydrolyzing the structural polysaccharides and lipid bodies. Various factors including enzyme composition and

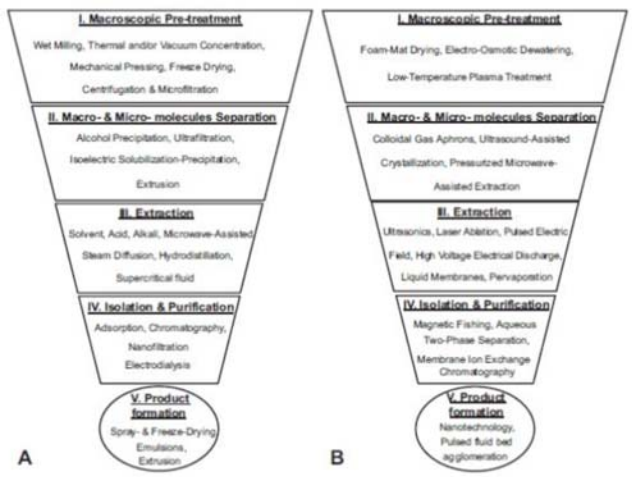

Fig. 3. Recovery stages of high-added value components from food wastes: (A) established and (B) emerging technologies (Galanakis, 2012)

concentration, particle size of plant materials, solid to water ratio and hydrolysis time are recognized as key factors for extraction. Improved release of phenolic compounds from *Ribes nigrum* pomace was observed using various enzymes pretreatments. Extraction of phenolic antioxidant from raspberry solid wastes was increased by application of enzyme in hydro-alcoholic extraction. The supercritical fluid extraction (SCFE) has a higher extraction rates due to its higher diffusion coefficient, lower viscosity and surface tension than a liquid solvent (leading to more penetration to sample matrix and favorable mass transfer), reduced extraction time, complete extraction due to reflux of supercritical fluid, higher selectivity of supercritical, separation of solute from solvent in conventional extraction process can easily be bypassed by depressurization of supercritical fluid, SFE is operated at room temperature, so an ideal method for thermo labile compound extraction, small amount of sample can be extracted compared with solvent extraction, reduced use of organic solvent and considered as environment friendly, on-line coupling of SFE with chromatographic process is possible which is useful for highly volatile compounds, recycling and reuse of supercritical fluid. Polyphenols and procyanidins were extracted from grape seeds using SFE, where methanol was used as modifier and methanol modified CO_2 (40%) released more than 79% of catechin and epicatechin from grape seed.

The fourth stage is recovery stage which aims at the isolation or the clarification of the target compounds from co-extracted impurities. Adsorption, supported by resins, activated carbons or polysaccharide-based materials is an attractive process that enables the separation of selected low molecular weight phenols from dilute solutions with high capacity and insensitivity to toxic substances. Moreover, it requires a relatively simple design, operation and scale up, which adsorbents can be easily regenerated and re-utilized. Adsorption has typically been applied for the isolation of flavonoids and phenols (i.e. hesperidin) from orange peel as well as phenolic acids (ferulic, cinnamic, gallic etc) from olive mill waste. Membrane processes is one of the direct methods which perform more selective separations between monovalent and multivalent ions. Besides, they can optimize lactic acid purification with simultaneous recovery of whey proteins in the concentrate stream. Reverse osmosis allows only water molecules to pass through the membrane pores, while nanofiltration is an alternative method when monovalent salt permeation is desirable. Nanofiltration has also been suggested for the clarification of a phenol containing beverage derived from olive mill wastewater by removing polymerized phenolic fractions.

The final step of downstream processing is product formation (encapsulation or drying). This step is important as it ensures the further stability and activity of bioactive compound. Encapsulation entraps bioactive food components inside a physical barrier (coating material), preserves their stability, masks undesirable organoleptic characteristics and protects them against environmental stresses. In addition, it is a useful tool to prevent non-functional interactions with food matrix during their utilization as additives and improve their delivery into foods. In the case of recovering polysaccharides, dietary fibers or proteins, encapsulation stage is replaced with drying. On the other hand, polysaccharides (starch, cellulose, cyclodextrin, inulin, pectin, gums, carrageenans, alginate etc.) and proteins are typically used as coating materials. Whey protein gels and dietary fibers from soybean solid residue, palm trunk and oil palm frond have also been explored for this purpose.

Utilization of by-products and/or their extracted components in functional foods

The phytochemical extracts can be used either for their biological properties as ingredients for nutraceutical preparations or functional foods or for their food-quality-related properties – which include antioxidant properties, colour properties (pigments) and flavour properties The food industry can take advantage of the physicochemical properties of respective derived/extracted products to improve the nutritional value, viscosity, texture, sensory characteristics and shelf-life of conventional products. Fibre-rich byproducts may be incorporated into food products as inexpensive, non-caloric bulking agents for partial replacement of flour, fat or sugar, as enhancers of water and oil retention and to improve emulsion or oxidative stabilities. Grape pomace extracts may be used as functional components of enriched foods both to color the products with anthocyanins and to supplement with biofunctional plantmetabolites. The most recent developments considering the simultaneous recovery of pectin and polyphenols including yellow colored pigments, seed oil and saccharides suitable for their use as natural sweeteners are being carried on apple pomace.

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HACCP in Food Processing

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Genesis of HACCP

In the early 1960s, a collaborated effort between the Pillsbury Company, NASA, and the U.S. Army Laboratories began with the objective to provide safe food for space expeditions. People involved in this collaboration included Herbert Hollander, Mary Klicka, and *Hamed El-Bisi* of the United States Army Laboratories in Natick, Massachusetts, Dr. Paul A. Lachance of the Manned Spacecraft Center in Houston, Texas, and Howard E. Baumann representing Pillsbury as its lead scientist.To ensure that the food sent to space was safe, Lachance imposed strict microbial requirements, including pathogen limits (including E. *coli*, *Salmonella*, and *Clostridium botulinum*). Using the traditional end product testing method, it was soon realized that almost all of the food manufactured was being used for testing and very little was left for actual use. Therefore, a new approach was needed. NASA's own requirements for critical control points (CCP) in engineering management would be used as a guide for food safety. CCP derived from failure mode and effects analysis (FMEA) from NASA via the munitions industry to test weapon and engineering system reliability. Using that information, NASA and Pillsbury required contractors to identify "critical failure areas" and eliminate them from the system, a first in the food industry then. Baumann, a microbiologist by training, was so pleased with Pillsbury's experience in the space program that he advocated for his company to adopt what would become HACCP at Pillsbury. Soon, Pillsbury was confronted with a food safety issue of its own when glass contamination was found in farina, a cereal commonly used in infant food. Baumann's leadership promoted HACCP in Pillsbury for producing commercial foods, and applied to its own food production. This led to a panel discussion at the 1971 National Conference on Food Protection that included examining CCPs and good manufacturing practices in producing safe foods. Several botulism cases were attributed to under-processed low-acid canned foods in 1970–71. The United States Food and Drug Administration (FDA) asked Pillsbury to organize and conduct a training program on the inspection of canned foods for FDA inspectors. This 21-day program was first held in September 1972 with 11 days of classroom lecture and 10 days of canning plant evaluations.[4] Canned food regulations (21 CFR 108, 21 CFR 110, 21 CFR 113, and 21 CFR 114) were first published in 1969. Pillsbury's training program to the FDA in 1969, titled "Food Safety through the Hazard Analysis and Critical Control Point System", was the first time that HACCP was used.

While food is essential for sustenance and nourishment, contaminated food can be harmful to health. Worldwide concerns about food quality led Food and Agriculture Organization (FAO) and World Health Organization (WHO) to jointly establish the Codex Alimentarious Commission (CAC) in 1962 with the aim to protect consumer health, harmonize food standards, and promote international trade. However, realizing that mere ex-post inspection methods of processed foods does not guarantee safety to consumers, CAC recommended adoption of a food safety management system, known as Hazard Analysis and Critical Control Points (HACCP), which was made mandatory by virtue of the 1995 agreement on Sanitary and Phytosanitary measures (SPS) reached by the member countries of the World Trade Organization (WTO, 1995).

Need for HACCP

Food safety in the early twenty-first century is an international challenge requiring close cooperation between countries in agreeing standards and in setting up transnational surveillance systems. The lessons of the past two decades are plain to those engaged in the food industry. No longer can farmers grow just what they want or use technical aids to farming without taking into account the effect on the quality of the food produced. Foods to be exported needs to meet the requirements of not only safety but much higher dietary quality, hygiene and health standards. Consumers look for certification and reassurance of products' origins (national or geographical) and production methods. This heightened consumer awareness is reflected in the demand for products endowed with individual characteristics due to specific production methods, composition or origin

What is HACCP?

Hazard Analysis and Critical Control Points (HACCP) is a management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the finished product (U.S. Food and Drug Administration). HACCP approach is internationally recognized as being effective in ensuring the safety and suitability of food for human consumption and in international trade.

In simple words '*HACCP is a systematic approach to the identification, evaluation, and control of food safety hazards*'.

Advantages of HACCP

HACCP offers a number of advantages over previous systems. Most importantly, HACCP (1) focuses on identifying and preventing hazards from contaminating food, (2) is based on sound science, (3) permits more efficient and effective government oversight, primarily because the record keeping allows investigators to see how well a firm is complying with food safety laws over a period rather than how well it is doing on any given day, (4) places responsibility for ensuring food safety appropriately on the food manufacturer or distributor, (5) helps food companies compete more effectively in the world market, and (6) reduces barriers to international trade.

Seven principles of HACCP

1. **Analyze hazards**. Potential hazards associated with a food and measures to control those hazards are identified. The hazard could be biological (e.g., a microbe), chemical (e.g., a toxin), or physical (e.g., ground glass or metal fragments).
2. **Identify critical control points**. These are points in a food's production-from its raw state through processing and shipping to consumption by the consumer at which the potential hazard can be controlled or eliminated. Examples are cooking, cooling, packaging, and metal detection.
3. **Establish preventive measures with critical limits for each control point**. For a cooked food, for example, this might include setting the minimum cooking temperature and time required to ensure the elimination of any harmful microbes.
4. **Establish procedures to monitor the critical control points**. Such procedures might include determining how and by whom cooking time and temperature should be monitored.
5. **Establish corrective actions to be taken when monitoring shows that a critical limit has not been met-** for example, reprocessing or disposing of food if the minimum cooking temperature is not met.
6. **Establish procedures to verify that the system is working properly**-for example, testing time and temperature recording devices to verify that a cooking unit is working properly.
7. Establish effective record keeping to document the HACCP system. This would include records of hazards and their control methods, the monitoring of safety requirements, and action taken to correct potential problems.

Sanitation program as a perquisite to HACCP plan

Sanitation controls may be included in the HACCP plan. The minimum allowable sanitary conditions for the equipment and facilities are identified in such a pre-requisite and are called as Sanitation Standard Operating Procedures. SSOPs consist of written cleaning and sanitizing procedures, validation procedures, and records regarding sanitary conditions both pre-processing and during processing. Once a Sanitation program and necessary pre-requisite programs are implemented, a HACCP plan can be developed. Several tasks are required prior to HACCP program development. Those preliminary tasks include:

Assemble the HACCP team, the team consists of individuals who have specific knowledge and expertise appropriate to the product and process. Other team members include the person(s) responsible for plan maintenance. One person on the HACCP team must be HACCP-trained. A team can be as few as one or two people.

How to develop a HACCP Plan

Here are the seven steps used in HACCP plan development.

1. Preliminary steps: (a) General information. (b) Describe the food. (c) Describe the method of distribution and storage. This provides information on the ingredients, processing methods, and distribution methods (frozen, refrigerated or at ambient temperature). (d) Identify the intended use and consumer. These may be the general public or a segment of the population such as infants, elderly, military, hospital patients, etc. (e) Develop a flow diagram. This diagram provides a clear, simple outline of the steps involved in the making the product. A block flow diagram is usually sufficient.
2. Hazard Analysis Worksheet: (a) Set up the Hazard Analysis Worksheet. (b) Identify the potential species-related hazards. (c) Identify the potential process-related hazards. (d) Complete the Hazard Analysis Worksheet. (e) Understand the potential hazard. (f) Determine if the potential hazard is significant. (g) Identify the critical control points (CCPs).
3. HACCP Plan Form: (a) Complete the HACCP Plan Form. (b) Set the critical limits (CLs).
4. Establish monitoring procedures: (a) What. (b) How. (c) How often. (d) Who.
5. Establish corrective action procedures.
6. Establish a record-keeping system.
7. Establish verification procedures. The HACCP team should perform an on-site review of the operation to verify the accuracy and completeness of the flow diagram. Perform a walk-through of the process to make sure all process steps are covered.

Every processor should have and implement a written HACCP plan whenever a hazard analysis reveals one or more food safety hazards that are reasonably likely to occur. A HACCP plan should be specific to (1) each location where products are processed by that processor and (2) each kind of product processed by the processor. The plan may group kinds of products or kinds of production methods together, if the food safety hazards, critical control points, critical limits, and procedures that must be identified and performed are identical for all products so grouped or for all production methods so grouped.

Contents of the HACCP Plan

The HACCP plan should, at a minimum:

- *List the food safety hazards* that are reasonably likely to occur, as identified, and that thus must be controlled for each product. Consideration should be given to whether any food safety hazards are reasonably likely to occur as a result of natural toxins; microbiological contamination; chemical contamination; pesticides; drug residues; decomposition in products where a food safety hazard has been associated with decomposition; parasites, where the processor has knowledge that the parasite-containing product will be consumed without a process sufficient to kill the parasites; unapproved use of direct or indirect food or color additives; and physical hazards.
- *List the critical control points* for each of the identified food safety hazards including, as appropriate,

  (1) Critical control points designed to control food safety hazards that could be introduced in the processing plant environment and

  (2) Critical control points designed to control food safety hazards introduced outside the processing plant environment, including food safety hazards that occur before, during, and after harvest.

  List the critical limits that must be met at each of the critical control points.
- List the procedures, and frequency thereof, that will be used to monitor each of the critical control points to ensure compliance with the critical limits.
- Include any corrective action plans that are to be followed in response to deviations from critical limits at critical control points.

- List the verification procedures, and frequency thereof, that the processor will use.
- Provide for a record-keeping system that documents the monitoring of the critical control points. The records should contain the actual values and observations obtained during monitoring.

Signing and Dating the HACCP Plan

The HACCP plan should be signed and dated (1) upon initial acceptance, (2) upon any modification, and (3) upon verification of the plan. The plan should be signed and dated either by the most responsible individual on site at the processing facility or by a higher level official of the processor. This signature should signify that the HACCP plan has been accepted for implementation by the firm.

One way of looking at the HACCP requirement is to think of the HACCP plan as a pyramid (Fig. 1). The HACCP program is built upon the sanitation program and other prerequisite programs. These programs address the suitability and food safety of the process.

Fig. 1.

The underlying Sanitation and prerequisite programs prevent the introduction of food safety hazards into the plant, and thus are a foundation for the HACCP plan. For example, not having an equipment maintenance program may lead to the physical hazard of broken machinery parts contaminating a ground product. The HACCP plan is a proactive, continual assessment of ongoing food safety during the processing of the food. For the HACCP plan to be successful, all of the underlying programs must be working properly. In the pyramid, the prerequisite programs and written Sanitation program uphold the HACCP plan as the critical food safety system.

Example of a HACCP plan for minimally processed fresh cut fruits and vegetable processing plant.

An illustration of a HACCP system with the steps involved in processing and packaging of minimally processed plant for fresh cut Fruits and Vegetables. The table given below enlist the steps involved and the critical control points that may also depend on the specific fruit or vegetable. The process adopted, involving the equipment's, machinery and handling of the fruit during these steps may involve some changes in the control measures.

Critical operational step	**Hazards**	**Critical control point(s)**	**Preventative and control measures**
Harvesting	Microbial spoilage and insect invasion Cross- contamination	Assessment of produce maturity Handling practices Temp. control Sanitation	Harvest prior to peak maturity Minimize mechanical injuries Harvest in the morning or at night Employ pickers trained in elementary hygiene
Transporting	Microbial growth Cross-Contamination	Time/temperature loading practices Produce containers	Keep the temperature low Avoid long distance transport Maintain uniform cooling in transport containers Avoid damage, do not overload the containers Separate sound and injured produce in the field Use well washed/disinfected metal or plastic containers
Washing	Contamination from water	WaterWashing practices Dewatering	Use potable water Test routinely for the presence of coliform bacteria Control microbial contamination by chlorination and antimicrobial dipping Do not overload washing tanks Change the water periodically Remove excess water

Critical operational step	Hazards	Critical control point(s)	Preventative and control measures
Sorting	Cross- contamination	Sorter Lighting Conveyer	Employ sorters having experience in inspection of produce Provide adequate lighting Clean and disinfect periodically
Packaging	Microbial growth	Packaging film Relative humidity and temp. control	Choose the permeability of film correctly Analyze gas composition routinelyby using simple techniques Use fungicide impregnated film\ Use films which have antifogging properties Dewater the drenched produce carefully Check product/storage temperature at regular intervals
Storage / Distribution	Growth and spread of micro- organisms	Temp. control Light Consumer practice	Maintain the refrigeration of produce in the range of 0-5^0 C Prevent moisture condensation byproper temperature control Take the effect of light into consideration Provide labeling with instruction forstorage conditions

Certification Process for HACCP

Its implementation and certification is not done by the International Organization for Standardization; rather, there are a number of so-called accredited registrars, or Accredited Certification Bodies, which perform the necessary audits and procedures for certification in various ISO standards, including HACCP certification. For instance, Bureau of Indian Standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002 (Tel : +91 11 23239402, Fax : +91 11 23234062, Email : info@bis.org.in, Website: www.bis.org.in) is one such Conformity Assessment Bodies (CAB) in India, although there are several other Consultants and Accreditation agencies to help and award HACCP Certification (JAS-ANZ, CDC, National Centre for HACCP Certification, etc.). Following Flow Chart indicates the different chronological stages required for the certification process:-

1. Proposal/ application for certification
2. Pre-assessment
3. Training
4. Documentation Review
5. Audit for certification
6. Certification

Differences between ISO 22000 and HACCP

HACCP process identifies hazards that could threaten food safety (e.g. sources of bacteria or chemical contamination). Critical control points (CCP) are the points in food production or handling during which these hazards become a factor. HACCP is the part of ISO 22000 that directly addresses these hazards and sets up procedures for monitoring the CCP. ISO 22000 is a complete food safety management system (FSMS). In scope, it goes beyond the actual processing of the food to include things such as goal setting, management review and setting up effective communication channels, both within a company and with outsiders, such as suppliers and regulators. It also involves developing a food safety policy and a procedure for recalling products in case that becomes necessary.

HACCP originated in the US (1960s), deriving from guidelines and regulations set forth by the Department of Agriculture and the Food and Drug Administration. The Pillsbury Co. originally developed HACCP concept for NASA to prevent food safety incidents on manned space flights. ISO 22000 is a worldwide (global) standard issued by the International Organization for Standardization and first published in 2005.

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Encapsulation of Bioactive and Functional Ingredients

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With increased awareness on health benefits of functional ingredients, the demand is increasing for the food products that are tasty, healthy and convenient. The addition of bioactive ingredients directly to food and feed products for fortification poses many challenges such as very limited solubility of many interesting ingredients, incompatibility between active ingredient and food matrix. Encapsulation technologies have the potential to meet above demands as well as challenges concerning controlled release of nutraceuticals, probiotics, enzymes and food/ feed ingredients. Nano-encapsulation delivery systems induces improved water solubility, thermal stability, oral bioavailability, sensory attributes and physiological performance to the food and feed ingredients. There is gap in basic understanding of electrostatic, short range and long ran range colloidal interactions between delivery system and active ingredients in terms of the basic underlying physicochemical principles for encapsulation and among delivery system particles/emulsions to predict stability with reference aggregation and precipitation. The understanding of these phenomena leads to easy scale up of process. Encapsulation methods are vigorously pursued by researchers to achieve above goals. However, these research efforts are generally focused on influence of process and formulation parameters at lab level leading to qualitative or semi empirical relations which are inadequate for effective process scale up. Different encapsulation methods such as coacervation, spray drying, and interfacial polymerization are adopted/modified to produce micro/nano delivery systems incorporating bioactive/nutraceutical ingredients. Development of equipment and processes for the encapsulation of these ingredients is discussed.

Introduction

Microencapsulation paves way for development of innovative functional foods as well as diagnostic indicators in food safety. With increased awareness on health benefits of functional ingredients, the demand is increasing for the food products that are tasty, healthy and convenient (Zuidam and Nedovic, 2010). However, direct addition of ingredients to food products to add functionality can compromise their taste, color, texture, and aroma. Many ingredients may not be compatible with the food constituents as well. Microencapsulation technology can become saviour of food industry in such situations. It provides viable texture blending, appealing aroma release, and taste-, odor-, and color-masking and can incorporate minerals, vitamins, and essential oils, creating foods in functional foods. With the growing urbanization and increasing quality consciousness, the market for processed foods and functional foods is expected to grow more rapidly. The major segments of functional foods with encapsulated ingredients are dietary supplements, health foods, beverages and confectionaries such as candies and chewing gums. A timely and targeted release improves the effectiveness of feed and food additives, broadens the application range of feed and food ingredients and ensures optimal dosage, thereby improving cost-effectiveness for the manufacturer.

Microencapsulation is a process of entrapping solid particles, liquid droplets or gases in thin polymeric coatings. The outer film (wall) protects the encapsulated material (core) and allows for its controlled release. Application of this technique is wide spread in several industrial fields, including the manufacture of foods, pharmaceuticals, agrochemicals, nutraceuticals, probiotics and cosmetics. Microencapsulation in food industry is aimed at effective delivery of nutrients, bio-active compounds and sensitive ingredients through food systems. Common food ingredients subjected to microencapsulation include probiotic bacteria, acidulents, flavours, colours, sweeteners, minerals and vitamins. A number of coating materials are employed in production of microcapsules, such as gums, starch, and starch derivatives, cellulosic materials, lipids, proteins and inorganic materials.

Actually the development of micro-encapsulates was partially inspired by the nature. Eggs, seeds, grains, nuts, fruits etc. are typical examples of the food encapsulation and encapsulation is natures own way of conserving and protecting natural products against its own deteriorating elements. Taking clue from this, man adopted this technology for protection of some of the foodstuffs as sauces, puddings etc.

Microencapsulation can improve the convenience of food. The shell provides a barrier between reactive components (for instance, delaying the release of leavening agents for fluffier bread products or protecting oxygen-sensitive materials during processing and storage). Microcapsules can help fragile and sensitive materials survive processing and packaging conditions and stabilize the shelf-life of the active ingredient. For effective delivery of functional foods, the carrier systems should have properties such as good uptake, extended circulation time, no/ acceptable clinical side effects, high biocompatibility and low immunogenicity (McClements, et al., 2007).

The possibility of controlled release further widens the capabilities of technology and is thus attracting attention of industry players.

In addition, microencapsulation can simplify the food manufacturing process by converting liquids to solid powder, decreasing production costs by allowing batch processing using low-cost, powder-handling equipment. To improve food safety, the technology can be used to indicate product tampering, thermal spoilage, and freeze-thaw cycles.

Reasons for microencapsulation

The reasons for microencapsulation are countless. In some cases, the core must be isolated from its surroundings, as in isolating vitamins from the deteriorating effects of oxygen, retarding evaporation of a volatile core, improving the handling properties of a sticky material, or isolating a reactive core from chemical attack. In other cases, the objective is not to isolate the core completely but to control the rate at which it leaves the microcapsule, as in the controlled release of drugs or pesticides. The problem may be as simple as masking the taste or odor of the core, or as complex as increasing the selectivity of an adsorption or extraction process.

Microencapsulation offers food companies a viable means of penetrating this lucrative growth sector because it has the ability to mask the undesirable tastes associated with some of these ingredients.

This also implies significant opportunities in the highly profitable children's market. While consumers are becoming more health-conscious and are demanding more nutritious products, they are unwilling to compromise on taste.

Microencapsulated ingredients can be used to

- Mask undesirable flavours
- Prevent chemical reactions
- Improve delivery, control delay
- Increase stability of finished product
- Reduce production losses
- Increased quality of finished product
- Increase plant capacity without capital expense
- Improve production yield
- Increase saleable products and increase profit.

Although microencapsulation technology was long considered far too expensive for use in the food industry, manufacturers are increasingly adopting this technology to add value to their product range. As food manufacturers consistently track consumer trends and tastes, food ingredients companies must continually look to develop innovative products that help meet end-user needs. Microencapsulation is progressively attracting the interest of food ingredient manufacturers as a way of achieving much-needed differentiation and enhancing product value.

Methods of microencapsulation

A number of microencapsulation methods have been developed over the years for pharmaceutical, agrochemical, textile and cosmetics industries. How these can be adapted for food industry is a good researchable issue. Various methods such as extrusion, spray drying can be used for encapsulation of food ingredients (Karel, 1994). Though there is no clear cut classification of various methods, they can be broadly categorized in to two classes viz. physical and chemical methods.

Physical methods to manufacture microcapsules

Pan coating

The pan coating process, widely used in the pharmaceutical industry, is among the oldest industrial procedures for forming small, coated particles or tablets. The particles are tumbled in a pan or other device while the coating material is applied slowly.

Air-suspension coating

Air-suspension coating of particles by solutions or melts gives better control and flexibility. The particles are coated while suspended in an upward-moving air stream. They are supported by a perforated plate having different patterns of holes inside and outside a cylindrical insert. Just sufficient air is permitted to rise through the outer annular space to fluidize the settling particles. Most of the rising air (usually heated) flows inside the cylinder, causing the particles to rise rapidly. At the top, as the air stream diverges and slows, they settle back onto the outer bed and move downward to repeat the cycle. The particles pass through the inner cylinder many times in a few minutes.

Centrifugal extrusion

Liquids are encapsulated using a rotating extrusion head containing concentric nozzles. In this process, a jet of core liquid is surrounded by a sheath of wall solution or melt. As the jet moves through the air it breaks, owing to Rayleigh instability into droplets of core, each coated with the wall solution. While the droplets are in flight, a molten wall may be hardened or a solvent may be evaporated from the wall solution. Since most of the droplets are within ± 10% of the mean diameter, they land in a narrow ring around the spray nozzle. Hence, if needed, the capsules can be hardened after formation by catching them in a ring-shaped hardening bath. This process is excellent for forming particles 400-2000ìm in diameter. Since the drops are formed by the breakup of a liquid jet, the process is only suitable for liquid or slurry. A high production rate can be achieved, i.e., up to 22.5 kg of microcapsules can be produced per nozzle per hour per head. Heads containing 16 nozzles are available.

Vibrational Nozzle

Core-Shell encapsulation or Microgranulation (matrix-encapsulation) can be done using a laminar flow through a nozzle and an additional vibration of the nozzle or the liquid. The vibration has to be done in resonance of the Rayleigh instability and leads to very uniform droplets. The liquid can consists of any liquids with limited viscosities (0-10000 mPas have been shown to work), e.g. solutions, emulsions, suspensions, melts etc. The solidification can be done according to the used gelation system with an internal gelation (e.g. sol-gel processing, melt) or an external (additional binder system, e.g. in a slurry). The process works very well for generating droplets in the range of 100-5000 micrometer, applications for smaller and larger droplets are known. The units are deployed in industries and research mostly with capacities of 1-10000 kg/h at working temperatures of 20-1500°C (room temperature up to molten silicon). Nozzles heads are available from one up to several hundred thousand are available.

Spray–drying

Spray drying serves as a microencapsulation technique when an active material is dissolved or suspended in a melt or polymer solution and becomes trapped in the dried particle. The main advantages is the ability to handle labile materials because of the short contact time in the dryer, in addition, the operation is economical. In modern spray dryers the viscosity of the solutions to be sprayed can be as high as 300mPa.s. The existing spray dryers can be explored for microencapsulation on large scale with slight modifications. It is mostly used for encapsulation flavours and other functional ingredients with starch derived wall materials such as maltodextrins.

Coaxial air flow bead generator

An easy way for production of small alginate beads in a controllable manner is the use of a coaxial-air-flow bead generator. Low production rate is one of the main disadvantages of these systems. The basic principle of the instrument is the use of a coaxial pressurized air stream which pulls droplets from a needle tip into the gelling bath. The process is capable of producing capsules with diameter 200 µm or more.

Simple droplet generator system for encapsulation of the pancreatic islets employing chitosan-alginate matrix was developed by Hardikar et al. ((1999). The droplet generator system comprised of a needle assembly, a 3-way valve with extended rubber tubing and a filtration unit connected to a pressure pump.

In pursuit of simple and cost effective microencapsulators, microencapsulator with multiple air jet droplet generator for production of microcapsules (Narsaiah and Oberoi 2011) and an autoclavable microencapsulation system with multistage break up two fluid nozzle (Narsaiah et al. 2011) were developed for microencapsulation of sensitive functional ingredients for incorporation in food products at CIPHET, Ludhiana.

Jet Cutting

It is based on the mechanical impact of a cutting wire on a completely filled stream of liquid jet. This jet of polymer is formed by forcing the solution through special nozzles. This jet is broken-up into equal cylindrical segments when passed through a cutting tool consisting of several thin wires fixed onto a holder. Surface tension induces sphericity to these cylindrical segment as they pass through air. The resulting diameter of droplet depends on number of cutting wires, number of rotations of the cutting tool, the mass flow rate through nozzle and the mass flow depending both on nozzle diameter and velocity of the fluid (Prusse et la. 1998).

Spinning disk atomization

The principle of operation is based on disintegration of feed liquid when dropped onto the surface of a rotating disk due to high velocity generated by centrifugal acceleration. The droplets are released from tip of the rotating disk or from ligamentry streams released from the edge of the disk (Ogbonna 2004). The process is capable of producing capsules with diameter 200 µm or more with narrow size distribution and ease of scale up is noteworthy.

Chemical methods to manufacture microcapsules

Interfacial polymerization

In Interfacial polymerization, the two reactants in a polycondensation meet at an interface and react rapidly. The basis of this method is the classical Schotten Baumann reaction between an acid chloride and a compound containing an active hydrogen atom, such as an amine or alcohol, polyesters, polyurea, polyurethane. Under the right conditions, thin flexible walls form rapidly at the interface. A solution of the pesticide and a diacid chloride are emulsified in water and an aqueous solution containing an amine and a polyfunctional isocyanate is added. Base is present to neutralize the acid formed during the reaction. Condensed polymer walls form instantaneously at the interface of the emulsion droplets.

In-situ polymerization

In a few microencapsulation processes, the direct polymerization of a single monomer is carried out on the particle surface. In one process, e.g. cellulose fibers are encapsulated in polyethylene while immersed in dry toluene. Usual deposition rates are about 0.5ìm/min. Coating thickness ranges 0.2-75ìm. The coating is uniform, even over sharp projections.

Matrix polymerization

In a number of processes, a core material is imbedded in a polymeric matrix during formation of the particles. A simple method of this type is spray-drying, in which the particle is formed by evaporation of the solvent from the matrix material. However, the solidification of the matrix also can be caused by a chemical change.

Proteins from plant sources as wall materials for encapsulation

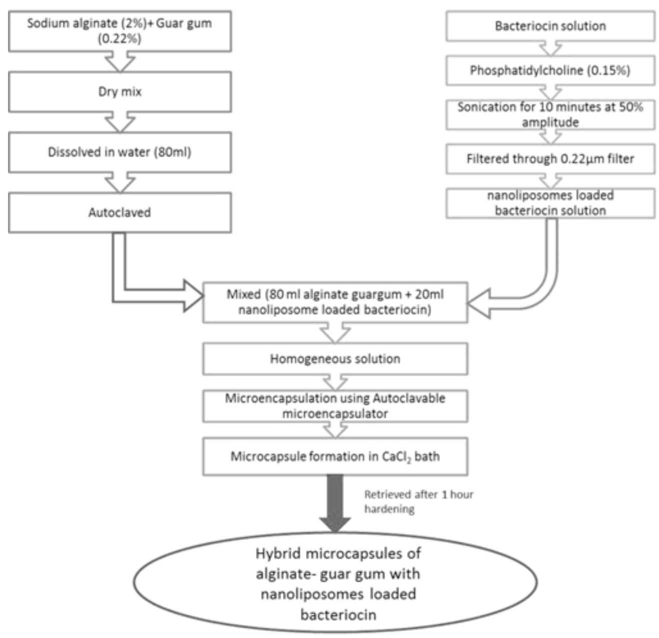
Proteins from plant sources are gaining popularity for different functional uses besides regular use for nutrition (Boye et al. 2010). One of the uses include as wall material for encapsulation. Legume protein isolates derived from chickpea (CPI), faba bean (FPI), lentil (LPI) and soy (SPI) were used as wall materials to test the effect of protein-type on the protective nature of the capsule (Johnston, 2013). However, the micron sized capsules produced were not adequate for protecting *Bifidobacterium adolescentis* during acid challenge. Although soy proteins dominate the plant protein ingredient market, concerns over allergens are driving research activities towards other legume based proteins derived from chickpea, faba bean, lentil and/or pea, due to their similar physicochemical properties (Joshi et al., 2012).

Application of Micro Encapsulation for Active ingredients

Microencapsulation of bacteriocin

Bacteriocin is of special interest in the food and dairy industry due to its natural antimicrobial properties. It is added in the food formulations as a natural preservative in order to increase the shelf life of food. However, direct addition of bacteriocin in the food causes reduction in the antimicrobial efficacy due to their structural instability, undesirable interaction with the food constituents and inactivation by enzymatic degradation. In addition, it may also result in development of bacteriocin resistant bacteria. Encapsulation or entrapment of bacteriocin may bring about the protection of them from the adverse conditions of the food environment. It may also facilitate the development of controlled release properties of bacteriocin by reducing its transfer rate to the outside environment. Encapsulation of nisin in calcium alginate was purposed for improving its long term effectiveness in food (Narsaiah et al. 2012). Nisin is primarily active against Gram-positive bacteria but when combined with a chelator, nisin can inhibit growth of some Gram-negative bacteria also and is thus potentially effective against a broad spectrum of bacteria. The study optimized the conditions for microencapsulation of nisin at different air pressures using response surface methodology. For this purpose, an autoclavable microencapsulation system was developed with multistage break up two fluid nozzle and programmable pump. Microencapsulation was successfully carried out through this microencapsulator with encapsulation efficiency of 36.65 % and leads to an increase in shelf life and stability of nisin.

Similarly, pediocin, a small antilisterial polypeptide bacteriocin was also encapsulated through this two fluid nozzle system using different wall materials such as phospholipids, proteins, carbohydrate polymers and combinations of these (Narsaiah et al. 2013). The study compared the controlled release behavior of pediocin loaded in delivery systems of different wall materials and found hybrid capsules of alginate plus guar gum incorporated with pediocin-loaded nanoliposomes of phosphatidylcholine as the most effective delivery system for controlled release of pediocin. A recent study conducted by Hosseini et al. (2014) also performed encapsulation of nisin in alginate (Alg) and alginate-resistant starch (Alg-RS) in order to improve its stability. Studies found that more encapsulation efficiency and loading capacity values were obtained when the resistant starch was added to the alginate formulation. The *in vitro* nisin release from these microparticles followed a controlled-release pattern and the release rate from Alg-RS microparticles was less than that from the Alg microparticles. In another study, a potentially probiotic bacteria was isolated from shellfish digestive gland and screened for activity against different pathogens. The active antimicrobial bacteriocin produced by this isolate was partially purified and encapsulated in 3% of alginate and an alternative using $BaCl_2$ instead of $CaCl_2$ in the hardening bath significantly improved its encapsulation (Fajardo et al. 2014). The coating of alginate (2% (w/w)) with bacteriocin could be used to store minimally processed papaya for 3 weeks without compromising physico-chemical qualities or microbial safety (Narsaiah et al., 2015).



Process flow chart

Optimized Process for encapsulation of bacteriocins

Alginate (0.2g) and guar gum (0.22g) were mixed as dry powders. This mixture was dissolved in distilled water (80 ml) and solution was autoclaved. Phosphatidylcholine (0.15g) was added to bacteriocin solution and sonicated at 50% amplitude for 10 minutes to prepare nanoliposomes. Pediocin loaded nanoliposomes solution was filtered through 0.22µ filter. Filtered solution (20ml) was added to alginate guar gum solution and stirred to get homogeneous solution. Mixed solution was atomized through autoclavable microencapsulator into calcium chloride (0.2M) bath to generate microcapsules. Microcapsules were hardened for one hour. Hybrid microcapsules of alginate- guar gum with nanoliposomes loaded bacteriocin were retrieved from calcium chloride bath using muslin cloth. This process was optimized to yield about 65% encapsulation efficiency and good antimicrobial activity with controlled release of pediocin.

Microencapsulation of vitamins and proteins

Desai, et al (2005) reports the properties of vitamin C encapsulated sodium alginate beads prepared by an alternative approach. The alternative encapsulation process mainly involves immobilization of vitamin C in hydrated zinc oxide layers and encapsulation of prepared immobilized particles in sodium alginate bead. The immobilization of vitamin C in hydrated zinc oxide layers was achieved by a coprecipitation process. Fourier transform infrared (FTIR) spectroscopy showed that the vitamin C was found to be stable after its immobilization. X-ray diffraction (XRD) studies revealed that anionic vitamin C molecules are adsorbed between positively charged zinc hydroxide layers with a 1:1 layer sequence, since well-defined change in basal spacing was observed. Well-defined change in surface morphology was observed by scanning electron microscopy (SEM) when vitamin C immobilized particles are encapsulated in sodium alginate bead. The biological activity of vitamin C was retained, even after its immobilization which was confirmed by 4-dihydroxy-L-phenylalanine (L-DOPA) oxidase inhibition and free radical scavenging activity studies. The release rate of vitamin C from immobilized particles and beads was sustained through an ion exchange process. A higher amount of stable vitamin C was recovered from the bead when compared to neat vitamin C itself.

Katti (1999) described preparation of albumin microspheres by an improved process. In this study microspheres were prepared by the suspension cross linking method for the first time in the absence of any surface active agent, using paraffin oil as the dispersion medium and formaldehyde as the cross linking agent. The microspheres thus obtained were characterized using a Scanning Electron Microscope and found to be spherical and having a particle size distribution in the range 50-400 microns. A preliminary drug release study of chlorothiazide invitro indicated a diffusion controlled release of the drug. This method, being simple and cost effective, could be a promising technique for the large scale manufacture of microspheres.

Taste and odour masking (Prem, 2004) is yet another application of microencapsulation. High protein concentrate from casein, soy protein, fish protein are made palatable by microencapsulation with fats having melting point above 70^{o}F. To overcome the objection, encapsulated garlic oil is strongly recommended , specially in food plant, as its also helps in preventing the cross contamination of the flavour.

Microencapsulation of fish oil

Omega-3 (ù-3) and omega-6 (ù-6) fatty acids found in fish oils are among the most important functional food ingredients. They improve the cardiovascular activity, enhance long-term memory and normal brain function (Kralovec, et al., 2012). However, ù-3 fatty acids are susceptible to degradation releasing unhealthy products such as secondary oxidation products of poly unsaturated fatty acids, aldehydes, ketones, alcohols, volatile organic acids, hydrocarbons and epoxy compounds (Shahidi and Zhong, 2010). Encapsulation is an excellent approach to avoid above problems as it can provide stability and protection, confer targeted and controlled release characteristics. Furthermore, it masks unpleasant odour and taste, extends the shelf life and enhances the bioavailability and palatability of the encapsulated materials. For effective delivery of functional foods, the carrier systems should have properties such as good uptake, extended circulation time, no/acceptable clinical side effects, high biocompatibility and low immunogenicity (McClements, et al., 2007).

Fish oils represent a functional food as it contains important components for maintenance of good health and prevention of a range of human diseases via the beneficial effects on the heart, brain and nervous system (Wu et al., 2009). Fish oil supplements contain significant amounts of omega-3 fatty acids including á-linolenic acid (C18:3, n -

3), eicosapentaenoic acid (C20:5, n - 3), and docosahexaenoic acid (C22:6, n -3) and may be important dietary sources. Nonetheless, fish oil has a strong odour and it is easily susceptible to oxidation of its constituent highly unsaturated long chain fatty acids. These negative attributes could be minimized or eliminated by encapsulation of the fish oil. As well, encapsulation would protect fish oil from auto oxidation of polyunsaturated fatty acid (Jafari, et al., 2008).

Chen et al., 2013 has encapsulated fish oil with phytosterol esters and limonene by milk proteins. Their study has provided some useful insight into the application of the co encapsulation concept to protect spray-dried fish oil microcapsules from oxidation by introducing other lipophilic bioactive components, namely phytosterol esters and limonene as core material. Current finding indicates that co-encapsulation of fish oil with phytosterol esters could effectively prevent polyunsaturated fatty acids from oxidation, and the incorporation of limonene showed good ability to mask the undesirable fishy odour.

A process was standardized at ICAR-CIPHET for preparation of nano emulsion of fish oil and lecithin in water using high pressure homogenizer. Alginate, with either skim milk powder or whey protein concentrate powder, was explored as delivery matrix to further stabilize the nano emulsion of fish oil for incorporation in functional foods. Fish oil emulsion was oozing out in beads of alginate with skim milk powder. Alginate with whey proteins yielded beads with an encapsulation efficiency of 89% and without any oozing fish oil emulsion. These beads were coated with vanilla flavored high melting fat to fully mask the smell of fish oil.

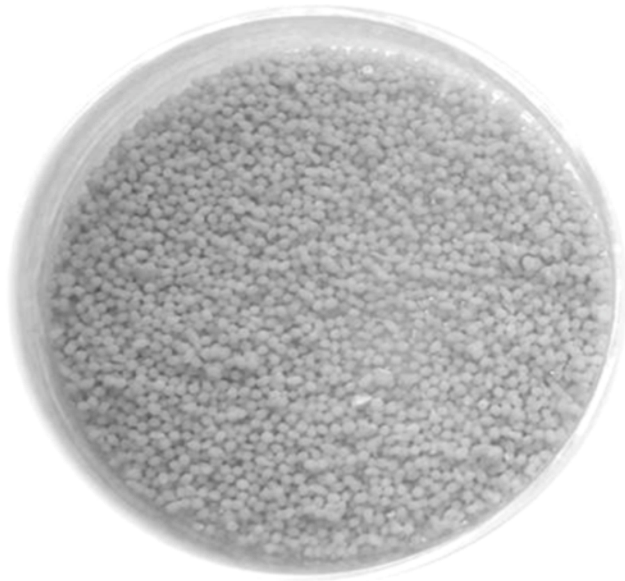


Fig: Beads of alginate, whey protein and fish oil coated with high melting fat

Microencapsulation of Flax seed oil

Flaxseed oil is polyunsaturated oil extracted from the flax plant (*Linum usitatissimim*) rich in á-linolenic acid (ALA), the essential fatty acid omega (ù)-3, which represents about 57% of its total fatty acids. The high content of ù-3 fatty acid present in this oil allows the attribution of functional food, which means that besides the nutritional functions, its consumption may have beneficial effects on health like promoting eye health, development of brain and nervous system in infants, reducing the risk of hypertension, hypercholesterol and cancer including colon, breast & prostate, improving intelligence and memory, inhibition of aging, reduction of inflammatory bowel diseases & coronary heart diseases, lessening neurodegenerative disorders and controlling diabetes (Goyal et al. 2014; Rodriguez-Leyva et al. 2010; Carraro et al. 2012; Singh et al. 2011). Helena et al., (2013) obtained encapsulation efficiency values which varied from 62.3% to 95.7% of flaxseed oil microencapsulated by spray drying using different combinations of wall materials.

Microencapsulation of polyphenols and pigments

Ersus et al (2007) acidified ethanol extracts of black carrots which has a high anthocyanin content (125 ± 17.22 mg/100 g) and were spray dried using a range of maltodextrins [Stardri 10 (10DE), Glucodry 210 (20–23DE) and MDX 29 (28–31 DE)] as a carrier and coating agents, at 3 different inlet/outlet air temperatures with constant feed solid content (20%). Higher inlet/outlet air temperatures caused greater anthocyanin loss during spray drying. The quality attributes of the powders which were produced at optimum drying temperatures (160°C) were characterized by their anthocyanin content, antioxidant capacity, L*, a*, b*, C* and H°values, dry matter content and hygroscopicity. The best dried pigment containing powder was found where the Glucodry 210 was used as wall material. Scanning electron microscope was used for monitoring the structures and size (3–20 µm) of the powders. For determination the stability and half-life period of microencapsulated pigments, samples were stored under different storage temperatures (4°C and 25°C) and light illumination (3000 lx).

Shu et al (2006) investigated the effects of technological parameters including the ratio of core and wall materials, ratio of gelatin and sucrose, homogenization pressure, inlet temperature, feed temperature, and lycopene purity on encapsulation yield (EY), encapsulation efficiency (EE). Lycopene microcapsules were prepared by a spray-drying method using a wall system consisting of gelatin and sucrose. The resulting microcapsules were characterized in terms of lycopene isomerisation, storage stability, PS, PSD, and outer and inner structures. Results showed that EY and EE were significantly affected by the ratio of core and wall materials, ratio of gelatin and sucrose, homogenization pressure, inlet temperature, feed temperature, and lycopene purity. The optimal condition was determined as follows: the ratio of gelatin/sucrose of 3/7 and the ratio of core and wall material of 1/4, feed temperature of 55°C, inlet temperature of 190 °C, homogenization pressure of 40 MPa, and lycopene purity of not less than 52%, at which the microencapsulated lycopene showed some isomerisation, but a good storage stability. SEM and XRD analysis showed that lycopene microcapsules had a regular spherical shape with a PSD of 2–15 µm, mean PS of 5 µm, smooth outer surface, ‘‘bee net’’-like interior structure, and lycopene was embedded in the wall system consisting of gelatin and sucrose.

Shi et. al., (2008) encapsulated the photosensitive resveratrol was successfully encapsulated in yeast cells for the first time, as characterized by FT-IR spectra, fluorescence and confocal micrographs of the yeast cells, resveratrol and microcapsules. The release characteristic of the obtained yeast-encapsulated resveratrol in simulated gastric fluid was evaluated, and its storage stability as a powder was investigated at 25 °C/75% relative humidity (RH), 25 °C/90% RH and 60 °C under the laboratory fluorescent lighting conditions (ca. 300 lx) or in the dark. Also, the scavenging capacity of yeast-encapsulated resveratrol on DPPH radical was compared with that of non-encapsulated resveratrol. It could be demonstrated clearly that no chemical changes occurred during the encapsulation. Besides, the DPPH radical-scavenging activity increased after the encapsulation. In addition, the yeast-encapsulated resveratrol exhibited good stability, and its bioavailability was enhanced as a result of increased solubility of resveratrol and sustained releasing.

Microencapsulation of Flavours and Pigments

Shaikh (2006) reported microencapsulation of black pepper oleoresin by spray-drying, using gum arabic and modified starch as wall materials. The microcapsules were evaluated for the content and stability of volatiles, non-volatiles, total piperine and entrapped piperine for six weeks. Gum arabic offered greater protection to the pepper oleoresin than modified starch, as seen from the t1/2, time required for a constituent to be reduced to 50% of its initial value.

Jun-xia et al (2011) investigated the coacervation between soybean protein isolate (SPI) and gum Arabic (GA) for sweet orange oil microencapsulation as functions of pH, ionic strength, SPI/GA ratio, core material load and micro molecules. SPI was exposed to ultrasonic to increase solubility before use and microcapsules were spray-dried before analysis. It was found that the optimum pH for SPI/GA coacervation was 4.0. High ionic strength reduced the coacervation between the two biopolymers. The highest coacervate yield was achieved in SPI/GA ratio 1:1 and the core material load for the highest microencapsulation efficiency (MEE) and microencapsulation yield (MEY) was 10%. The addition of sucrose in sucrose/SPI ratio 1:1 increased the MEY by 20%, reaching 78% compared to 65% of control. The microcapsules were spherical without holes on the surface by SEM observation and flavour components were well retained in microcapsules according to GC–MS analysis, indicating good protection for core material.

Shu et al.(2005) prepared lycopene microcapsules by a spray-drying method using a wall system consisting of gelatin and sucrose. The effects of technological parameters including the ratio of core and wall materials, ratio of gelatin and sucrose, homogenization pressure, inlet temperature, feed temperature, and lycopene purity on encapsulation yield (EY), encapsulation efficiency (EE) were investigated. Results showed that EY and EE were significantly affected by the ratio of core and wall materials, ratio of gelatin and sucrose, homogenization pressure, inlet temperature, feed temperature, and lycopene purity. The optimal condition was determined as follows: the ratio of gelatin/sucrose of 3/7 and the ratio of core and wall material of 1/4, feed temperature of 55 °C, inlet temperature of 190 °C, homogenization pressure of 40 MPa, and lycopene purity of not less than 52%, at which the microencapsulated lycopene showed some isomerization, but a good storage stability. SEM and XRD analysis showed that lycopene microcapsules had a regular spherical shape with a PSD of 2–15 ìm, mean PS of 5 ìm, smooth outer surface, "bee net"-like interior structure, and lycopene was embedded in the wall system consisting of gelatin and sucrose.

Korus et al. (2003) described a method for preparation of microcapsules from granular potato starch by its prolonged (up to 48 h) soaking in water is proposed. The effects of temperature and size of granules is studied. Such treatment removes the amorphous part of the granule interior, forming empty domains inside granules. Material evacuated from the granules was identified as amylopectin together with amylose. The application of such pre-treated granules for microencapsulation of various fragrant compounds (angelicalactone, diacetyl, dibenzyl ether, 2,6-lutidine and myrcene) from their vapours and from their liquid state is described. Depending on pre-treatment of starch and the microencapsulation method applied, the amount of trapped guest molecules is up to 30 wt%.

Soottitantawat et al. (2005) studied about microencapsulation of *l*-menthol by spray drying, using gum arabic (GA) and modified starch (CAPSUL, HI-CAP 100) as capsule materials. The results showed a higher retention of *l*-menthol with the increasing of initial solid concentration. HI-CAP 100, showed a higher retention than the other capsule materials. However, it also showed a higher residue of *l*-menthol on the surface of powder especially at the high concentration of *l*-menthol in the feed emulsion. That might be from the interaction between the wall materials and *l*-menthol which can re-crystallize to form whisker after the spray drying. Furthermore, the release characteristics of *l*-menthol were also investigated. The release rate increased upon elevation of relative humidity and temperature. The activation energies of the release of *l*-menthol from GA wall matrices at 75 and 83%RH were 140 and 48 kJ/mol, respectively.

Shaikh et al. (2006) reported a method for microencapsulation of black pepper oleoresin by spray-drying, using gum arabic and modified starch as wall materials. The microcapsules were evaluated for the content and stability of volatiles, non-volatiles, total piperine and entrapped piperine for six weeks. Gum arabic offered greater protection to the pepper oleoresin than modified starch, as seen from the $t_{1/2}$, time required for a constituent to be reduced to 50% of its initial value.

Prem (2004) reported a method for coffee aroma encapsulation. Liquefied coffee aroma is passed in to the emulsifying tank that contains the wall material, i.e., an aqueous gelatin material and a modifier, e.g., non –ionic surface reactive agent, such as tween. The mixture is homogenized and an emulsion of the coating substance and aroma. The emulsion is slurred in to the spinning tank, which has the pricess oil, i.e., white mineral oil, such as Nujol. With proper stirring and cooking of the content in the spinning tank, droplets or globules formation occurs in spinning tank. Droplets are formed and remain suspended in the process oil. Globules formation occurs in spinning tank primarily because of aqueous gelation emulsion is insoluble in process liquid. Suspended globules are dried by anhydrous alcohol in the dehydration tank. Dried globules become capsules and are suspended from the process liquid and dehydrating medium by centrifugation or filtration. The capsules are washed free of the process liquid with the aid of a solvent and the solvent is recovered. Last traces of solvent are removed. Encapsulated coffee aroma can be retained for a year.

Prem (2004) stated that chewing gum composition has been found to have prolonged sourness, flavour and juiciness through incorporation of a delivery system comprising a food acid (e.g.malic acid) encapsulated in low molecular weight polyvinyl acetate material. Other process relates to the hydrophobic encapsulation of active material into the chewing gum. Controlled release of flavour together with aspartame gives a long lasting sweetened flavour perception during chewing of the gum.

Souza et al. (2005) studied about chitosan microspheres containing the natural curucum pigment. There is growing trend towards replacing synthetic additives with natural products in the food and pharmaceutical industries. Encapsulation has become an important process to protect natural pigments. This paper reports on the encapsulation of the natural urucum pigment with chitosan using different techniques and its release under different pH conditions.

The material loaded with pigment was evaluated by infrared spectroscopy, scanning electron microscopy and thermal analysis. Chitosan was found to be an effective encapsulating agent for urucum pigment.

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Artificial Intelligence and Advanced Analytics Technology Oriented Solutions for Empowering Indian Farmers: A Scientific Perspective

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The core of science is to obtain reliable knowledge discoveries, *i.e.*, to obtain conceptual model, empirical model, physical model, rules, law of causality and theory from experimental or observed data and to test the prediction based on the knowledge with the data. In Computer Science terminology, this method is known as Knowledge Discovery in Databases (KDD) or Data Mining, which is supported by Advanced Analytics (involving clustering, regression, correlations, Principal Component Analysis, *etc.)* and Artificial Intelligence (AI) based emerging Machine Learning (ML) algorithms including artificial neural network (ANN) models, fuzzy systems, genetic algorithms (GA's), neuro-fuzzy systems, neuro-evolution algorithms, support vector machines (SVM), random forests (RF), decision trees (DT), *etc.* AI techniques learn from data (rather than crunching numbers, conventionally) to figure out hidden patterns. Once clear patterns are defined, the methodology is further strengthened when fed more data to it. The resultant is an artificial brain (loosely speaking, human-brain like model) that intelligently gathers, analyses and interprets an amount of data that a human being would be unable to manage over its entire life. The more data it has and the more patterns it finds, the more accurate the interpretation will be. Hence, several new AI-based technologies like Cloud Machine Learning, Satellite Imagery and advanced analytics are emerging, which can potentially empower small-holder farmers in India to increase their income through higher crop yield and greater price control.

The process of knowledge discovery starting from data is becoming an urging issue whose relevance is growing with the advancement of technology that permits the manipulation of massive amounts of data. KDD involves the study of mechanisms, which allow recognising precise patterns inherent in a dataset that can be exploited as a form of knowledge in particular learning tasks. Hence, knowledge discovery is a wide ranged process including data mining, which is used to find out meaningful and useful patterns in big data. In this context, the emerging role of hybrid ML models such as Adaptive Neuro-Fuzzy Inference System (ANFIS) and neuro-evolution algorithms assume crucial relevance amongst the innovative approaches that make use of natural language expressiveness to tackle KDD problems thus improving comprehensibility of the obtained results. These hybrid intelligent systems lend themselves well to handle incomplete and heterogeneous data and their application to knowledge discovery processes results very helpful in terms of interpretability. The use of AI algorithms in agricultural research is common nowadays (please see the Bibliography).

Generally, ANN models (also known as connectionist models) consist of layers of interconnected neurons, each neuron producing a nonlinear function of its input. The input to a neuron may come from other neurons or directly from the input data. Also, some neurons are identified with the output of the network. The complete network, therefore, represents a complex set of interdependencies, which may incorporate any degree of nonlinearity, allowing very general functions to be modelled. In the simplest neural networks, the output from one neuron is fed into another neuron in such a way so as to propagate the inherent features through layers of interconnecting neurons (Fig.1).

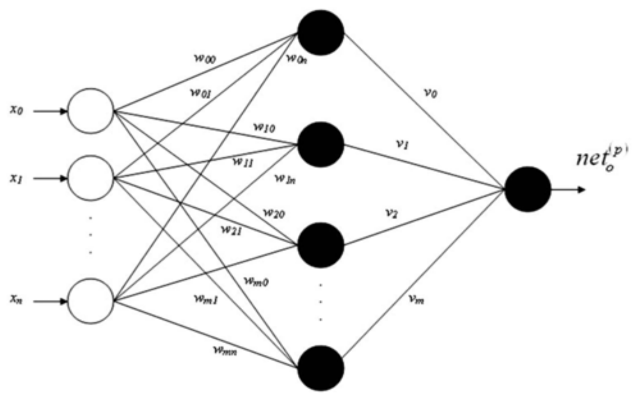

Fig. 1. Schematic of a feed-forward ANN model

Feed-forward ANN models used in this study allow signals to travel in one direction only, *i.e.*, from input towards output. These models can be considered as simple straightforward networks that associate inputs with outputs. ANN models consist of the following three principal elements:

- Topology – the way a neural network is organised into layers and the manner in which these layers are interconnected;
- Learning – the technique by which information is stored in the network; and
- Recall – how the stored information is retrieved from the network.

Fuzzy logic (FL) is a departure from classical Boolean logic as it implements soft linguistic variables on a continuous range of truth values, which allows intermediate values to be defined between conventional binary. Fuzzy logic application to problem solving involves three steps: converting crisp (numerical) values to a set of fuzzy values, an inference system (based on fuzzy if-then rules) and defuzzification. Fuzzy Inference System (FIS) model can be of two types, Mamdani and Sugeno. As a more compact and computationally efficient representation than a Mamdani system, the Sugeno system lends itself to the use of adaptive techniques for constructing fuzzy models. The later system is used to model an inference system in which the output membership functions are either linear or constant. These adaptive techniques can be used to customise the membership functions (MF's) so that the fuzzy system best models the data.

The ANFIS is a combination of the ANN and FIS as the artificial neural networks are used to determine the parameter of the FIS. That is, it combines the advantages of fuzzy systems, which deal with explicit knowledge that can be explained and understood; and that of the ANN's, which deal with implicit knowledge acquired through learning. The FL also enhances the generalisation capability of a neural network by providing more reliable output when extrapolation is needed beyond the limits of the training data. This approach provides means of training a family of membership functions to emulate a nonlinear, multi-dimensional mapping function. The ANFIS approach integrates the basic elements and functions of a conventional FIS into the neural network connective structure, which distributes the learning ability to obtain the membership functions and fuzzy logic rules.

The architecture of ANFIS has five layers (Fig.2) to accomplish the tuning process of the fuzzy modelling system.

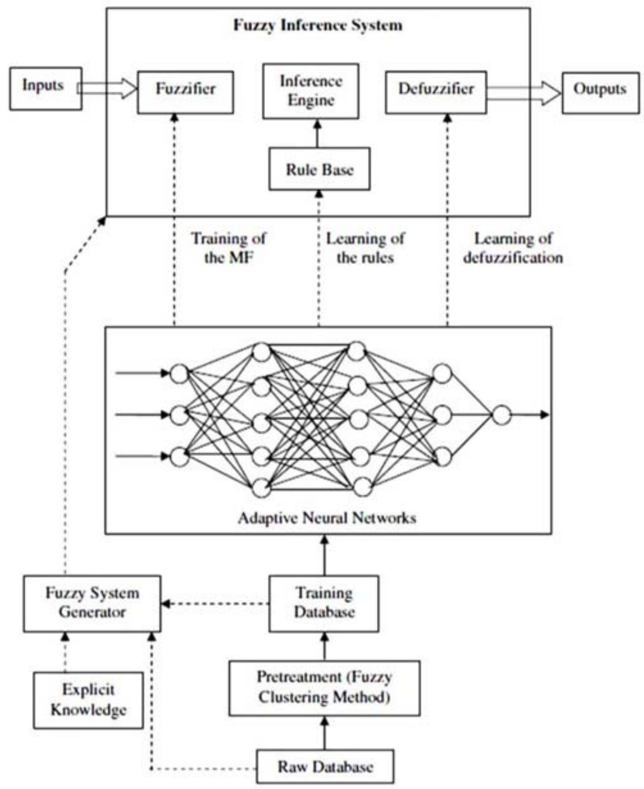

Fig. 2. Architecture of the Adaptive Neuro-Fuzzy Inference System

These five layers are as follows:

i) Layer 1: Every node in this layer is an adaptive node with a node function (*i.e.*, membership function). Parameters of membership functions are referred to as premise or antecedent parameters.

ii) Layer 2: Every node in this layer is a fixed node, which multiplies the incoming signals and sends the product out. Each node represents the firing strength of a fuzzy rule.

iii) Layer 3: Every node in this layer is a fixed node, which calculates the ratio of the one firing strength to the sum of all rules' firing strengths. The outputs of this layer are called normalised firing strengths.

iv) Layer 4: Every node in this layer is an adaptive node with a node function (*i.e.*, linear combination of input variables). Parameters in this layer are referred to as consequent parameters.

v) Layer 5: The single node in this layer is a fixed node that computes the overall output as the summation of all incoming signals.

Hence, this five-layer network architecture, ANFIS is a hybrid model that puts the fuzzy model into the framework of adaptive networks that can compute gradient vectors systematically.

The idea of combining GA's and ANN's (*i.e.*, neuro-evolution algorithms) to solve difficult problems has been a field of intense research. Neuroevolution algorithms are used in the decision making in various fields of study. As stated earlier, ANN's mimic human brain and nervous system while evolutionary algorithms (or, GA's) are based on Darwin's theory of survival of the fittest. They involve operations such as selection, crossover and mutation to find the best solution over a number of generations. Thus, GA is basically an optimisation technique that moves towards optimum solution through artificial evolution.

A typical procedure for optimising ANN with GA recently developed by the author is outlined below:

1. Initialisation of ANN
2. Chromosome in GA is constructed by concatenating weights from the network
3. Minimisation of Mean Square Error (MSE) is used as objective function for GA optimisation.
4. Weights evolved by GA are fed to ANN.

This procedure is depicted diagrammatically in Fig.3.

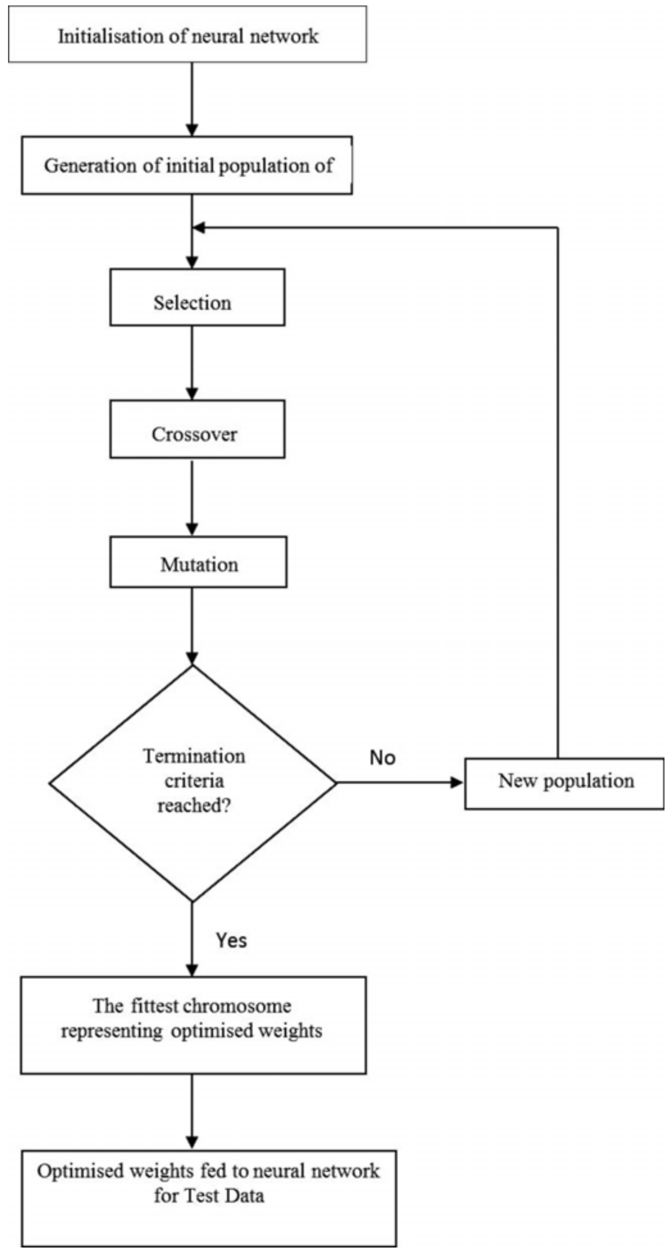

Fig. 3. Flowchart of the neuroevolution algorithm

Machine learning studies conducted at ICAR-NDRI, Karnal

Animal Science Applications

1. Classification of healthy and mastitis Murrah buffaloes by application of neural network models using yield and milk quality parameters
2. Prediction of lameness based on the percent body weight distribution to individual limbs of Karan Fries cows
3. Effective and accurate discrimination of individual dairy cattle through acoustic sensing
4. Predicting economic traits in Murrah buffaloes with connectionist models
5. Comparative efficiency of artificial neural network and multiple linear regression analysis for prediction of first lactation 305-day milk yield in Sahiwal cattle
6. Comparison of connectionist and multiple regression approaches for prediction of body weight of goats
7. Prediction of first lactation 305-day milk yield in Karan-Fries dairy cattle using ANN modelling
8. Modelling fertility in Murrah bulls with intelligent algorithms.

Dairy and Food Engineering Applications

1. Prediction of convective heat transfer coefficient during deep-fat frying of *pantoa* using neuro-computing approaches

2. Modelling moisture sorption characteristics in *dried acid casein* using connectionist paradigm *vis-à-vis* classical methods
3. Intelligent modelling and analysis of moisture sorption isotherms in milk and pearl millet based weaning food 'fortified *Nutirmix'*
4. Comparative study of kinetic and connectionist modelling for shelf life prediction of *Basundi* mix
5. Prediction of sensory quality of UHT milk – A comparison of kinetic and neural network approaches

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Adulteration Detection in Food Samples: Role of Near Infra-Red Spectroscopy

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Adulteration means the addition of foreign or inferior ingredients which are not permitted in food. The deliberate contamination of food material with low quality, cheap and non-edible or toxic substances is called food adulteration. The adulteration can be incidental due to negligence or intentional as they are added because of business profit only. The food items are mostly adulterated in most of developing countries or sometimes in developed countries where regulations are not very strict. Adulterated foods are harmful for human health as they contain the unauthorized food ingredients. Adulteration in foods also decreases our moral and social value. The major disadvantages of adulterants are: consumers have to pay more for foodstuffs of lower quality and some adulterants have injurious health effects.

Now a days the new term "economically motivated adulteration" (EMA) is used for adulteration. According to the U.S. Food and Drug Administration (FDA) economically motivated adulteration (EMA) is defined as the "fraudulent, intentional substitution or addition of a substance in a product for the purpose of increasing the apparent value of the product or reducing the cost of its production, *i.e.*, for economic gain".

Analytical methods/techniques used for adulterant detection

1. **Physical methods**: Used in adulterant detection are macroscopic and microscopic methods, visual and structural evaluation, studies related to the determination of texture, solubility and bulk density *etc*.
2. **Biochemical spectroscopic methods:** UV-Vis spectroscopy, mass spectrometry (MS); nuclear magnetic resonance (NMR); Infra-red (IR) spectroscopy, Near infra-red (NIR) spectroscopy, atomic spectroscopy (AS), Fourier Transform Infrared spectroscopy (FTIR) etc.
3. **Biochemical separation techniques:**These techniques includeuse of spectroscopy UV/VIS, high performance liquid chromatography (HPLC), thin layer chromatography (TLC), gas chromatography (GC), gas chromatography mass spectroscopy (GC-MS),Supercritical fluid chromatography (SFC),liquid chromatography mass spectroscopy (LC-MS), capillary electrophoresis, polyacrylamide gel electrophoresis (PAGE), liquid chromatography nuclear magnetic resonance (LC-NMR)*etc.*
4. **Immunological methods** are enzyme linked immunosorbent assay, electronic nose, and biosensors.
5. **DNA based molecular tools** are more ideal for adulterant detection in different crop-based commodities when the adulterants are biological substances. Molecular methods include PCR based methods.

There are various methods for adulteration analysis but they have to follow the destruction of specific lot or specific area of foodstuff, in modern era with growing economic as well as quality standards we need to develop or discover such technique which do not impart any qualitative change into the product while analyzing. Among the different methods the Infra-red (IR) spectroscopy and Near infra-red (NIR) spectroscopy are fast, non-destructive, non-invasive, with high penetration of the probing radiation beam, suitable for in-line use, and require minimum sample preparation.

Infra-red spectroscopy

Infra-red spectroscopy examines the outcome of interaction among radiated energy and matter in the infra-red range, and the effect is assessed by quantifying the absorption of different infrared frequencies through a sample positioned in the infra-red beam pathway. The radiation can either be transmitted or absorbed, relying up on the frequency of it and the molecular structure in the sample, when a beam consisting of infra-red radiation is passed from the sample. When the energy quanta are provided, the molecular mechanical behavior is changed, hence changing their rotational as well as vibrational modes. The energy absorption exhibits at different frequencies parallel to the molecular means of vibration of the analogous chemical group or molecule.

The infrared electromagnetic spectrum ranges from 12500 to 10 cm^{-1}, and being categorized in three sub categories: a) Near infrared b) Mid infrared c) Far infrared. The near infrared region lies in the range of 12500 to 4000 cm^{-1}, while mid infrared occupies the region of 4000 to 400cm^{-1}, and far infrared ranges from 400 to 10 cm^{-1}.

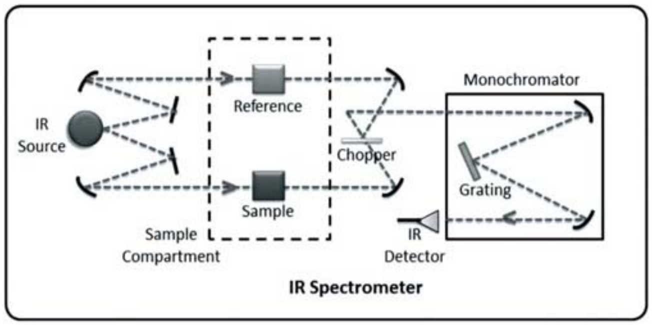

Fig. 1. Infra-Red Spectroscopy: overview (http://namrataheda.blogspot.com/2014/01/spectrophotometry-ir-spectroscopy_30.html)

Spectral regions and corresponding analytical techniques

	λ (μm)	υ (cm^{-1})
Near infrared region(near infrared spectroscopy, NIR)	0.8-2.5	12500-4000
Mid infrared region (mid infrared spectroscopy, Mid IR, MIR)	2.5-25	4000-400
Far infrared region (far infrared spectroscopy, FIR)	25-1000	400-10

MIR – normal vibrational transitions; NIR – overtones; FIR – normal vibrations of weak bonds and bonds of heavy atoms

Near-infrared (NIR) Spectroscopy

Near-infrared (NIR) Spectroscopy is based on the absorption of electromagnetic radiation at wavelengths in the range 750-2500 nm. NIR spectra of foods comprise broad bands arising from overlapping absorptions corresponding mainly to overtones and combinations of vibrational modes involving C-H, O-H and N-H chemical bonds. Its overall objective is to probe a sample in order to acquire qualitative and/or quantitative information coming from the interaction of near-infrared electromagnetic waves with its constituents. NIR technology has incorporated all the benefits brought by the evolution of correlated fields such as Chemo-metrics, new materials for optical components, new sensors and sensor arrays, microcomputers and micro-electronics.NIR spectroscopy is used routinely for the compositional, functional and sensory analysis of food ingredients, process intermediates and final products.

Applications of NIR spectroscopy

Detection of adulteration in milk

Conventional techniques for checking milk legitimacy depend up on wet science to focus the measure of an artificial compound in a suspected stuff and a resulting examination of the values acquired by the identical material. He *et al.*, 2010 used Fourier Transform Infrared spectroscopy (FTIR) combined with two-dimensional (2D) correlation spectroscopy for the discriminative analysis of adulteration in milk. They found the characteristic peaks of the raw milk were in the range of 4000-400 cm^{-1} region by its original spectra. Then, 2D correlation spectra of the samples were obtained which had high time resolution and provided information about concentration-dependent intensity changes that was not readily accessible from one-dimensional spectra. The characteristic peaks in the synchronous 2D correlation spectra of the suspected samples was compared with those of raw milk and melamine, urea, tetracycline and glucose adulterations in

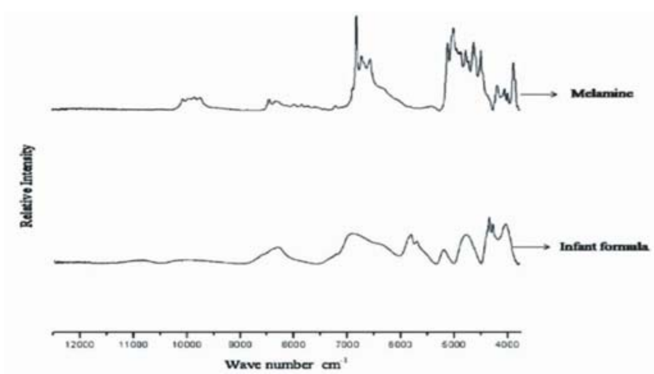

Fig. 2. NIR absorption spectra of melamine and infant formula powder collected after automatic baseline correction and smoothing (Source: Mauer *et al.*, 2009)

milk were identified. Kasemsumran *et al.* (2007) used NIR spectroscopy to examine two milk adulterants (water and whey) in natural cow milk. They used discriminant partial least squares (DPLS) and soft independent modelling of class analogy (SIMCA) methods for classification of milk adulterations and natural milk.

Detection of adulteration in coffee

Briandet *et al.*, 1996 used Fourier transform infrared (FTIR) spectroscopy as a rapid alternative method for the detection of adulteration of freeze dried instant coffee samples adulterated with glucose, starch or chicory in the range 20–100 g kg^{-1}.

Detection of adulteration in honey

According to the international honey standards, honey should not have any added food ingredients, other than honey, to it nor should any particular constituent be removed from it. When honey from one country is sold in another country to increase its sales adulterants can have an effect on the sales of other honeys in that country. It is quite possible to detect adulteration using NIR based techniques and by calibrating enough honey samples and analyzing them using principal component analysis (PCA) and partial least square (PLS) techniques. The adulteration of honey with invert sugar or syrup may not readily be detected by direct sugar analysis because its constituents are the major natural components of honey and the adulterated product would also have similar physical properties to natural honey. Tu *et al.* (2011) used NIR combined with pattern recognition methodsto discriminate the unadulterated and adulterated honey samples. Similarly, Kamaravelu and Gopal (2015) used Near Infrared spectroscopy technique for detection and quantification of jaggery adulteration in honey.

The differentiation models for adulteration of honey were constructed by four kinds of pattern recognition methods, including partial least squares discriminate analysis (PLS-DA), soft independent modeling of class analogy (SIMCA), error back propagation network (BP-ANN), least-squares support vector machine (LS-SVM). The results showed that four methods could all correctly differentiate honey samples that were adulterated with high fructose syrup and fructose-plus-glucose solutions. Compared with the four kinds of models, it was found that LS-SVM had the best results, the classification accuracy for both calibration set and prediction set were 100% for two kinds of adulteration.

Detection of durum wheat adulteration

NIR spectroscopy has been used in the cereal analysis since the late seventies (Osborne, 2000), being successful in modelling many quality variables, such as protein, moisture, dietary fibre contents, and wheat hardness. Wheat for human feeding can be essentially distinguished in two species, *i.e.*, durum wheat (*Triticum durum*) and bread wheat (*Triticum aestivum*), which are characterized by different chemical and physical properties that give rise to different quality, nutritional contribution and, consequently, commercial value of the final products. The problem of durum wheat adulteration with common bread wheat is of particular interest in the Italian, French and Spanish markets, where semolina is the only allowed constituent for pasta, while in the north European countries both bread and durum wheat are allowed. Cocchi *et al.*, 2011 used NIR spectroscopy in order to quantify the degree of adulteration of durum wheat flour with common bread wheat flour.

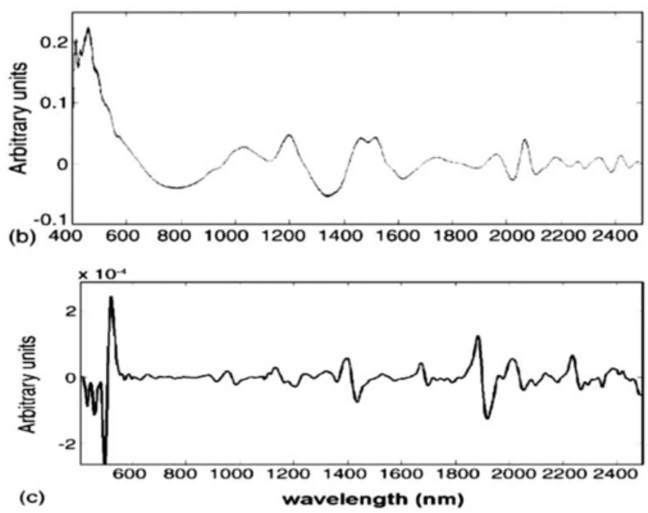

Fig. 3. Comparison between NIR spectra of b) pure durum wheat sample and c) pure bread wheat samples (Source: Cocchi *et al.*, 2011)

Detection of adulteration in fruit juices

NIRS have been applied for the detection of adulterations in a wide range of products including fruit juices and fruit products. Leon *et al.*, 2005 used near-infrared transflectance spectroscopy to detect adulteration of apple juice samples. They suggested that discriminant partial least squares (PLS) regression could detect authentic apple juice with an accuracy of 86-100% and adulterant apple juice with an accuracy of 91-100% depending on the adulterant type and level of adulteration considered.

Conclusions

NIR spectroscopy is a logical technique for use as it offers a rapid, low-cost and convenient analysis of key constituents and adulterants. NIR spectroscopy allows the detection of contaminants and their quantification faster. NIR instrumentation is, in general, less sensitive to environmental conditions and is highly flexible.Fast responses are particularly important to industry, where an answer is needed within minutes. NIR technology can be applied for screening of large number of samples. Apart from its powerful prediction capability, the non-destructive nature of this technique is very useful for fast analysis in on-line and at-line inspections and authentication of food. However, predictive performance of developed near infra red method depends on the precision of the reference method used for calibration.

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Processing of Foods for Addressing Malnutrition

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"A well-nourished child is one-third more likely to escape poverty, learn better in school, be healthier and grow into productive contributors to their economies" …Jessica Fanzo

Malnutrition in India

Malnutrition is a condition that results from eating a diet in which one or more nutrients are either not enough or are too much such that the diet causes health problems. Malnutrition, both undernutrition and overnutrition is a global challenge affecting every country and placing more than a quarter of the world's population at serious health risk. Furthermore, micronutrient malnutrition due to insufficient intake of essential micronutrients has taken centre stage in recent years.

As per the Global Nutrition Report (2017), India has a disappointing number of population suffering from one or other form of malnutrition. Over the decade between 2005 and 2015, there has been an overall reduction in the proportion of underweight children in India, mainly on account of an improvement in stunting. While the percentage of stunted children under 5 reduced from 48% in 2005-06 to 38.4% in 2015-16, there has been a rise in the percentage of children who are wasted from 19.8% to 21% during this period (Fig.1). Moreover, 51 per cent of the women of reproductive age suffer from anemia and more than 22 per cent of adult women are overweight. The percentage of overweight men in the country is slightly lower and stands at 16 per cent of adult men. This double burden of malnutrition—undernutrition and overnutrition —increasingly threatens the economies of country that must underwrite the health-care costs and lost productivity associated with nutrition-related illnesses.

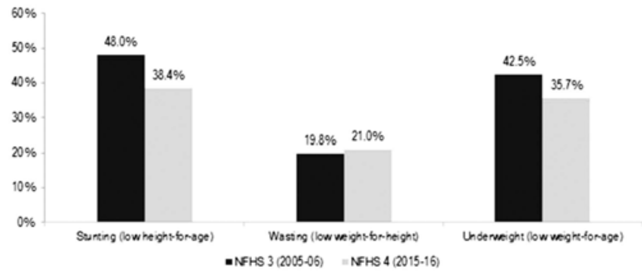

Fig. 1. Percentages of stunted, wasted and underweight children in India (Source: National Family Health Survey 3and 4)

Habitual diets in India

Diets of poor income groups are deficient in several nutrients such as energy, protein, iron, vitamin A, calcium and B-vitamins. Dietary deficiency of these nutrients occur more frequently and to a greater extent among children, pregnant and lactating women whose requirements of nutrients are higher than others. Deficiency of these nutrients in their diet is reflected in widespread prevalence of deficiency diseases like PEM (Protein Energy Malnutrition), anaemia, vitamin A and B-complex deficiency (predominantly riboflavin) and goiter in endemic areas. These dietary deficiencies are aggravated by infective morbidity amongst poor due to poor environmental and personal hygiene. Diets of the poor are predominantly based on cereals which provide 80% of energy and some amount of nutrients excepting vitamin A and vitamin C. Cereals have to be supplemented with food items such as pulses, vegetables, fruits, meat, milk and fat to balance and adequate in all the nutrients.

Foods can be grouped into five groups based on the content of major nutrients (Table1). This grouping of foods converts quantitative nutrient data into food related information that can be used by consumers in diet planning to achieve nutritional adequacy.

Food processing strategies

The global food system can drive economic growth while delivering healthier diets for farming households. Making agriculture more productive raises incomes for farming families, which can increase access to nutrient-rich foods. Women, who comprise nearly half of the world's farmers, can also be empowered to make better nutritional decisions for themselves and their families. Basic principle of nutritionally adequate diet to maintain health is that it must contain a variety of foods from all the food groups. Therefore, strategies to improve the nutritional status of a

Table 1. Five food group system (Nutritive value of Indian Foods, ICMR)

Food group	Nutrients supplied
Cereal grains & products Rice, Wheat, ragi, bajra, maize, jowar, barley, rice flakes, wheat flour	**Energy, protein**, Invisible fat, B vitamins, iron, folic acid, calcium, fibre
Pulses and legumes Bengal gram, black gram, green gram, red gram, lentil. Cowpea, peas, rajmah, Soyabeans	**Protein, energy**, Invisible fat, B vitamins, iron, calcium, fibre
Milk & meat products **Milk:** milk, curd, skimmed milk, cheese **Meat:** meat, chicken, fish, egg	**Protein**, Fat, riboflavin, calcium, vitamin B 12, fat soluble vitamins
Fruits & vegetables **Fruits:** mango, guava, tomato (ripe), papaya, orange, water melon, sweet lime **Green Leafy Vegetables:** Amaranth, spinach, drumstick, coriander, mustard, fenugreek **Other vegetables:** carrots, brinjal, ladies fingers, capsicum, beans, onion, cauliflower.	**Vitamins, minerals and fibre**, Invisible fat, trace minerals and vitamins
Fat & sugars **Fats:** butter, ghee, hydrogenated oils, cooking oils **Sugar:** Sugar, Jaggery	**Energy,** Essential fatty acids

population should include efforts to increase dietary diversity which can be brought about by processing and value addition.

Types of Food processing

Food processing encompasses many steps starting right after harvesting to the time it arrives on consumer's plate. Processed foods can be classified as-

- Primary processing is the conversion of raw materials to food commodities. It includes basic cleaning, grading and packaging as in case of fruits and vegetables.
- Secondary processing is the conversion of ingredients into edible products - this involves combining foods in a particular way to change properties. Peeling, dicing, juicing in case of fruits and vegetable is secondary processing.
- In tertiary processing, foods are so prepared and presented as to be easily and quickly ready for consumption. Tertiary processing leads to a high value-added ready-to eat food like frozen dinners or canned soup, instant foods, health drinks, etc.

Functions of Food Processing

Traditional food processing had two functions: to make food more digestible and to preserve food during times of scarcity as most crops are seasonal. By processing food, it can be customized to suit the nutritional requirements of groups such as the elderly, pregnant women, infants, young children and athletes. Modern food processing has three major aims:

- To make food safe (microbiologically, chemically)
- To provide products of the highest quality (flavor, color, texture)
- To make food into forms that are convenient (ease of use)

Thermal processing

Blanching, pasteurization and sterilization

Each type of heat processing has a specific purpose and the severity of each process depends on each objectives. Most fruits and vegetables are blanched prior to canning, freezing or dehydrating them. Food may be blanched by exposure to either boiling water, steam or hot air for approximately one to three minutes. Blanching inactivates enzyme system which degrade flavor and colour and which cause vitamin loss during subsequent processing and storage. It removes air from the tissue which is an important advantage, since oxygen can affect product quality and shelf life detrimentally. Blanching also destroys some of the contaminating microorganisms present.

Nutrient loss due to blanching usually results directly from leaching of water soluble vitamins into the water used for blanching. Blanching with steam, hot air or microwave does not require immersion in water and hence, substantially reduces leaching of vitamins.

Heat treatment during the canning process is specifically designed for each type of food product and container to destroy microorganisms of public health concern. Nutrient loss due to canning can vary considerably depending on variety of factors, such as type of food, container and the severity of heat applied. Retention of certain vitamins may be as low as 10% or as high as 100%. Because of these variations, it is difficult to make general statement about the effect of heat processing on nutrients. Nutrient loss can be minimized with the use of proper processing and cooking techniques.

Commercial sterilization is the application of sufficient heat to prevent any growth of microorganisms. Low acid foods (pH 4.7 and above) must be sufficiently heated to destroy the spores of *Clostridium botulinum* and render them incapable of germinating, multiplying and producing toxin. Canning process of these food depends on the product, type of retort, container size and ranges from 110-135°C for 12-325 minutes. The process used for high acid food is less severe because the acidity of the food itself inhibits the growth of *botulinum* microorganisms and thus requires less heat (approx. 100-105°C for 5-280 mins). Traditionally, food was canned in glass jars or can. Now it is also done by new, high temperature-short time (HTST) technique, coupled with aseptic packaging in flexible or brick style packages. These types of packages are currently used primarily for fruit juices, allowing substantial reduction in temperature and time thus providing increased nutrient retention and food quality. Retention of thiamine and pyridoxine, in particular is substantially improved.

Aseptic packaging, which was developed to overcome the problem of heat transfer through cans, allow fluid products to be pumped continuously through heat exchangers where they can be heated to the appropriate temperature very quickly. The juice is held at that temperature for the required time and then cooled. The sterile product in placed in sterile container and the opening sealed.

Heat transfer is slow in conventionally canned products, particularly non liquid products such as meat. Since heat is applied outside the product (or the container), the outer material is subjected to more total heat than necessary, to ensure sterility at the centre. Canned beans retained approximately 55% of the heat sensitive vitamin, thiamine, while canned tomatoes retain a larger percentage.

Pasteurization does not destroy or inactivates all the microorganisms. Some spoilage microorganisms remain which are capable of multiplying, thus spoiling the product. Moreover, not all the enzymes are also inactivated. Therefore, these products must be dated for shelf life. Treatments used for pasteurization include low-temperature-holding (LTH), high temperature short time (HTST) and ultra high temperature (UHT). LTH process involves heating the milk to a temperature between 62.8 and 65.6ºC, holding it at that temperature for 30 min, and rapidly cooling it to below 10ºC. In India, Milk generally undergoes High Temperature Short Time (HTST) pasteurization or Ultra High Temperature (UHT) sterilization. In HTST pasteurization process, milk is heated at 72 ºC for 15 sec followed by immediate cooling of <4ºC. The pasteurized milk is verified for key quality parameters to assure adequate food safety prior to hygienic packaging/ filling. In UHT process, milk is heated between 135°C to 145°C for 1-2 sec with subsequent cooling to ambient temperature.

HTST process provides more advantages over the older LTH method for pasteurization as a result of the effect of temperature on bacterial destruction compared to the effects on chemical reactions. The higher the temperature and shorter the processing time, greater is the nutrient retention- a fact which should also be noted while cooking at home. Milk pasteurized with HTST retains 90% of vitamin C and 100 % vitamin B_{12}, little or no loss of vitamin A, niacin, or riboflavin.

Baking

Various heat-utilizing techniques are employed in the commercial processing of foods. Of these, baking is the major one. Destruction of one or more nutrients often occurs during the baking process. This adverse effect on nutrients is more intense in the crust portions since the interior (crumb) of most baked foods rarely approaches the oven temperature. Temperature aside, other factors that influence nutrient stability include time, pH, moisture (water activity), light, oxygen, metals, oxidants, enzymes and possibly certain additives. Nutrient losses or the possible formation of antinutritional substances, are not the only consequence of baking. Baking may also improve the nutritional profile of food products, although this aspect of baking is often not considered. Improvement results from inactivation/ destruction of undesirable microorganisms, certain antinutrients, for example, amylase and protease inhibitors, and breakup of complexes that otherwise render some nutrients poorly absorbable. In some cases, content of some of the nutrients, B vitamins in particular, may actually increase, for example, during fermentation because of synthesis by yeast cells. While the heat of baking denatures protein and this enhances protein digestibility, in the presence of reducing sugars, for example, maltose, fructose and lactose, the quality of protein may be adversely affected by nonenzymatic (chemical type) browning-the Maillard reaction. Maillard reaction primarily affects the basic amino acids of which lysine is particularly significant.

Maillard reaction products appear to have no nutritional value for the mammalian system. In fact, they may be of toxicological concern, although a few studies have also shown them to possess hypocholesterolemic properties.

Frying

Recent consumer interest in ‘healthy eating’ has raised awareness to limit the consumption of fat and fatty foods. Frying has little or no impact on the protein or mineral content of fried food, whereas the dietary fibre content of potatoes is increased after frying due to the formation of resistant starch. Moreover, the high temperature and short transit time of the frying process cause less loss of heat labile vitamins than other types of cooking. For example, vitamin C concentrations of French fried potatoes are as high as in raw potatoes and thiamine is well retained in fried potato products. The nutritive value of the frying media is also important to take into consideration. Although some unsaturated fatty acids and antioxidant vitamins are lost due to oxidation, fried foods are generally a good source of vitamin E. It is true that some fat is inevitably taken up by the food being fried, contributing to an increased energy density. However, this also results in highly palatable foods with a high nutritional content. It is concluded that fried foods certainly have a place in our diets. When oil is heated to a high temperature for a long period of time, toxic aldehydes are formed, which has been linked to an increased risk of cancer and other diseases. The type of oil, temperature and length of cooking time affect the amounts of aldehydes produced.

Drying and dehydration

Foods may be dried by removal of water either by sun drying or by various other drying methods. As of result of sensitivity of vitamin C to heat in the presence of oxygen and that of vitamin A and beta-carotene to oxygen, most dehydration processes result in loss of these vitamins. Newer method of drying, spray and freeze-drying use less severe heat treatments than conventional methods and result in greater vitamin retention. Freeze drying does not detrimentally affect the retention of vitamin C since it is carried out in absence of oxygen.

Sulphur dioxide is commonly added in dehydrated product to inhibit browning and to prevent the colour of the product. Sulphur dioxide also result in increased retention of vitamin C, A and beta-carotene, since it inhibits oxidation. Sulphur dioxide however can cause considerable loss of thiamine. Since dehydrated sulphurated food products are not major sources of dietary thiamine, the net dietary effect of Sulphur dioxide on thiamine retention is nil.

Another process which may be considered a form of drying involves binding of water. Water may be bound (made unavailable for chemical and biological reactions) by the addition of salt, sugar, gelling agents and other additives. This procedure has less detrimental effect on nutrients since there is less energy input. However, the solutes (salt, sugar) added may create unfavourable changes.

Parboiling

About 60 percent of the rice in India is parboiled. In the parboiling process the paddy is steeped in hot water, subjected to low-pressure steam heating, then dried and milled as usual. Parboiling makes more nutrients (largely vitamin B_1) transferred from the outer coverings to the endosperm, improving the nutritive value of the finished product. Even though parboiling leads to a decrease in the thiamine content of brown rice, milled parboiled rice contains more thiamine than milled raw rice at the same degree of milling. This observation is commonly explained by an inward diffusion of the vitamin during parboiling. Similar trends were observed for nicotinic acid and riboflavin. Parboiled rice may contain two to four times as much thiamine (vitamin B_1) and niacin as milled raw rice and losses in cooking may also be reduced. In ordinary rice, especially when open cookers are employed, or excessive water is used, nutrient losses can be high. Parboiled rice also exhibits higher starch digestibility than raw rice, however, it is lower than ready-to-eat expanded products. The starches in parboiled rice become gelatinized, then retrograded after cooling. Through gelatinization, amylose molecules leach out of the starch granule network and diffuse into the surrounding aqueous medium outside the granules which, when fully hydrated are at maximum viscosity. Cooling brings retrogradation whereby amylose molecules re-associate with each other and form a tightly packed structure. This increases the formation of type 3-resistant starch which can act as a prebiotic and benefit good health in humans. Parboiled rice takes less time to cook and is firmer and less sticky.

In preprocessed expanded rice products such as puffed rice, popped rice and rice flakes, the starch digestibility is higher than raw milled rice.

Extrusion cooking

Extrusion cooking, as a multi-step, multi-functional and thermal/mechanical process, has permitted a large number of food applications. Effects of extrusion cooking on nutritional quality are ambiguous. Beneficial effects include destruction of antinutritional factors, gelatinisation of starch, increased soluble dietary fibre and reduction of lipid oxidation. On the other hand, Maillard reactions between protein and sugars reduce the nutritional value of the protein, depending on the raw material types, their composition and process conditions. Apart from affect on lysine availability, recent studies have confirmed that Maillard reaction is an important reaction route for acrylamide formation in potato, rice and cereals products. Heat-labile vitamins may be lost to varying extents. Changes in proteins and amino acid profile, carbohydrates, dietary fibre, vitamins, mineral content and some non-nutrient healthful components of food may be either beneficial or deleterious. The nutritional value in vegetable protein is usually enhanced by mild extrusion cooking conditions, owing to an increase in digestibility. It is probably a result of protein denaturation and inactivation of enzyme inhibitors present in raw plant foods, which might expose new sites for enzyme attack. Oligosaccharides (raffinose and stachyose) decreased significantly in extruded high-starch fractions. Extrusion cooking increases the total dietary fibre. The increase in total dietary fibre is the result of an increase in soluble dietary fibre. The retention of vitamins in extrusion cooking decreases with increasing temperature, screw speed and specific energy input.

Microwave cooking

Microwave cooking has gained considerable importance as an energy-saving, convenient, and time-saving cooking method. Most reports indicated that microwave cooking resulted in higher moisture losses compared with conventional methods. Overall, the nutritional effects of microwaves on protein, lipid and minerals appear minimal. There is no report on the effects of microwaves on carbohydrate fraction in foods. There are only slight differences between microwave and conventional cooking on vitamin retention in foods. In conclusion, no significant nutritional differences exist between foods prepared by conventional and microwave methods. Any differences reported in the literature are minimal. But because microwave cooking times are shorter, cooking with a microwave does a better job of preserving vitamin C and other nutrients that break down when heated.

Non thermal processing

Refrigeration and Freezing

The storage life of fresh perishable foods such as meats, fish, vegetables and fruits can be extended by several days by storing them at temperatures just above freezing, usually between 1 and 4°C or at subfreezing temperatures, between 18 and 35°C, depending on the particular food. Refrigeration slows down the chemical and biological processes in foods and the accompanying deterioration and loss of quality and nutrients. Sweet corn, for example, may lose half of its initial sugar content in one day at 21°C, but only 5 percent of it at 0°C. The ordinary refrigeration of foods involves only cooling without any phase change. The freezing of foods, on the other hand, involves three stages: cooling to the freezing point (removing the sensible heat), freezing (removing the latent heat) and further cooling to the desired subfreezing temperature (removing the sensible heat of frozen food). Fresh fruits and vegetables are live products, and thus they continue giving off heat that adds to the refrigeration load of the cold storage room. The storage life of fruits and vegetables can be extended greatly by removing the field heat and cooling as soon after harvesting as possible. The optimum storage temperature of most fruits and vegetables is about 0.5 to 1°C above their freezing point. But this is not the case for some fruits and vegetables such as bananas and cucumbers that experience undesirable physiological changes, when exposed to low (but still above-freezing) temperatures, usually between 0 and 10°C.

Freezing preserves the nutritive quality of fresh foods. In general, nutrient loss during freezing is negligible, using proper packaging and process conditions. Exceptions are small losses of vitamin C and other water soluble vitamins in vegetables and fruits during blanching. Proper freezing conditions are important to retain nutrients. Foods which are frozen quickly and solidly, and maintained at a constant low temperature (-18 ºC or lower) or which undergo intermittent thawing exhibit a greater than normal loss of nutrients. The shelf life of frozen foods (9months to 1 year) is shorter than that of canned foods because not all the water in food freezes. Also, because some fatty acids as well as some vitamins (A, C and E) tend to oxidize during storage when exposed to air. This allows some chemical changes to occur, even in the frozen state.

Fermentation

Products such as aged cheese, bread, yoghurt, sauerkraut, pickles, soya sauce, tempeh, idli etc. are made by microbial fermentation. The microorganisms used may be natural components, selectively grown by manipulation of various factors in the environment or they may be added as a special starter culture. Fermentation can have multiple effects on the nutritional value of food. Microbial fermentation leads to decrease in the level of carbohydrates as well as some non-digestible poly- and oligosaccharides. The latter reduces side effects such as abdominal distention and flatulence. Certain amino acids may be synthesized, and the availability of B group vitamins may be improved. Fermentation of cereals by lactic acid bacteria has been reported to increase free amino acids and their derivatives by proteolysis and/or by metabolic synthesis. The microbial mass can also supply low molecular mass nitrogenous metabolites by cellular lysis. Fermentation has been shown to improve the nutritional value of grains such as wheat and rice, basically by increasing the content of the essential amino acids lysine, methionine and tryptophan. Improvement in starch digestibility during fermentation can be related to enzymatic properties of fermenting microflora that brings about the breakdown of starch oligosaccharides. The enzymes bring about cleavage of amylase and amylopectin to maltose and glucose. Reduction in amylase inhibition activity may also be responsible for the starch digestibility. Similarly, an improvement in protein digestibility of fermented products is mainly associated with an enhanced proteolytic activity of the fermenting microflora. Fermentation also provides optimum pH conditions for enzymatic degradation of phytate which is present in cereals in the form of complexes with polyvalent cations such as iron, zinc, calcium, magnesium and proteins. Such a reduction in phytate may increase the amount of soluble iron, zinc, calcium by several folds. Fermented foods are known to exert a beneficial effect on gut microflora through a probiotic effect.

During the manufacture of cheese, loss of water soluble vitamins may occur during the process but they may be partially replaced by microbial synthesis of these vitamins while aging. Some loss of vitamin C may occur during the fermentation of sauerkraut. Fermentation plays at least five roles in food processing:

- Enrichment of the human dietary through development of a wide diversity of flavours, aromas and textures in food.
- Preservation of substantial amounts of food through lactic acid, alcoholic, acetic acid and alkaline fermentations.
- Enrichment of food substrates biologically with protein, essential amino acids, essential fatty acids and vitamins.
- Detoxification during food fermentation processing.

- A decrease in cooking times and fuel requirements.

Refining cereal grains and legumes- dehulling, milling, refining, polishing

Cereals and legumes are important part of dietaries and contribute substantially to nutrient intake of human beings. They are significant source of energy, protein, dietary fiber, vitamins, minerals and phytochemicals. They are rich sources of nutrients especially when used as whole grains. However, most grains are processed further after cleaning and grading. These processing operations such as dehulling, milling, refining, polishing, etc. alter the nutritional composition of resultant product to varying degrees. These could also modify the matrices, the surrounding in which nutrients are embedded in a grain, which in turn influences the nutrient availability.

Structurally, all grains are composed of endosperm, germ and bran. The endosperm comprises < 80% of the whole grain, whereas the percentages accounted for the germ and bran components vary among different grains. Whole rice grain after dehusking retains all the nutrients prior to the polishing step, however, polished rice grains lose many nutrients and phytochemicals depending upon the degree of polishing, the higher the degree, more would be the loss. Reduction of phytate, tannin, and phenolic elements during the refining process lead to improved availability of minerals and digestibility of protein and carbohydrates, however, these components also exhibit strong antioxidant properties which may stop free radical activity and reduce oxidative stress in human body. So using whole grain or milled flour without sieving and separating different portion can be beneficial for health. Elements in whole grain associated with health status include lignans, tocotrienols, phenolic compounds and antinutrients including phytic acid, tannins and enzyme inhibitors. In the process of refining grain, the bran is separated, resulting in the loss of dietary ûber, vitamins, minerals, lignans, phytoestrogens, phenolic compounds and phytic acid. Thus refined grains are more concentrated in starch since most of the bran and some of the germ is removed in the refining process.

An amazing 70–80% of the original vitamins are lost when grains are milled. The higher the degree of milling, the greater is the nutrients loss. When wheat is milled into wheat flour, there is an approximate 70% loss of vitamins and minerals (range 25–90%) and fiber, 25% loss of protein, 90% loss of manganese, 85% loss of zinc and linoleic acid, and 80% loss of magnesium, potassium, copper and vitamin B_6.

Germination and malting

Malting is a controlled germination and drying process that changes the microstructure of cell walls, proteins, and starch granules. The traditional process consists of steeping to increase the moisture content to a level required to initiate germination, germination to modify the kernel and kilning to dry it. Germination and malting of grains is associated with an improvement in the nutrient content as well as decrease in antinutrients such as tannins, polyphenols and phytic acid, thereby increasing the digestibility and availability. The nutritional content in sprouted seeds varies, depending on species, but as a general rule, sprouts contain notable amounts of vitamin C; traces of B vitamins; a surprising amount of protein and fiber; and small amounts of calcium, iron, magnesium, phosphorus, potassium and zinc. In particular, mung beans are quite high in potassium, with 155mg in a cup-size serving. Home practices such as soaking, dehulling, fermentation, germination and cooking effectively improve the nutritional value of legumes. Sprouting also increases the protein content and shortens the cooking time of legumes. During the process of sprouting, some of the stored starch in the legume is used up for forming the tiny leaves and rootlets and in manufacturing vitamin C. Iron and zinc availability were reported to be increased in soaked and sprouted legumes in comparison to control.

The greatest potential drawback of sprouting seeds is food safety. That's because the warm, humid conditions it takes to grow sprouts also happen to be the perfect conditions for growing dangerous bacteria like salmonella, listeria and E. coli. Contamination can be minimized using potable water for sprouting.

Conclusion

The food processing sector is an important component of the food value chain. Food processing has a main role and huge potential in both to increase dietary diversity and to enhance concentrations of nutrients thereby improving the nutritional status of the population. Food processing is applied to preserve foods, enhance food safety, add convenience, improve flavour, enhance nutritional value and save energy. Conversely, food processing can be detrimental to nutritional quality when it manufactures foods that are high in added sugar, fat and sodium or when it removes nutrient dense fractions from whole foods as is often the case in cereal milling operations. Overall, processing method that best retains nutrients is one that cooks quickly, heats food for the shortest amount of time and uses as little liquid as possible. Thus, wise selection of processing techniques for particular product will aid in alleviating malnutrition problems, at least to a certain extent.

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Bioprocessing of Agro-Industrial Waste for Production of Microbial Proteins

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Introduction

Technological advancement in the field of agriculture has headed to the availability of large quantities of surplus agricultural produce and residues. Agro-processing involves a set of techno-economic activities carried out for preservation, handling, and value addition of agricultural produce, which includes all the operations starting from harvesting till the transformation of material in to desirable form.(Kachru, 2006). The total impact of all these activities inclines towards the rapid growth of food processing industries making both the primary and secondary processed products.

The tough environmental legislations have meaningfully contributed to the introduction of viable waste management practices throughout the world. During the last few decades, there has been an increasing trend for the utilization of agro-industrial residues for value added products. Various biotechnological process, especially fermentation process, have contributed massively in the zone of agro-waste and residue utilization. The exploitation of agro-industrial residues through fermentation will not only provide a substitute substrate but also help in the reduction of environmental pollution as well as up gradation of agro- residues and by-products.

The utilization of agro-industrial waste as the resource material in microbial protein processes serves two function, i.e., reduction in pollutants and production of edible protein, which can be either used as a food component or as animal feed. However, each waste material must be assessed for its suitability for conversation to microbial protein. The main reasons for the increasing interest in microbial protein production from agro-industrial wastes are escalating cost of conventional protein sources, cheap rather negative values of the substrates, and feasibility of large scale microbial protein production by using computer controlled fermentation processes (Litchfield, 1983). The production of microbial protein at commercial scale is determined by the economic considerations such as a availability and cost of raw material, water, Value Addition of Agro-Industrial Wastes and Residues labor, capital resources, transportation of finished product, capital investment for fermentation equipment, efficacy of the process, market price of the traditional protein sources , and the disposal of secondary by- products. (Arora et al., 2000). Microbial protein production has also been carried out utilizing wastes from fermentation industries, such as winery, brewery and distillery (Hang, 1986).

A number of microorganisms including bacteria, yeast and molds can be employed for the production of microbial protein, although each of them has their own advantages and disadvantages. Microbial protein production process utilizing waste substrates have been reported using various organisms. The substrates and producer organisms used include sulfite waste liquor (*Paecilomyces variotii, Candida utillis*), molasses *(Saccharomyces cerevisiae)*, and cheese whey *(Kluyveromyces fragilis)* while the Symba process developed in Sweden utilizes starchy wastes, e.g., wastewater from potato processing plant by combing two yeasts, *Endomycopsis fibuligera* and *C. utilis* (Litchfield, 1983). Potato peels supplemented with ammonium chloride have also been used for the production of protein using *Pleurotus ostreatus* (Khalon and Arora, 1986). Another popular process in microbial protein production is Pekilo process. Pekilo is a fungal protein product that has been produced by continuous fermentation of carbohydrates derived from spent sulfite liquor using P. variotii (Oura, 1983).

Utilization of Some Agro-Industrial Waste for microbial protein Production

Agro-Industrial Residues	Microorganism Employed/Producer Strain	Reference(s)
Apple pomace	*Saccharomycopsis fibuligera and C. utilis*	Fellows and Worgan (1988)
Apple pomace	*T. viride and A. niger*	Hang (1986)
Citrus peel waste	*Fusarium sp.*	Bahar and Azuaze (1984)
Molasses	*S. cerevisiae, T. utilis, andRhizopus sp.*	Shukla and Dutta (1967)
Potato processing waste	*E. fibuligera and C. utilis*	Skogman (1976)
Potato peels	*P.ostreatus*	Kahlon and Arora (1986)
Sulfite waste liquor	*P. variotii and C. utilis*	Oura (1983)
Soybean oil waste	*C. lipolytica*	Takata (1992)
Whey	*Saccharomyces fragilis*	Powell and Robe (1964)
Whey	*K.lactis, K.fragilis, Torulopsis bovina* and *Candida intermedia*	Moulin and Galzy (1984)
Whey	*K.marxianus A2*	Anvari and Khayati (2011)

Microorganism selection and development

Microorganisms are the biocatalysts and maintain a host of enzymatic path- ways that are used to produce the food component of interest. The characteristics of a good industrial microorganism for the production of food ingredients are

(1) It must be effective in producing large quantities of a single product,
(2) It can be efficiently isolated and purified,
(3) It is easy to maintain and cultivate,
(4) It is generally stable,
(5) It grows best in an inexpensive culture medium, and
(6) It is safe for human consumption.

Microbial proteins are dried cells of microorganisms which can be used as dietary protein supplement. They are used as animal feed & can be used for human feed as protein supplement and also called as 'Novel Food' & 'Mini food'. Bacteria, Molds, Yeasts, Green and Bluegreen algae are widely used as source of such protein. It can also be named as biomass, bio protein or microbial protein. The first step is to isolate the hardiest starter culture possible, then to begin strain improvements via classical mutagenesis or genetic engineering. The genetic stability of cultures requires minimum culture transfer and long term storage capabilities. Fermentation media are inoculated from working cultures which are produced every few month from master cultures depending on the microorganism. The most common procedures for long term storage are freeze drying (<–18^{o} C) and ultra- low temperature storage (–70^{o} – – 80^{o} C). Freeze drying requires a cryo-protectant, such as sterile skim milk, followed by freeze drying and vial sealing under a vacuum (Demain, 1999). Sealing under nitrogen gas can also help to stabilize the culture and extend the shelf life. Ultra – low temperature storage is in a rich culture medium with 20% sterile glycerol. Some cultures are sensitive to freeze drying , thus ultra-low is the most common method employed today, because of long-term culture viability. The risk is loss of electrical power and refrigeration problems. Suspended cell cultures or spore suspensions are used as inoculant for these industrial scale fermentations. Purity is constantly checked until inoculation. For suspended cell inoculation the sequence employed would be culture slant, shake-flask culture , benchtop fermenter, pilot-scale fermentation, then into full scale fermentations, Many fungal fermentation, such as citric acid and soy sauce fermentations, required a suspension of viable fungal spores as the inoculum. These spore suspension are generated on large agar trays, and then are aseptically transferred into culture bottles suspended in sterile water or saline (Demain

1999). Furthermore , microbial system are ideal for the production of essential micro nutrients such as amino acids , vitamins, and enzymes, and bulk ingredients such as organic acids and alcohols, whole cell flavor enhancers, and polysaccharides. Besides high protein content (about 60-82% of dry cell weight), it also contains fats, carbohydrates, nucleic acids, vitamins and minerals. Another advantage with microbial proteins is that it is rich in certain essential amino acids like lysine, methionine which are limiting in most plant and animal foods. In food industry it is used as aroma carriers, vitamin carriers, emulsifying aids and to improve the nutritive value of baked products in soups, in readymade-to serve meals, in recipes.

Production of Baker's Yeast

The strains of Baker's yeast *(S.cerevisiae)* have been used all over the world in bread leavening. Earlier, the yeast employed was generally taken from breweries or distillers. Nowadays, sugarcane or beet molasses are widely used for the production of baker's yeast. However these raw materials are not sufficiently rich in nitrogenous and phosphorous compounds, and usually the addition of inorganic ammonium compounds, biotin, and phosphoric acid is needed for the good growth of Baker"s yeast (Paturau, 1987).

Value Addition of Agro-Industrial Wastes and Residues

Lactobacillus bulgaricus and *Streptococcus thermophilus* strains have been recommended for the conversation of lactose in whey and its subsequent utilization for baker's yeast multiplication (Champagne et al., 1990). The industrial process for the production of baker's yeast *(S.cerevisiae)* from whey has been used by Nutrisearch Company at Winchester, Kentucky. The process involves lactose hydrolysis in chesse whey by immobilized lactose followed by glucose-galactose fermentation (Castillo, 1990). The use of nonconventional yeasts as baker's yeast has also been made, but to make this approach workable, such yeasts should show baking properties similar to the baker's yeast. Yeasts like *T. utilis, Torula cremoris,* and *Torula casei* have been successfully grown on whey (Vij and Gandhi, 1993).The use of apple pomace extract as an alternative to molasses (traditionally used as a carbon source) for baker's yeast production has also been explored (Bhushan and joshi, 2006). Apple pomace extract-based medium in an aerobic fed-batch culture has been employed for the production of baker's yeast. Interestingly, the dough-raising capacity of the baker's yeast grown on the apple pomace extract was apparently the same as that of commercial yeast.

Conclusion

By-products and residues of agri-industry will increase new markets in food industry as functional food ingredients. Current trends in science and innovation uplifts the utilization of agricultural by-products for valuable end products with increase profitability. Most of these by-products are a good source of proteins, minerals, fatty acids, fibre, and bioactive compounds. The efficient utilization of the by-products from agro-industry can help in reducing the negative cost, reduce environmental pollution, demonstrating sustainability in food industry and that has direct impact on the economy of the country. Microbial protein meets the criteria of nutritive proteins, but other cellular components can also be of ever-increasing importance, driving new progress for microbial-based by-products. These non-conventional sources of protein are products of biotechnological processing of agricultural, industrial and forestry wastes. Such protein has been grown by culturing desired microbes on suitable substrates like corn cob, starch, whey, wheat, starch hydrolysates, hydrocarbon, molasses and sugarcane bagasse. The production of microbial proteins as an alternative source has considerable benefits over conventional sources because of its decreased production time, lower land requirement and ability to be produced in all kind of climates.

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Modern Analytical Techniques for Food Analysis

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Introduction

The aim of food products analysis is obtaining results, which provides information about the composition of food products or food raw material sample. This obtaining information can be carried out on different levels. These levels can be the following: elemental, molecular, and structural. The level of the chemical elements (elemental) means that answer can be given to the question that what (qualitative analysis) and how much (quantitative analysis) can be found in the given sample. Although, on the molecular level the answer can be given about what compounds and crystalline forms consist of the sample from the building elements. The examination of the structure can mean arrangement of the molecules as well (e.g.: determining the order of the amino acids in a protein). The difficulty of the analytical task differs among levels. Any technique selected for food analysis depends on what the researcher is looking for, and there is a host of food properties from which to choose. The development and application of analytical methods and techniques in food science has grown parallel to the consumers concern about what is in their food and the safety of the food they eat.

In the food industry, food safety and quality are still performed as an important issue all over the world, which are directly related to people's health and social progress. Consumers are gradually looking for quality seals and trust marks on food products, and expect manufacturers and retailers to provide products of high quality. All of these factors have underlined the need for reliable techniques to evaluate the food quality (Haiyan and Yong, 2007). Protein, Fiber and fat content are the routine biochemical food quality parameters which are employed world-wide to determine the quality of any food matrices.

Classifications of analytical methods

In case of the applied analytical methods at first one can decide whether the classical or the instrumental analytical method is better to apply. The classical analytical methods, in other words the wet-chemical methods, preceded the instrumental analytical methods by over a hundred years.

Classical analytical methods

In the first years of the analytical chemistry the majority of the analysis was done by dividing the components of the sample that should be examined. During this process precipitation, extraction or distillation was applied. Afterwards the divided components, meant to be used for qualitative analysis, were handled by other reagents with the help of which chemical reaction was used either results in coloured compound or changes of its boiling/freezing point or its solubility. Moreover, reactions which were applied leaded to variously perceptible gases (e.g.: odours) or changes in the compound's optical characteristics or optical activity. When classical analytical method is chosen for the quantitative analysis of the components (to determine its relative or absolute concentration) gravimetric or volumetric method can be used. In gravimetric measurements, the determination of the components' concentration in the given sample is led back to the changes in the mass of the examined analyte or to the mass of the precipitate that was formed with another component. In case of volumetric, also known as titrimetric methods, the component which is analysed, in form of a solution, must be reacted with the reagent, already being in the standard solution and after the reaction of all the amounts of reagent in the sample, from the loss of the amount of the standard solution (from the proportional value of the stoichiometric quantity), the concentration can be counted. All of these classical analytical methods, can be used to either for separating or defining these components, are still used in several laboratories nowadays; but the number of those, who generally use these methods is slowly decreasing due to the appearance of more developed and more conveniently applicable methods of instrumental analysis, these new methods are slowly, but surely superseding the aforementioned ones.

Modern Analytical techniques/ Instrumental analytical methods for food analysis

At the beginning of the twentieth century scientists began to take more and more advantage of the different opportunities provided by the measured components' physical correlations. With the help of them they developed better and better instrumental analytical methods which they found solution for several problems of the classical analytical methods. Such physical characteristics are for example: conductivity, electrode potential, light absorption, light emission, fluorescence and the mass-charge ratio, which were started to be used for quantitative analysis. Furthermore, highly effective chromatographic and electrophoretic techniques were also used to substitute distillation, extraction or precipitation, applied to divide the mixture of components of food or food raw material samples with unusually complex matrix before the qualitative or quantitative determination. The aforementioned new methods, used for the separation and determination of different components, are called instrumental analytical methods. The rapid development of the computer and electronics industry highly contributed to the improvement and spread of the modern instrumental analytical methods.

Performance characteristics of the analytical methods

1. Selectivity,
2. Specificity,
3. Ruggedness,
4. Measurement range,
5. Linearity,
6. Detection limit,
7. Quantitation limit,
8. Accuracy, and
9. Precision.

1. Atomic absorption spectrometry

In atomic absorption spectrometry (AAS) the analysed element is transformed into free ground state atoms with energy transfer (in a flame or graphite furnace). Through this atomic vapour a light with the wavelength

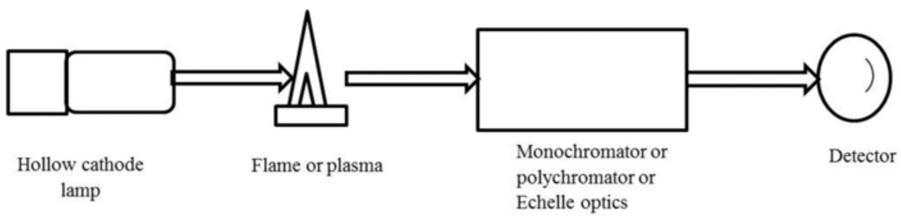

Fig. 1. Working principal of atomic absorprtion spectrometers

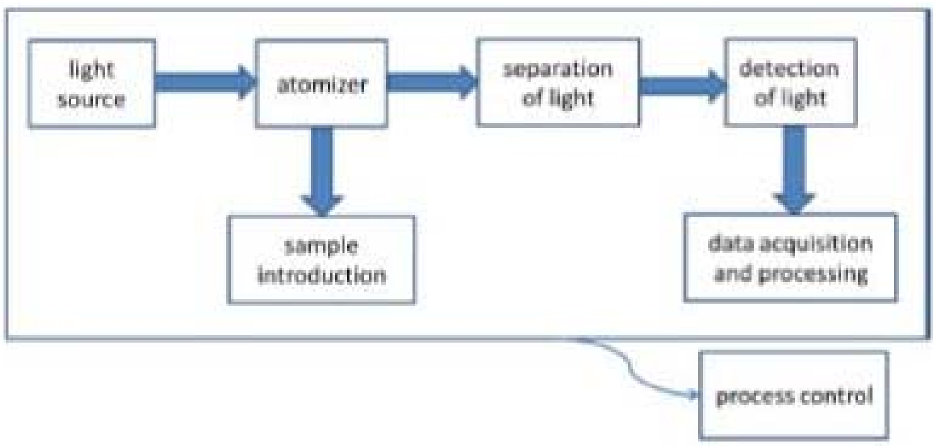

Fig. 2. Units of atomic absorprtion spectrometers

characteristic for the element that is directed through and the decrease of the intensity of light is measured. The wavelength of the used light determines the quality of the analysed material, while the relative decrease of the intensity of light determines the relative and absolute quantity of the element.

2. Inductively coupled plasma mass spectrometry (ICP-MS)

In the field of elemental analytical measurements, inductively coupled plasma mass spectrometry (ICP-MS) is one of the most sensitive method nowadays. The inductively coupled plasma mass spectrometry – issuing from its name – has 2 main parts. The first of them is the inductively coupled plasma, and the second one is the mass spectrometer which carries out the separation and the detection. In ICP-MS the ions of the measured element (isotope) are produced, and when directed into the mass spectrometer, the ions are separated in the magnetic or electrostatic field according to mass/charge (m/z). The mass-charge ratio of the isotope is typical for the quality of the element, while relative intensity of the produced ion beam is proportional to the relative or absolute quantity of the measured element.

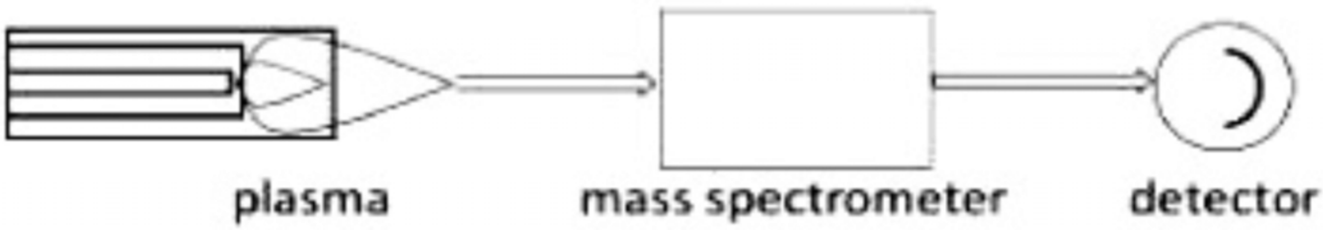

Fig. 3. Working principal of inductively coupled plasma mass spectrometers

3. Chromatography techniques

Chromatography is a useful separation method in the field of food analysis, and has a great impact in analytical chemistry.

3.1 Gas chromatography

Gas chromatography is a column chromatography technique, where the mobile phase is gas and the stationary phase is either an immobilized liquid or a solid packed in a closed tube. GC is useful for separation of thermally stable volatile components of a mixture (for example fatty acid methyl esters). During the gas–liquid GC the sample is vaporized and injected into the head of the column. By using a controlled temperature gradient, the sample is transported through the column by the mobile phase, which usually is an inert gas. The volatile components then are separated based on boiling point, molecular size, and polarity.

GC has been used for the determination of fatty acids, triglycerides, cholesterol and other sterols, gases, solvent analysis, water, alcohols, and simple sugars, as well as oligosaccharides, amino acids and peptides, vitamins, pesticides, herbicides, food additives, antioxidants, nitrosamines, polychlorinated biphenyls, drugs, flavor compounds, and many more.

3.2 Supercritical fluid chromatography

Supercritical fluid chromatography (SFC) refers to chromatography that is performed above the critical pressure (Pc) and critical temperature (Tc) of the mobile phase. A supercritical fluid (or compressed gas) is neither a liquid nor a typical gas. The combination of Pc and Tc is known as the critical point. A supercritical fluid can be formed from a conventional gas by increasing the pressure or from a conventional liquid by raising the temperature.

Carbon dioxide frequently is used as a mobile phase for SFC, because it is not a good solvent for polar and high molecular-weight compounds. Other supercritical fluids are nitrous oxide, trifluoromethane, sulphur hexafluoride, pentane and ammonia. The high diffusivity and low viscosity of supercritical fluids mean decreased analysis times and improved resolution compared to LC.

SFC offers a wide ranges of selectivity adjustment, by changes in pressure and temperature as well as changes in mobile phase composition and the stationary phase. SFC makes possible separation of nonvolatile, thermally labile compounds that are not amenable to GC. SFC can be performed by using either packed columns or capillaries, and has used primarily for nonpolar compounds. Fats, oils, and other lipids are compounds which SFC is increasingly applied.

3.3 High-performance liquid chromatography

Originally, high-performance liquid chromatography (HPLC) was the acronym for high pressure liquid chromatography, reflecting the high operating pressures generated by early columns. By the late 1970s, high-performance liquid chromatography had become the preferred term, emphasizing the effective separations achieved. HPLC can be applied to the analysis of any compound with solubility in a liquid that can be used as the mobile phase. Although most frequently employed as an analytical technique, HPLC also may be used in the preparative mode. There are many advantages of HPLC over traditional low-pressure column liquid chromatography: Speed, because many analyses can be accomplished in 30 min or less, a wide variety of stationary phases, improved resolution and greater sensitivity, because various detectors can be employed, and easy sample recovery, because of less eluent volume to remove. A basic HPLC system consists of a pump, injector, column, detector, and data system. HPLC is widely used for the analysis of small molecules and ions, such as sugars, vitamins, and amino acids, and is applied to the separationand purification of macromolecules, such as proteins and polysaccharides.

3.4 Gas Chromatography-Mass Spectromatry (GC-MS)

Gas Chromatography–Mass Spectrometry (GC-MS) is a hyphenated analytical technique that combines the separation properties of gas-liquid chromatography with the detection feature of mass spectrometry to identify different substances within a test sample. GC is used to separate the volatile and thermally stable substitutes in a sample whereas GC-MS fragments the analyte to be identified on the basis of its mass. The further addition of mass spectrometer in it leads to GC-MS/MS. Superior performance is achieved by single and triple quadrupole modes.

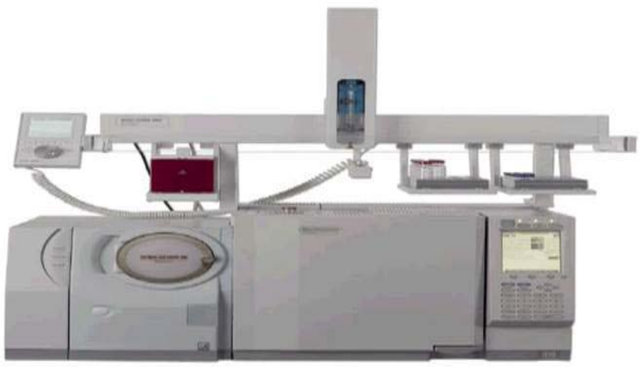

Fig. 4. A typical GC-MS with head space of Shimadzu company

Foods and beverages have several aromatic compounds existing naturally in native state or formed while processing. GC-MS is exclusively used for the analysis of esters, fatty acids, alcohols, aldehydes, terpenes etc. GC-MS is also used to detect and measure contaminants, spoilage and adulteration of food, oil, butter, ghee that could be harmful and should to be controlled and checked as regulated by governmental agencies. It is used in the analysis of piperine, spearmint oil, lavender oil, essential oil, fragrance reference standards, perfumes, chiral compounds in essential oils, fragrances, menthol, allergens, olive oil, lemon oil, peppermint oil, yiang oil, straw berry syrup, butter triglycerides, residual pesticides in food and wine.

4. Infra-red (IR) spectroscopy

Infra-red spectroscopy is used to measure IR radiation absorbed by or reflected from a sample. The absorption of IR radiation is related to the changes of vibrational or rotational energy states of molecules. Its applications for analysis of gaseous, liquid or solid samples, identification of compounds and their quantitative analysis *etc.* The IR spectrum obtained for functional groups of molecules, constitution of molecules and interaction among molecules provides information about the samples.

Main components of an instrument

1. radiation source

2. measuring (and reference) cell
3. wavelength selector
4. detector (transducer)

Types of instruments

1. Simple instruments with a filter
2. Classical instruments with a monochromator
3. Instruments based on an interferometer (FTIR)

4.1 Near-infrared (NIR) Spectroscopy

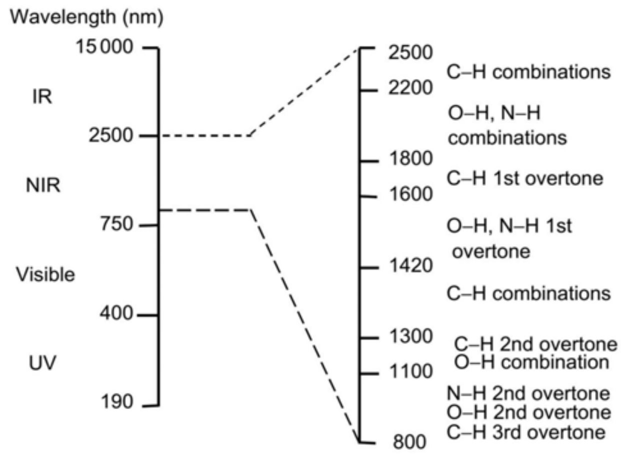

Fig. 5. Principal types of NIR absorption bands and their locations

Near-infrared spectroscopy (NIRS) provides an alternative, non-destructive technology for measuring constituents of biological materials with little sample preparation and is able to provide reliable and accurate results of larger range of samples of multiple properties at one time (Stuth *et al.*, 2003). NIRS is widely used for the quantitative determination of quality attributes such as moisture, protein, fat, and kernel hardness in agriculture and food products (Williams and Norris, 2001). NIRS is broadly accepted in quality assessment of foods, beverages and various other matrices in contemporary scientific fraternity. NIRS is an accepted method to predict forage fiber traits of barley straw (Mathison *et al.*, 1999), rice (Jin, 2007), green cereal crops (Bruno-Soares *et al.*, 1998), leguminous shrubs (Garcia *et al.*, 2004), and oat hulls (Redaelli, 2007).

4.2 Fourier Transform Infrared (FTIR) Spectroscopy

FT-IR is a spectroscopic technique that makes use of the naturally occurring electromagnetic spectrum defined by the wavelengths between 2,500 nm and 25,000 nm. This is the 'mid-infrared' region so the method referred to as 'mid infrared'. Generally, though, it is the name of a technique used to convert measurement data into a usable result (Fourier Transform) that is popular, hence, Fourier Transform Infrared, or FTIR for short. Fourier transform infrared spectroscopy (FTIR) has been available to researchers since the early 1970s (Griffiths & de Haseth, 1986).

FTIR advantages

The overall advantages of using FTIR analysis are that it provides rapid analysis data for better decision making in food and agriculture production processes. It is particularly useful for testing liquid samples such as milk and wine. Compared to traditional analysis methods it requires little or no sample preparation and no chemicals or consumables. It is non-destructive, operator friendly, fast, reliable and precise.

How FTIR works

- Light from a broad-band light source containing the full spectrum of wavelengths to be measured is through a device called an interferometer.
- The interferometer modifies the light in a special way to allow for subsequent processing of the data
- The beam is passed through the sample where a sample-dependent absorption takes place.
- The light is detected and passed to a computer.
- The computer processes all the data to infer what the absorption is at each wavelength and generates a spectrum corresponding to the data using the Fourier Transform technique.

Proximate analysis of foods is one area which can benefit from FTIR, as food systems are mainly composed of fats, proteins, carbohydrates, and moisture, all of which contribute to the gross spectrum obtained. Characteristic absorption bands are associated with these components, e.g. the carbonyl ester and CH signals associated with fat, the amide signals for protein, the COH bands for carbohydrate and the HOH bending absorption of water. Although water absorbs strongly across the IR spectrum, it can readily be ratioed or subtracted out of the spectrum to reveal the residual absorptions due to other components. In principle, simple standardized, quantitative preparation procedures can be developed to dissolve and disperse most food components in water, or another solvent if selective extraction is required, so that samples are suitable for FTIR analysis.

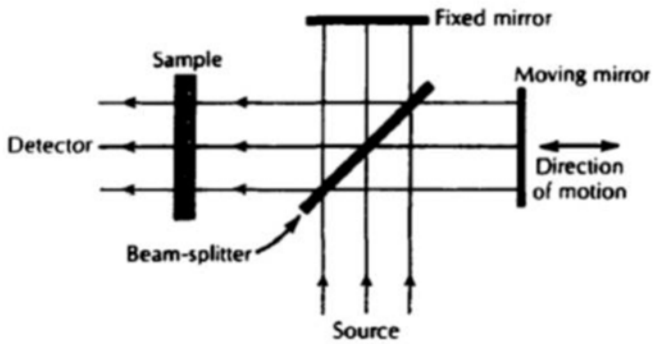

Fig. 7. Schematic diagram of the essential components of an interferometer

Conclusion

Traditional analytical methods *viz*. Folin-Lowry (Protein), Gravimetric (fiber) and Soxhlet method (oil content) are time tested but are tedious and time consuming. These methods are suitable for laboratory level analysis where representative samples can be analyzed. But at industrial level, these methods are not fitted in the scheme and could not serve the purpose of screening or monitoring of quality parameters of each product.

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Cold Plasma based Processing Systems for Grains

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Grains provides nutrients, energy and phytochemical for health. Grains undergo various processes like, splitting, drying, grinding, roasting, coating, cooking to make the grain to be fit for consumption. Processed grains are nutritionally rich than unprocessed grains and processing of grains also provides shelf-stable products that are convenient and good tasting for consumers. Since most of the processes are thermal processing, it affects the grain qualities. Moreover, many of these methods does not disinfest the grains. Cold plasma is an alternate processing technology which can be used for grain processing.

Introduction

Grains are source for complete diet of people. It has carbohydrates, protein, fat, fibre and minerals. It supplies all necessary nutrients that are required for human body. After harvesting the grains are being stored for increasing its shelf life and for future use. Whole and processed grains are consumed in all countries. These grains undergo some processing after dehulling such as roasting, splitting, coating and other disinfestation treatments to maintain or improve the qualities like flavor, color, texture, and appearance as well as providing shelf stable products. Processing methods of grains can enhance the appeal and consumption of the grains and grain products. The maintenance of nutritive value of the grains during processing is important (Slavin, Jacobs, & Marquart, 2000). The existing methods are heat sensitive and/or expensive. Besides that many preservation methods did not act as disinfestation method. So the alternative to these methods is cold plasma processing of grain.

Plasma is a quasi-neutral ionized gas and often it is fourth state of matter which originates as conversion solid-liquid-gas-plasma (N. Misra, Tiwari, Raghavarao & Cullen, 2011). From 150 year of now plasma has been used in industries for many technological applications (Milosavljeviae, Karkari & Ellingboe, 2007). Plasmas are used in microelectronic technology, electron and ion beam projection lithography, materials processing, flat panel displays, semiconductor chip fabrication, anticorrosion coatings, toxic waste treatment, improvement of barrier properties in packaging materials and recently for food sterilization (Chu, 2007; Helhel, Oksuz & Rad, 2005; Schneider et al., 2005). Plasma composed of two types of species such as light (photons) and heavy (all other constituents) (N. Misra et al., 2011) and has neutral charge due to its equal number of positive and negative ions (Kudra & Mujumdar, 2009). Plasmas are classified as thermal and non-thermal plasma based on its thermodynamic properties (N. Misra et al., 2011; Schlüter et al., 2013).

In plasma, if ionized gas components such as electrons, ions and neutral particles are in thermodynamically equilibrium, then the plasma is called thermal plasma. Similarly in plasma, if ionized gas components such as electrons, ions and neutral particles are in thermodynamically non-equilibrium then the plasma is called non-thermal plasma or cool plasma or cold atmospheric plasma or cold plasma (Fernández & Thompson, 2012; N. N. Misra, Keener, Bourke, Mosnier & Cullen, 2014). Cold plasma was invented by Werner von Siemens at 1857 (Kevin Keener, 2011). Generation of thermal plasma requires high pressure more than atmospheric pressure and high temperature with heavy energy, whereas generation of non thermal plasma requires atmospheric pressure or vacuum at low energy, hence non thermal plasma is often called as atmospheric cold plasma. At atmospheric pressure or low pressure, collisions between electrons and heavier particles occur constantly due to the high molecule density and allow rapid exchanges of energy. It results the plasma temperature is in the order of several thousand of Fermi temperature at the state of equilibrium. Temperature of thermal plasma is usually above 6000 K under atmospheric pressure (Moreau, Orange & Feuilloley, 2008). On the contrary the temperature of cold plasma is usually up to10,000 K, though the electron temperature of cold plasma is up to10,000 K, gas temperature close to70°C to ambient temperature (Schlüter et al., 2013). Since the temperature range of cold plasma is 30-60^{o}C and no marked temperature increase, it is preferred in the food industry because of its least heat sensitive to food products (N. Misra et al., 2011; Niemira, 2012; Perni, Deng, Shama & Kong, 2006). Description about atmospheric and low pressure plasmas has already been given (Laroussi, 2005; Rossi, Kylián & Hasiwa, 2006) and (Moreau et al., 2008). Some important cold plasma studies on grains, fruits, vegetables and fish are given in the table 1.

Recent studies on the microbial inactivation by plasma technology with log reduction is reported elsewhere(Mir, Shah, & Mir, 2016). The effective bacterial spores inactivation potential of cold plasma was reported by many authors (Boudam et al., 2006; Lassen, Nordby, & Grün, 2005; Moreau et al., 2008; Schnabel et al., 2012; Van Gils, Hofmann, Boekema, Brandenburg & Bruggeman, 2013). Cold plasma technology is successfully studied for effective inactivation of vegetative bacteria, molds and bacterial endospores on almonds (Deng et al., 2007), fresh pork meat (Fröhling et al., 2012) or on different herbs and spices (Reyes-Moreno, Cuevas-Rodríguez, Milán-Carrillo, Cárdenas-Valenzuela, & Barrón-Hoyos, 2004). Inactivation of *Escherichia coli* from fresh produce (Bermúdez-Aguirre, Wemlinger, Pedrow, Barbosa-Cánovas & Garcia-Perez, 2013), *Aspergillus parasiticus* and *Penicillium sp* from seeds of various vegetable, legumes and cereals (Selcuk, Oksuz, & Basaran, 2008), *Erwinia carotovora* in potatoes(Moreau et al., 2007), *Listeria monocytogenes* from plastic trays, paper cups and aluminum foil (Yun et al., 2010) were reported. Cold plasma can efficiently produce bactericidal molecules from air with product increase in temperature less than 5°C from atmosphere (Klockow & Keener, 2009).

Other than microbial inactivation, Cold plasma can be applied in soil treatment, fertilization, water treatment and purification, sterilization, seed treatment, storage improvement, insecticide, pre-harvest treatments, post-harvest treatments without appreciable thermal damage to plants, crops and fruits (Chirokov, Gutsol & Fridman, 2005; Fridman, Chirokov & Gutsol, 2005; Ito, Ohta & Hori, 2012; Koga et al., 2015). Plasma technology effectively works on improving seed germination (Sera et al., 2012) and retarding browning reaction (Tappi et al., 2014). Kordas, Pusz, Czapka and Kacprzyk (2015) reported that disinfection of winter wheat grain in a packed bed reactor using low-temperature plasma and fungi colony reduction was observed within 10 seconds. A non thermal plasma a green fumigant is induced within the confines of a grain conveyor, for rapid and continuous grain treatment during conveying (Anonymous, 2015). After plasma treatment wheat and beans qualities were not affected significantly(Butscher, Zimmermann, Schuppler, & von Rohr, 2016; Selcuk et al., 2008). Other than that the falling number which represents the starch damage and gluten content was not changed. The falling number (326/ 318 s) and gluten content (34.30 / 34.80%)of wheat has not changed significantly (Butscher et al., 2016).

Cold plasma is more advantageous than existing food safety technologies due to 1) it is a dry process; 2) it is easily and readily adaptable; 3) it requires little energy; 4) reactive gas species revert back to original gas within minutes to hours after treatment and 5) it requires short treatment times. Conversion rate for electricity to plasma is very efficient (80%). Since it s dry non-chemical based sterilization, it reduces effluents and waste water and environmental and economically beneficial(Anonymous). Furthermore, the uniqueness of cold plasma is that multifaceted interaction with macromolecules, spanning across multiple time and length scales and emerging from the action of a countless of chemically active species (Fayle & Gerrard, 2002). Selectivity of cold plasma that can interact with organic materials without causing thermal/electric damage to the cell surface is the additional advantage of cold plasma(Stoffels, Sakiyama, & Graves, 2008).

Principle of plasma treatment

During plasma generation, free electrons in the plasma collide with each other molecules provides excitation energy to create unique, highly reactive products (KM Keener, 2008) and the emission of UV light (Brandenburg et al., 2009).The ionized portion of the electromagnetic spectrum comprises visible light and shorter wavelengths, although visible light ionizes only certain chemicals (Faruki, Das, Khan & Khatun, 2007). Ionizing ultraviolet light with the wavelength of 10- 400 nm and photon energy 3-124 eV has used for surface treatment for grain and to control stored product insect pests (Faruki et al., 2007).

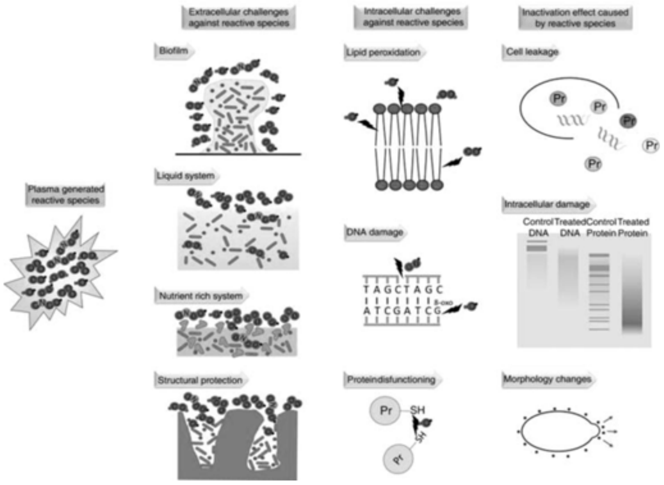
Experimental setup

Over the years, many systems are used for plasma generation such as dielectric discharge barrier (DBD), corona discharge, atmospheric plasma jet, pulsed plasma, microplasma and nanopulse plasma. However, DBD and plasma jet are the most widely used in food science application due simple in construction, easy to adopt and viable

Table 1. Different cold plasma application in food processing

Objective	Parameters	Results	References
Impact of cold air plasma on the wetting properties and water imbibition of beans (*Phaseolus vulgaris*)	Frequency:10 MHz Power: 20 W Pressure: 6.7×10^{-2} Pa Volume: 840 cm^3 Time : 2 min	When cotyledon and tissues were treated separately then it leads to to hydrophilization of the constituting the testa, while entire bean was treated , only the external surface of the bean was hydrophilized	(Bormashenko et al., 2015b)
Inactivation of aflatoxigenic fungal spores on maize samples using fluidized bed plasma reactor.	Gas: Air flow rate: 3000 L/h Electrode: Stainless steel Voltage: 5-10 kV Frequency: 18-25 kHz Power : 655 W	5.48 and 5.20 log (cfu/g) in Aspergillus Sp. after 5 min of treatment. No occurrence of re-growth during the storage of maize at 25 °C for 30 days,	(Dasan, Boyaci, & Mutlu, 2016)
To evaluate the microbial safety and physicochemical quality changes of commercial brown rice	Gas : Air Electrodes: Copper Voltage: 15 kHz, A bipolar square-waveform Power: 250 W Time: 5, 10 and 20 min.	At 20 min treatment time, *Bacillus cereus*, *Bacillus subtilis*, and Escherichia coli O157:H7reduced to 2.30 log CFU/g. The color L*, amylase activity and water uptake rate increased in pH, and the a*, b* and hardness decreased.	(Lee et al., 2016)
To study the effect of dielectric barrier discharge plasma on growth enhancement of *Raphanus sativus L*. seeds	Gas :air, O_2, N_2, He, and Ar, NO(10%)+N_2, Electrode : Stainless steel Voltage : 9.2 kV Current: 0.2 A. Power density: 1.49 W/cm^2 Time : 3min	2.3 times faster growth rate of seeds	(Pyler & Thomas, 2000)
To investigate the effect of plasma stress on mortality of *Tribolium Castaneum* and colour changes occur in the maida flour.	Power:1-40kV Frequency of 50Hz Electrode gap: 2-6 cm Voltage :500-3000 voltage Exposure time (sec): 1 to 7 sec	100 percent mortality and good colour retention was observed above 1750 voltage, 3 sec and at 4 cm distance	(Radhakrishnan, Ramanan, Sargunam, & Sarumathi, 2016)
To identify the effect of low doses of cold plasma treatment on wheat flour microbial load, chemical composition (protein and lipid) and dough rheology.	Gas: Air Frequency: 9 kHz Power: DC 40 ± 1W for 15 V and 90 ± 1W for 20 V respectively	At Low treatment No reduction of aerobic mesophiles, thermophiles, fatty acid, phospholipid and total protein. At high treatment Significant reduction of aerobic mesophiles, thermophiles and changes in protein fractions	(Bahrami et al., 2016)
To study the effects of a cold atmospheric pressure plasma treatment on the germination, production of biomass, vigor of seedlings, uptake of water of wheat seeds (*Triticum aestivum* L. cv. Eva)	Gas : air Electrode : Silver in 96 % alumina Power : 20 Kv Wave :Sinusoidal PtP: PtP 14 kHz Power: 400 W	Germination rate, dry weight and vigor of seedlings significantly increased.Surface fungus of wheat seeds was inhibited with the increased treatment time.	(Zahoranová et al., 2016)

Objective	Parameters	Results	References
	Time, Seed treatment :10–80 s Microbial : 30–300 s.		
To evaluate the effect of NTP on physico-chemical, amino acid content, pasting properties, X-ray diffraction pattern and protein characteristics of short and long grain rice flours.	Gas: Air Source : Aluminium resting over 10 mm thick perspex Voltage: 60 and 70 kV Time: 5 and 10 min.	The L*, b*, blue value, »max, pH, transmittance, swelling power, and syneresis of both rice types increased but a* value decreased. Decrease in crystallinity was observed using XRD.	(Pal et al., 2016)
To study plasma inactivation of *G. stearothermophilus* on wheat grains.	Gas : Argon (2.8 nlm, norm liter per minute) Electrodes : Aluminum Voltage : 8 kV Frequency: 5-15 kHz Pulses:8 kV, 500 ns pulses at 10 kHz, Pulse voltage: 6-10 kV	Reduction of endospore was caused by species generated by plasma and chemical sputtering Falling number and gluten content were not negatively affected	(Butscher et al., 2016)
To investigate the influences of cold plasma treatment on seed germination, seedling growth, antioxidant enzyme activities and osmolytes content of oilseed rape under drought stress	Gas: Helium Frequency: 13.56 MHz Power :100 W Pressure: 150 Pa Time: 15 s	Percent of germination rate, apparent contact angle , super-oxide dismutase and catalase activities for Zhongshuang 7 was increased by 6.2, 30.3, 17.7 and 16.5%; and for Zhong-shuang 11 increased by 4.4 and 16.9, 13.0 and 13.2% respect-ively. Seedling growth increased significantly.	(Ling, Jiangang, Minchong, Chunlei, & Yuanhua, 2015)
To determine the effect of plasma on 12 various fungi colonizing winter wheat grain	Gas: Air Electrode : Aluminum Power: AC supply Frequency: 100 Hz and 83 kHz Voltage: 8 kV Pressure: Atmospheric Time: 3, 10, and 30 seconds	Fungi colony occurrences were reduced at 10 seconds.	(Kordas et al., 2015)
To evaluate the effects of atmospheric pressure DBD on tomato peroxidase activity	Gas : Humid air Source :aluminum over polypropylene (PP) dielectric layers Volt : 30, 40 and 50 kV	The enzyme activity was decreased with both treatment time and voltage Treatment time exhibiting a more pronounced effect	(Pankaj, Misra, & Cullen, 2013)
To determine the efficacy of low pressure cold plasma (LPCP) system on inactivation of *Aspergillus spp*. and *Penicillum spp* of Wheat, Barley, Oats, Lentil, Rye, Corn and Chickpea	Gas: air and SF6 Source: Quartz plasma tube Wave : sinusoidal PtP: kHz Voltage: 20,000 Volt	Reduced the fungal attachment of seeds below 1% of initial load	(Selcuk et al., 2008)
To verify the pest insects control of major agricultural commodities	Type:DBD Density: 106-108 cm^{-3} Gas:Helium discharge Current densities: Order of 0.1 mA_{rms}/cm^{-2}. Temperature: Below 40^{o}C.	Significantly reducing the population by inducing mortality instantly. It occurs over a 24 hr - 72 hr period after treatment.	(Bures, Donohue, Roe, & Bourham, 2006)



Cleaning and Washing of Grains

⇩

Place in treatment chamber

⇩

Incubate for desired time for plasma treatment

⇩

Packing

⇩

Analysis

Fig. 1. Flow chart of cold plasma grain treatment

for commercially application. A DBD consists of two metal electrodes. Among the two electrodes at least one is coated with a dielectric layer to avoid the arc formation. Gas is passed between two electrodes and a high potential electric field is applied to the gas through the electrodes (Fig. 2a). A plasma jet is comprised of two concentric electrodes through which gas flow. The inner electrode is typically applied with a high voltage in the range of 100-250 V at a high frequency of 13.56 MHz causing ionization of the gas (Schutze et al., 1998), which is directed through the nozzle on to the food surface located a few millimeters downstream (Fig. 2b). Understanding the different experimental setups and equipments used for cold plasma generation is necessary to know the construction of system, evaluation procedure and parameters to be optimized during operation. The process flow chart for grain treatment is given in the figure 1.

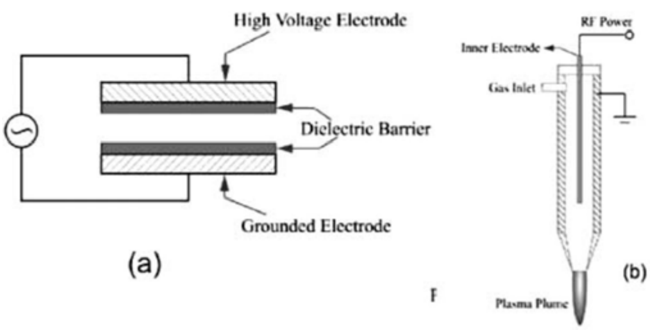


Fig. 2. a) Dielectric barrier discharge; and b) Plasma Jet

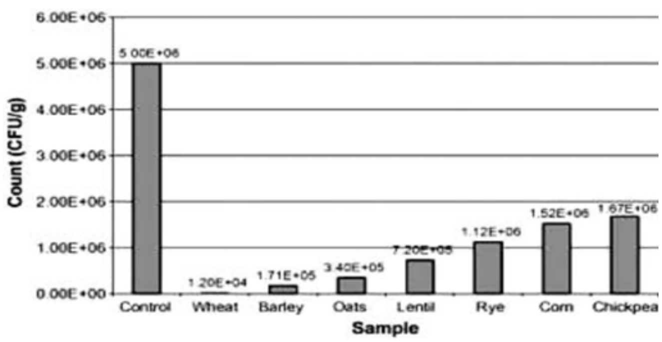


Fig. 3. Effect of plasma treatment of microbial decontamination (Selcuk et al., 2008)

Effects of Plasma Treatment on Grains

Effect of plasma on decontamination of grain

Cold plasma treated brown rice samples inoculated *Bacillus cereus*, *Bacillus subtilis* and *Escherichia coli* O157:H7 has shown reduction in bacterial counts by approximately 2.30 log CFU/g after 20 min of exposure time (Lee et al., 2016). The initial number of bacteria on wheat seeds 5.52 9 104 CFU/g before CAPP treatment, decreased 3.8 times after CAPP treatment in duration 600 s (Zahoranová et al., 2016). The exposure of winter wheat grain to low-temperature plasma resulted in the reduction of the number of colonies of fungi forming on grain in the optimum time of 10 seconds (Kordas et al., 2015).

Effect of plasma on treatment of grain seeds

Plant height of plasma treated wheat seedling was found almost 2.5 cm higher than the control. The root of the treated seed plant and control was 8.5 and 7.8 cm, respectively (Jiafeng et al., 2014). Germination and vigor indices of cold plasma treated soy bean significantly increased by 14.66% and 63.33%, respectively and characteristics of seedling growth, including shoot length, shoot dry weight, root length and root dry weight, significantly increased by 13.77%, 21.95%, 21.42% and 27.51%, respectively, compared with control(Ling et al., 2014). An intensity of 30 s CAPP produced significant (P\0.05) increases in germination rate (21 %) in dry weight (12 %) and vigor index I and II (28 and 36 %) respectively, compared to the control (without treatment) (Zahoranová et al., 2016). In plasma treated brown rice, water uptake rate increased and hardness decreased significantly ($p < 0.05$) (Lee et al., 2016). The speed of germination was markedly higher for the plasma-treated samples (Bormashenko et al., 2015a). A positive effect of the use of cold plasma on the basic values determining seed lot quality as well as on the development of winter wheat in the initial growth stage (Kordas et al., 2015).

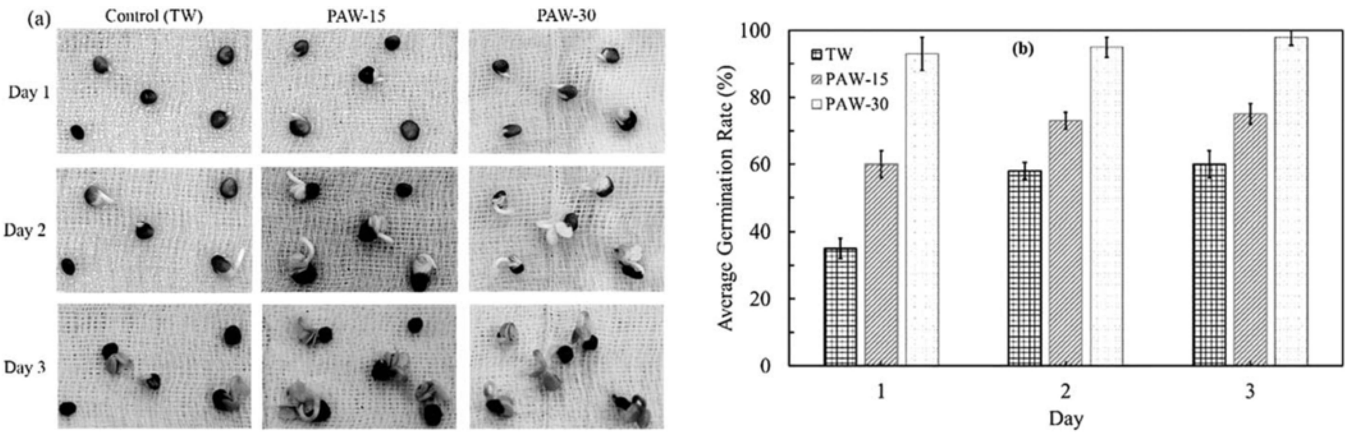


Fig. 4. (a) Seedling growth and (b) average germination rate of radish seeds watered with TW and PAW during the first 3 days after sowing on cotton (Sivachandiran & Khacef, 2017).

Effect of plasma on modification of composition

As a result of plasma treatment, the a-amylase activity and L* of brown rice increased while the pH, a* and b* values decreased (Lee et al., 2016). Lipid components of wheat flour changed after the low level cold plasma treatment at 15 V and for 60 s. Non-starch FFAs and phospholipids of wheat flour was found reduced. Progression of oxidation was evidenced by a significant increase in PV and n-hexanal concentration at all levels of treatment(Bahrami et al., 2016). An increase in plasma power and treatment time decreased the amylose content from 30.34 to 27.89 and the amylose to amylopectin ratio was found least 1.02 for 50 W 15 min sample due to degradation of amylopectin into smaller molecules by plasma immanent species like ions, free radicals. (Sarangapani et al., 2016). The reducing sugar content in control was found to be 0.08%. Significant increase ($p < 0.05$) in reducing sugars was observed among the plasma treated samples. This increase in reducing sugars is due to dextrinization of starch upon plasma treatment (Lii et al., 2002a, 2002b). Reducing sugars content was found more in parboiled milled rice than milled raw rice this is due enzymatic conversion of non-reducing to reducing sugars (Ali & Bhattacharya, 1980). Soluble sugar contents of cold plasma treated soybean at 80 and 100W power increased by 16.51% (p = 0.001) and 11.01% (p = 0.015), respectively, compared with the control(Ling et al., 2014). The chlorophyll content (9.8%), nitrogen (10.0%) and moisture content (10.0%) of plasma treated wheat were higher than the control(Jiafeng et al., 2014). FTIR spectroscopy revealed the alteration of the secondary structure of gluten proteins following ACP exposure(N. Misra et al., 2015). Enthalpy was found to be decreased in plasma treated samples compared to the control sample. Highest enthalpy was seen for control sample 7.90 J/g and the lowest enthalpy was observed for 50 W 15 min sample 7.47 J/g. results plasma treatment results, increase in gelatinization temperature and decrease the endothermic enthalpy of gelatinization (Zhang et al., 2014; Zou et al., 2004). The improved dough strength and optimum mixing time for

Rheological properties of dough prepared from ACP treated wheat flour.

Wheat type	Treatment	G' (Pa)	G" (Pa)	Tan δ
Strong	Control	37,893 ± 3383	12,383 ± 1407	0.326 ± 0.008
	60 kV-5 min	31,387 ± 1755	10,147 ± 1557	0.322 ± 0.031
	60 kV-10 min	45,090 ± 1414	14,002 ± 704	0.310 ± 0.005
	70 kV-5 min	46,841 ± 1359	14,687 ± 2689	0.313 ± 0.048
	70 kV-10 min	51,454 ± 1419	15,586 ± 887	0.303 ± 0.026
Weak	Control	52,693 ± 1974	17,442 ± 1413	0.332 ± 0.039
	60 kV-5 min	45,757 ± 1418	14,998 ± 1835	0.327 ± 0.029
	60 kV-10 min	54,432 ± 2776	17,086 ± 795	0.314 ± 0.001
	70 kV-5 min	72,028 ± 2711	22,908 ± 1411	0.319 ± 0.031
	70 kV-10 min	67,152 ± 1405	20,315 ± 1272	0.302 ± 0.012

both weak and strong wheat flours was observed for atmospheric cold plasma treated wheat flour than control. The elastic and viscous moduli of strong wheat flour increased with applied voltage and treatment time. (N. Misra et al., 2015).

Effect of plasma on antioxidant activity of grain

The total phenolic content plasma treated rice samples increased from 0.51mg/GAE100g of control ignificantly ($p < 0.05$). Increased phenolic content after plasma treatment is attributed to the release of phenolic compounds from glyosidic components and the degradation of larger phenolic compounds into smaller ones. The decrease in TPC is due to the reaction of these phenolic compounds with the free radicals which leads to possible oxidation of phenolic compounds. These results were found to be similar with the reports of previous works with irradiated samples (Beaulieu, D'Aprano & Lacroix, 2002; Breitfellner, Solar & Sontag, 2002; Fan, Toivonen, Rajkowski & Sokorai, 2003; Hanotel, Fleuriet & Boisseau, 1995). The Total antioxidant capacity (TAC) of plasma treated parboiled rice flour was found significantly increased ($p < 0.05$) from 1.21 mg/ AAE100g. Free radicals generated during plasma treatment may act as stress signals and may trigger stress responses, resulting in an increased antioxidant synthesis (Fan et al., 2003). The variations in ferric reducing power of plasma treated parboiled rice flour was observed. Cold plasma is resulting in an acceleration of flour oxidation (Bahrami et al., 2016).

Conclusion

Presently, need of alternate fumigation and quarantine system is vital for all food processing industries. By analogue and intuitive, it is proposed that cold plasma based system can be a hopeful for alternate system. However, many things about of cold plasma are still incomprehensible. Major aspects of cold plasma are yet to be studied with respect to food application especially how old plasma inactivates spores and how the electronically excited molecules of cold plasma interact with the food or packaging materials. Hence, following things are need to be studied and explored for further development of efficient cold plasma system for fumigation.

1. Effect of electrodes, gas types and gas flow rates, power supply on composition of cold plasma
2. Di-electrical properties of cold plasma
3. Effect of cold plasma on dielectric properties of grain and insect pests
4. Heating mechanism of cold plasma in insects
5. Grain quality both in quantitatively and qualitatively
6. Diffusion of cold plasma in bulk grains
7. Stability of the plasma for large-scale commercial operation

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Functional Dairy Foods: A Futuristic Approach for Enhancing Farmer's Income

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Introduction

The welcoming response in human life expectancy results in high health care costs, thus the society needs to adopt newer functional foods in routine diets along with the modifications in people's life style. This tendency promotes the academia and industry for providing efficient practices for improvement in the physical structure as well as chemical composition of food products to generate functional foods which also provide physiological attributes beyond their nourishing properties. Functional foods are those that contain one or more functional compounds/ nutraceuticals (like prebiotic, probiotic, antioxidants, polyphenols, sterols and carotenoids etc.) which offer important or limited functions in the organism, promoting health and welfare, or for the decreasing the risk associated with hypertension, cancer, diabetes, osteoporosis, and heart diseases.

Functional dairy products

Functional foods are the healthy food products of the future including probiotics, energy-boosting foods and those enriched with vitamins and minerals. Dairy products such as yogurt and cheese containing probiotics as well as milk containing omega-3 fatty acids have a foremost position in the development of functional foods. Dairy-based functional foods reported for nearly 43% of the market among functional foods, which is almost utterly made up of fermented dairy products. Dairy products including beverages and non-drinkable products containing Omega-3 fatty acids, conjugated linoleic acid (CLA), phytosterols, isoflavins, vitamins and minerals also have a major role in the development of functional foods. At present, a number of dairy-based beverages (containing probiotics likes yoghurt) are marketed all over the world but, still the dairy-based beverages market is a small market in comparison to the sales of plain milk.

Cheese

It is one of the most popular fermented dairy products with wide range of applications and is consumed in almost every part of the world. It is produced by milk coagulation, caused by lactic acid and enzyme rennet. The coagulation of casein takes place due to increased lactic acid that leads to drop in pH. If rennet is not supplemented, it will yield soft cheese (cottage or cream cheeses). Bacteria, yeasts and molds are all involved in the processes of manufacturing and ripening of different cheeses.

Qula: It is a grainy, hard, and yellowish color yak cheese product using yogurt to yak milk and produced mainly in Tibet. The traditional Qula has a shelf life of 2–3 years at room temperature without any contamination or degradation.

Churpi: It is a yak milk based traditional cheese product of Himalayan region. For its preparation yak milk is churned in shoptu, a large wooden drum and the cheese blocks were brined and aged for 4–5 months. Churpi is basically of two types (1) soft variety and (2) hard variety. Hard variety is again of two types i.e. chhurpi and dudh chhurpi.

Churkham: it is also a yak milk based cheese product formed during the preparation of churpi, which was aged for 2-12 months for improvement in taste.

Quark: It is a cheese like fermented milk product is prepared by acid, acid-rennet or thermal-acid coagulation of proteins by the inoculation of milk with *Lactobacillus* or combination of *Lactococcus* and *Str. thermophilus* following by removal of whey by pressing. The finished product should contain not less than 105 CFU/g of LAB and 14.0% protein content.

Yogurt

Yogurt which has been recognized as 'a healthy food' with therapeutically effects is a semisolid fermented dairy product made by natural acidification of the milk by the action of lactic acid bacteria. It is a traditional food in Asia, Middle East and Mediterranean and Western countries where is made from milk of cow, buffalo, goat and sheep. *Streptococcus thermophilus* and *Lactobacillus bulgaricus* are the two prime microorganisms which are employed for the commercial yogurt production. These two microorganisms complement each other in synergistic manner and are able to confer the probiotic benefits. Yoghurt is a rich source of calcium. The acid fermentation in yogurt preparation also results in partial hydrolysis of the milk proteins and formation of bioactive peptides. Folate is strongly produced by *S. thermophilus* during yogurt fermentation which results in the enhanced vitamins level in yogurt. Although the flavor and consistency may differ region to region but, the basic ingredients and manufacturing are consistent.

Yogurt types

Set yogurt: It is a solid set yogurt which was formed in a consumer container without disturbing.

Stirred yogurt: It is the most popular form of commercial yogurt. For this yogurt is first prepared in large container and then dispensed into secondary serving containers due to which the set consistency is broken and the texture is less firm.

Drinking sweet yogurt: In this additional milk, flavors, fruit or fruit syrups are mixed in stirred yogurt to enhance taste and to achieve the desired thickness. Fresh milk addition raised pH which increased the shelf life of product to 4–10 days.

Fruit yogurt: In this various fruit, syrups (fruits), or filling can be placed on top, on bottom, or stirred into the yogurt.

Yogurt cheese: it is prepared from yoghurt by overnight draining and separation off the whey with a flavor similar to sour cream and texture of soft cream cheese with a shelf life of 7–14 days when stored at less than 4°C.

Frozen yogurt: it is yogurt which is frozen by batch or continuous freezers.

Dried yogurt (Kurut in Turkey): It is yoghurt that is dried in sun for longer preservation.

Misti dahi or mistidoi

It is a popular sweetened fermented milk product which is prepared by the mixed cultures of *Streptococcus (Str.) lactis, Str. diacetylactis, Str. cremoris,* and *Leuconostoc ssp.*. usually it is prepared from buffalo milk or a combination of buffalo and cow milk and has high sugar (13%–19%) and fat (6%–12%) contents. *Str. thermophilus* and *Lb. delbueckii subsp. bulgaricus* in are used for the production of functional misti yogurt which can be served as a dessert or snack. It is prepared by heating milk with sugarcane juice at 60°C–70°C for 6–7 h in an open vessel. Then starter is added and contents were incubated for lactic fermentation. The final product has firm consistency, smooth texture, and pleasant aroma and cream to light brown color due to caramelization of sugar.

Matsoni

It is a yogurt like cultured dairy food with a syrupy consistency, prepared by starter cultures that have unique LAB by mesophilic fermentation. It was attributed to Bulgaria, Georgia, Armenia, or Russia.

Fermented dairy milk

Fermented milk helps to improve the digestion of lactose, enhanced digestive comfort, improve immune and digestive function, eliminate or reduce cholesterol. Fermented beverages constitute an important part of the human diet because fermentation is one of the cheapest ways of preserving the food, improving its nutritional value, and enhancing its sensory properties.

Ayran: It is a popular drink of Turkey, Azerbaijan, Iranian Azerbaijan, Bulgaria, Republic of Macedonia, Kazakhstan, and Kyrgyzstan and having yogurt as base material with salty taste (Yoghurt + water + salt). For fermentation, process requires same culture of Yogurt (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*) which also contributes for the development of flavor and textural properties of the final product. Other important fermented dairy milk is kefir, koumiss, acidophilus milk**,** bifidus milk and acidophilus bifidus milk (A/B Milk) which are having their significance in area specific market.

Bifighurt: It is a another probiotic milk drink, is produced by fermenting milk using 6% mixed culture of *Bifidobacterium bifidum* or *Bifi dobacterium longum* CKL 1969 and *Streptococcus thermophilus* at 42°C up to the level of final pH (4.7). Bioghurt has a mild acidic flavor and contains L(+) lactic acid at a level of 95%. Another variant i.e. diphilus milk is made from cow's milk and has a specificc taste and aroma.

Mil-Mil: This product is quite similar to Acidophilus–Bifidus milk and is very popular in Japan. In the production of Mil-Mil, pasteurized milk is inoculated with a mix culture of *Lactobacillus acidophilus*, *Bifidobacterium bifidum*, and *Bifidobacterium breve*. In most cases, glucose or fructose is added to balance the taste of the product and carrot juice is added as a colorant.

Ymer: It is a skim milk or whole milk based fermented sour milk product with high protein content (5%–6%) and pleasant acidic flavor. It is a Danish product. Milk is inoculated with starter culture comprises of mesophilic LAB such as *Lc. lactis subsp. lactis var. diacetylactis and Leuconostoc (Leu.) mesenteroides subsp. cremoris*. and incubated at 18°C–20°C until curdling. Microorganism converts milk lactose into lactic acid and drop the pH to make the product sour.

Ryazhenka: It is a fermented dairy product which is native to Russia and produced by the inoculation of baked milk with *Str. thermophilus* and in the final product bacteria count should not be less than 107 CFU/g.

Viili: It is a cultured dairy product prepared by Yeast and LAB fermentation which provide it a unique ropy, slimy, and sticky texture. Initially it hails from Scandinavian region of Sweden but is now popular in Finland. It has a mildly sour flavor and mainly served with a gooseberry jam which makes it a good option for children who are interested in naturally soured probiotic products.

Piima: It is a cultured dairy food similar to buttermilk which has a sour flavor of a mild cheese. Unlike other cultured dairy products, piima has thin uniformity and is cultured at room temperature. For the preparation of Piima starter culture required to inoculate the milk should be of Scandinavian origin.

Gariss: It is camel milk based fermented full cream sour milk product which is native to Sudan. It is prepared by semi continuous or fed-batch fermentation of camel milk in two leather bags of tanned goat skin by the action of LAB and yeasts. During its utilization the volume which is withdrawn for utilization by consumers same amount of fresh milk is added.

Shmen: It is Algerian butter-type product prepared from sour camel milk. It has bright white color due to the high contnet of non-fat components like proteins linked to the fat globules. Moisture and fat contents of Shmen ranged between 34%–35% and 49%–56%, respectively.

Shubat or chal: It is a popular fermented camel milk product of Kazakhstan and Turkmenistan. It is prepared by mixed starter cultures of *Lb. casei, Str. thermophilus*, and lactose-fermenting yeasts into camel milk and incubated for 8 h at 25°C followed by 16 h at 20°C. It is rich source of vitamins B1, B2, and C and has digestive as well as therapeutic properties.

Suusac: It is camel milk based fermented milk product of Kenyan produced by lactate fermentation at 26°C–29°C for 1–2 days which results in white-colored product with distinct smoky flavor and astringent taste. For preparation of suusac camel milk is heated to 85°C for 30 min and then cooled to 22°C–25°C, and inoculated with mesophilic starters at 27°C–30°C for 24 h.

Kurut: It is traditional yak milk based alcoholic fermented product like kefir and koumiss which has white color and has alcoholic and acidic sensation. It is native to Qinghai and Tibet of China. The fermentation of yak milk carried out at 10–20°C for 7–8 days by various spp of bacteria such as *Lactococcus (Lc.) lactis subsp. lactis, Lb. helveticus, Str. thermophilus, Lb. delbrueckii subsp. bulgaricus*, and *Acetobacter*.

Blaand: It is whey based alcoholic fermented traditional Scottish drink which is prepared by pouring the whey into an oak cask for alcohol fermentation.

Table 1. List of Functional Milk Components/ Ingredients

α-Lactalbumin	Lactoperoxidase	Vitamin B12-binding protein
β-Lactoglobulin	Lysozyme	Peptides of Whey protein: â-Lactorphin, á-Lactorphin, Casein macropeptide
Bovine serum albumin	Biotin-binding protein	Lipids: Butyric acid, Arachidonic acid, Sphingomyelin, CLA, Milk fat globule membrane
Immunoglobulins and immune system components	Epidermal growth factor	Hormones: Thyroid hormones, Pituitary hormones, Leptin, Steroid hormones
Lactoferrin	Fibroblast growth factor	Carbohydrates: Oligosaccharides, Mucins, Lactose
Lactoferricin	Riboflavin binding protein	

Health benefits of functional dairy foods

Functional milk products are widely consumed worldwide. These functional foods are prepared by modification by the action of microbes or their enzymes to attain desirable biochemical changes and by the addition of functional ingredients it the native product. Dairy products have shown a strong foundation toward the development of functional foods and dietary supplements with the addition of health-promoting innovative ingredients. Fermented dairy products are effective detoxifiers and are capable of removal of wide range of heavy metals from the body. Additionally when fermented dairy products are supplemented with probiotics they increase the contents of essential nutrients like vitamins B12, B6, K2, biotin, protein, essential amino acids, and fatty acids in the final product. Probiotics produce a range of antimicrobial substances, such as lactic acid, acetic acid, formic acid, propionic acid, ethanol, diacetyl, acetaldehyde, fatty acids, and bacteriocins which were found to have a strong inhibitory action against pathogens. Therefore, functional dairy products were recommended as an alternative to boost immune system, especially among children and elders and to lower the cholesterol level. Lactose intolerance can also be cured by consuming functional dairy ingredients as the probiotic strains of *Lb. acidophilus* and *Bifidobacteria* improve digestion of lactose by secreting lactase to digest lactose which otherwise cause diarrhea, bloating and abdominal pain. Functional dairy based probiotic products are also have anticancerous property as probiotics slow down carcinogens or pro-carcinogens, hinder the growth bacteria which convert pro-carcinogens to carcinogens and increase acidity of intestinal tract to alter microbial activity and to reduce bile acid solubility. Probiotics also helps in lowering down the cholesterol level as probiotics deconjugate bile acids, for their easily and high excretion which enhances cholesterol consumption and eventually reduces cholesterol. During the growth of probiotics incorporation of cholesterol into cellular membranes of probiotics converts the cholesterol into coprostanol which is directly excreted in feces. Functional dairy products are also proven to be helpful in management of acute viral and bacterial diarrhea and also in controlling of antibiotic-associated diarrhea.

Functional probiotics products containing *Lb. helveticus* and *Saccharomyces cerevisiae* also play a role in reduction of systolic and diastolic blood pressure. Additionally, probiotics present in fermented milk products increase in healthy gut flora which helps in strengthen digestion and better elimination of toxic wastes. Probiotics also helps in curing mental dysfunction problems. Functional foods also provides health benefits for GI system diseases, cardiovascular system diseases, musculoskeletal system diseases, immune system diseases, allergy, nervous system diseases, cognitive system diseases, weight control, obesity, aging and dental health.

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