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PLASTICULTURE TECHNOLOGIES IN POST-HARVEST MANAGEMENT: GRAIN STORAGE AND DRYING

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All India Coordinated Research Project on Plasticulture Engineering and Technology

Introduction

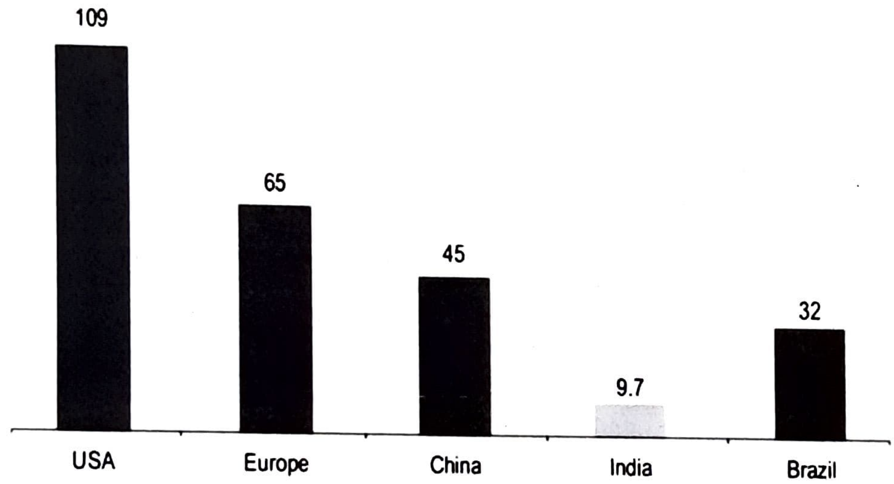
India supports nearly 16% of world's population with 2.4% land resource and 4% water resource and lately the dwindling quality and the vagaries of the availability of these resources are raising serious questions on the sustainability of the agricultural practice. To counter the problem, efforts need 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

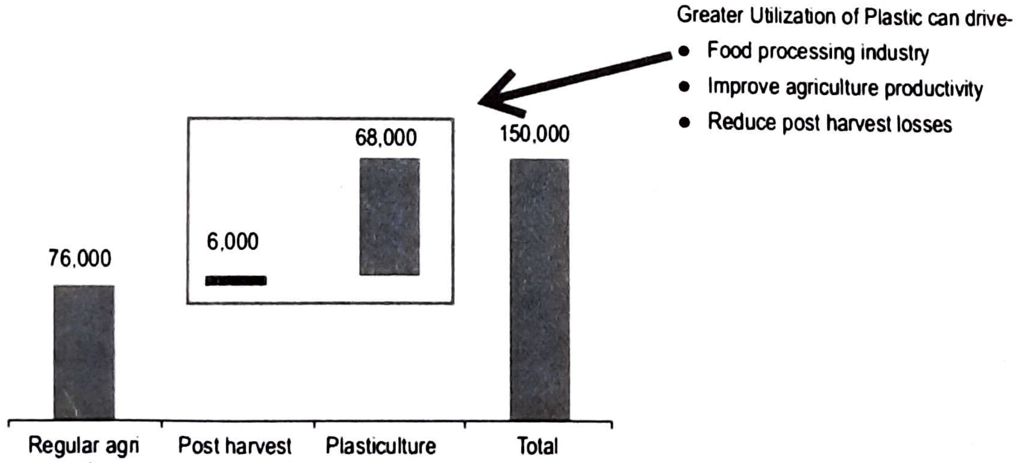
Compared to world average of polymer utilization in agriculture which stands at 8%, India has ploymer utilization of just 2%. Hence there is a lot of potential of plastic application in agriculture. There is also heavy pre and postharvest losses which further contribute to low availability of food grains 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 (as shown in the figure 1). 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. India is a vast nation. Every region has got specific agricultural characteristics and problems. These specific problems of the area could be tackled with tailored innovative and scientific use of plasticulture techniques. This would not only maximize the output of farms but also optimizes the input factors. For example, in Western Himalayan region the productivity is low because of constraints like severe soil erosion, degradation due to heavy rainfall/floods and deforestation and inadequate market delivery infrastructure. Each Plasticulture application can drastically save water by about 30 to 100%. In case of farm pond lined with Plastic film the total loss by seepage of water can be minimized, almost to zero. Also, efficient use of fertilizers can bring the costs down which again is beneficial for the farmers. Plasticulture can play a key role in energy conservation. It essentially stresses on the use of plastics in agriculture, horticulture, water management, food grains storage and related areas.

A multitude of plastic materials may be employed in plasticulture applications such as water conservation, irrigation efficiency, crop protection, including farm output practices like crop storage and transportation. Growing population and decreasing size of arable

Figure 1: Per capita plastic products consumption (Kg/person)



Source: PlastIndia, Business Press, Research by Tata Strategic.



Source: FICCI Report on potential of Plasticulture in India May 2016 lands has necessitated the need to employ clean, green and sustainable practices to save resources and enhance productivity.

Usage of plastics in agriculture can lead to: Yield improvement upto 50-60%, Water savings upto 60-70% , Prevention of weeds growth, Soil conservation , Protection against adverse climatic conditions, Fertilizer savings upto 30-40%, Reduction in post-harvest losses, Conversion – cold desert/wasteland for productive use

Plasticulture in post-harvest management

Total food grains production in the country is estimated as 252.22 million tonnes in 2016-17 which is marginally higher by 0.20 million tonnes than the previous year's foodgrains production of 252.02 million tonnes. India is a country with a large population with huge food requirements. Unfortunately, about 20-30% of the fruits and vegetables produced in the country are lost due to mismanagement, wastage and value destruction. So, a sizable chunk of the harvested product is lost before reaching its end-consumer. There is a huge potential to save this sizable fraction and improve the system. Lack of sorting facilities, inappropriate packaging, slow transport systems and inadequate storage facilities are some of the key factors behind this loss of perishable goods. Effective post-harvest management includes good quality storage infrastructure, bulk handling tools and creating the necessary infrastructure across the value chain. Plastics are used to make crates, seals, etc. which make the handling and packaging of the harvest easy. Advantages of plastics are: easy to handle, cheap, durable for long period and inert with most items, all of which make plastics a sustainable choice over its substitutes such as paper, cloth, etc. Plastics have the potential to play a significant role in preservation of quality and longevity of harvested produce. Application The value chain of the post harvesting process for both perishables and durables are described in the table below. 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. Post harvest management of farm produce including grains, cereals, fruits and vegetables is one of the theme area of the AICRP on Plasticulture engineering and technology

1. Safe Storage of agriculture products in plastic derived bags, containers etc
2. Drying of produce in solar poly tunnel/ Polyhouse dryer
3. Packaging of products for transportation and containment

Plasticulture technologies in storage of agriculture produce

In India, about 70% of farm produce is stored by farmers for their own consumption. Farmers store grain in bulk, using different types of storage structures made from locally available materials. While fulfilling the food demand of an increasing population remains a major global concern, more than one-third of food is lost or wasted in postharvest operations. Reducing the postharvest losses, especially in developing countries, could be a sustainable solution to increase food availability, reduce pressure on natural resources, eliminate hunger and improve farmers' livelihoods. Cereal grains are the basis of staple food in most of the developing nations, and account for the maximum postharvest losses on a calorific basis among all agricultural commodities. As much as 50%–60% cereal grains can be lost during the storage stage due only to the lack of technical inefficiency. Use of scientific storage methods can reduce these losses to as low as 1%–2%. Storage losses constitute a major share of food grain loss in postproduction operations. Storage of biomass in large plastic bags is a well established technique in many countries. The impact of changing temperatures on the quality of wheat grains during the anaerobic storage in the bags is controversially discussed. Freshly harvested wheat was stored for six months without additives in the large plastic bags and the quality is compared to that of a conventional storage. The results demonstrated that neither the anaerobic atmosphere in the bags nor the seasonal decreasing temperatures lead to quality differences between the grain varieties. The storage in large plastic bags can be recommended as a favorably alternative to the conventional storage. The range of products that can be stored in large polyethylene bags is fairly substantial. Besides sustainable vegetable products (e.g. grass, maize, whole plant silage, wet and dry grain, sugar beet), and substrates from processing in agro-industries (e.g. pulp for pellets, draff, pomace), organic leftovers may also be considered.

Preservation and storage in hermetically sealed large polyethylene bags is well known from silaged goods. Key reasons for this growing trend are low costs, limited risk, and high quality in a gas tight system. In addition to that, the storage in large polyethylene bags under anaerobic conditions facilitates the optional extension of storage periods to react on price changes, without having to invest in buildings. Farmers can deliberately forgo building efforts, choosing a flexible storage system instead, thus being able to adapt to conditions outside their realm of control. Christine (2012) stored freshly harvested wheat in polythene bags at storable dry matter content can be stored in large polyethylene bags up to six months without loss in quality. The initial question, whether the grain would lose in quality by storage in large polyethylene bags between summer and winter, can thus clearly be denied. The results indicate that both the content of the examined nutrients as well as the relevant micro organisms only changed marginally during storage. Otherwise, no differences were established in the quality of the samples from the different sample levels and from the different storage variants. Thus it can be concluded that storing wheat in large polyethylene bags is presumed not to affect baking properties in any respect. Further examinations shall be undertaken. Due to the very low costs of the flexible process, the storage in large polyethylene bags provides an alternative to high investment costs for durable storage constructions for grain. The location for storage can be chosen flexibly to optimize transport ways. With variable bag lengths farmers can adjust the storage capacity to actual batch dimensions and storage durations. Consequently, the grain can be stored to the point of highest potential market value. Christopher (2017) Hermetic storage (HS), also called as "sealed storage" or "airtight storage", is gaining popularity as a storage method for cereal, pulses, coffee, and cocoa beans in developing countries, due to its effectiveness and avoidance of the use of chemicals and pesticides. The method creates an automatic modified atmosphere of high carbon dioxide concentration using sealed waterproof bags or structures. As the structures are airtight, the biotic portion of the grains (insects and aerobic microorganisms) creates a self-inhibitory atmosphere over time by increasing carbon dioxide concentration (oxygen decreases) due to its respiration metabolism. Some studies have reported that the aflatoxin production ability of Aspergillus flavus is also reduced at high concentrations of CO_2. Hermetic storage has been observed to be very effective in avoiding the losses (storage losses less than 1%) during long distance (international) shipments also. Ease of installation, elimination of pesticide use, favorable costs, and modest infrastructure requirements are some of the additional advantages that make the hermetic storage options attractive.

Plasticulture technologies developed for storage, packaging and transportation by AICRP on PET centres: These developed Plasticulture technologies of the centre contributed in developing on farm storage of durables as well as perishables which made good impact in farmers field. From these explained results it can be stated that Plasticulture technologies made good contribution in storage area of post-harvest management because less loss of food/produce equals to increasing production and conserving the precious input resources with least cost. Some of the studies carried out by centre may illustrate more where they have standardized plastic material for specific commodity to improve its performance with low cost.

1. Low cost farm storage structure for fruits and vegetables
2. Storage of pulses, grains in LDPE, HDPE and Composite (double/triple layer) bags.
3. MAP for fruits and vegetables
4. Shrink wrap packaging of capsicum, kinnow and tomato
5. Foldable plastic box for transportation of fruits and vegetables

➢ Storage study under low cost shade net with fogger arrangement reveled that it is best practice for temporary storage of perishables. These plasticulture technologies help in extending the shelf life of commodity. Tomato and spinach could be stored up to 93 h and 45 h, respectively in 75% shade net structure. The storage cost for the tomato and spinach is estimated to 0.82 and 1.10 Rs/kg, respectively. The profit for tomato and spinach is found 2.24 and 1.49 Rs/kg, respectively.

➢ One of the centre carried storage study on pulses. Different packaging materials viz., polyethylene lined jute bag, PP woven laminated bag (Silo bag), HDPE bag with vacuum, multilayer coextruded plastic bag with vacuum, aluminum laminated polyethylene bag with vacuum, Perdue improve crop storage bag (PICS bag) and jute bag as a control were used for Desi chick pea (GJG-3) for storage. Chick pea grains were procured from Dhari Farm of Junagadh Agricultural University, Junagadh. The grains were consisted with cleaning and sorting manually. Safe storage moisture content of grains was kept 8.0-8.5 % (wb) by sun drying. Total 105 bags of 5 kg sample size for each bag were stored at room temperature in the laboratory. Proximate analysis was carried out before packaging of the grain. Pest population, weight loss, grain damage moisture content, germination per cent, protein content and cooking time will be measured at two months interval. Room temperature and relative humidity are being measured daily during experiment. The mean value of proximate analysis of the grain viz., moisture content, protein, carbohydrate, oil percent and ash content of twenty samples was observed to be 8.21%, 22.71%, 64.05, 3.56% and 3.20%, respectively. Initial germination percentage, vigour index and cooking time of chick pea grains was found 97.33 %, 14.58 and 30.50 min, respectively.

- Foldable plastic box with cells (FPBC) reduces transportation losses for delicate fruits and vegetables (sapota and tomato) limits loss upto 2-2.55% for sapota and tomato. The cost of one box is Rs. 425 per 10 kg.

- In modified atmosphere packaging (MAP) for sapota and mango shelf-life was increased by 49 days for sapota and 35 days for mango. Cost of packaging of Sapota is found to be Rs.4.25/ kg and Mango Rs. 5.03/ kg. Net profit from the technology is achieved as Rs. 8.75/ kg for Sapota and Rs. 14.97/ kg for Mango. From the study, it is recommended to use 25 micron thick LDPE film.

- One of the centre in North east India carried out storage study on rice and maize. Seeds of rice and maize were dried to the recommended moisture levels (8-10%), packed in single layered LDPE packets of 10kg and sealed. The packets were stored under ambient conditions. Maize seeds stored in this condition with acephate showed no deterioration in quality and resulted 96% germination and without acephate 89% germination. Rice seed without acephate resulted with 96% germination.

- Shrink wrap packaging of fruits and vegetables (kinnow, capsicum and tomato) performed by one of the centre in which they have standardized plastic film to improve its storability and shelf-life. LLDPE 25μ -Kinnow, Polyolefin film 15μ-Tomato, Polyolefin film 19μ- capsicum can be used for enhancing the shelf-life. Cost of

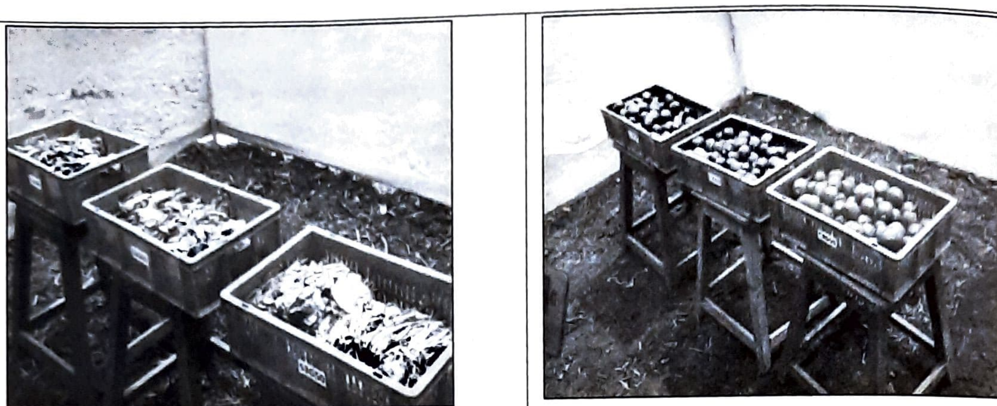


Fig.1. Low cost farm storage structure for fruits and vegetables at AICRP on PET centre

Fig.2. Storage of pulse at AICRP on PET centre

Fig.3. Different storage material for chickpea storage at centre

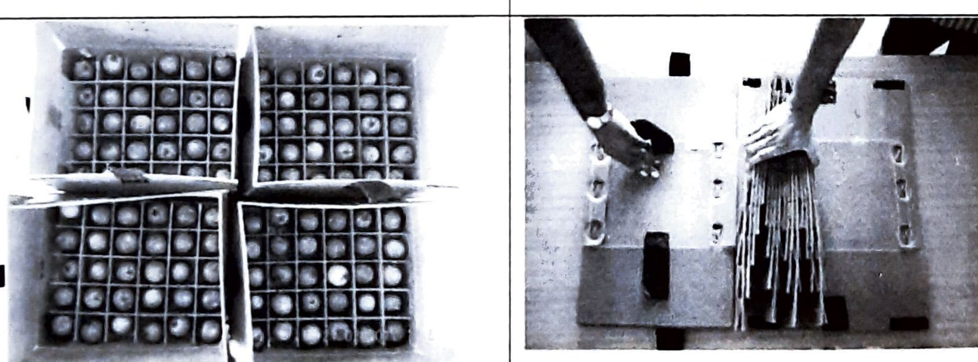


Fig.4. Foldable plastic box with cells (FPBC) Reduction of transportation losses for delicate fruits and vegetables (sapota and tomato) by AICRP on PET centre

shrink wrapping for one kg of fruit is Rs. 1.48. Storage increased by 4 weeks for Kinnow, 24 days ambient storage for Capsicum and 19 days for Tomato.

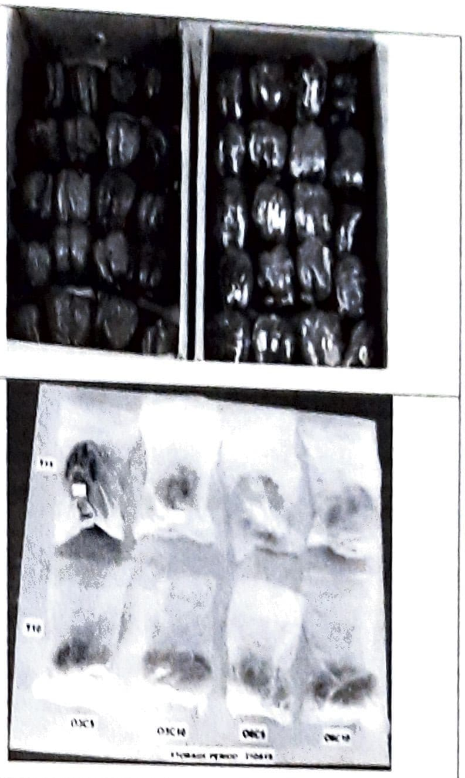


Fig.5. MAP (Modified atmospheric packaging storage) and Shrink wrap Plasticulture technology developed by AICRP on PET centres

Plasticulture technologies developed for drying of agriculture and animal produce by AICRP on PET centres as follows:

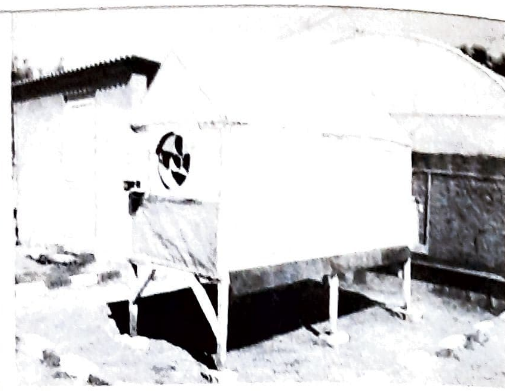
Drying is one of the most important unit operations in post-harvest management of agriculture/animal produce. Drying is a mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semi-solid or liquid. This process is often used as a final production step 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). Innovation in plasticulture technologies open new era in drying operation. To untapped the potential of abundant sunlight/ solar energy harnessed by polyhouse, polythene based material chambers proved to be more economical for drying operation. It had been revealed from the studies of the centres that drying with help of plasticulture innovation not only increases the storability but also maintains its quality with less operational cost. Solar dryers are more effective in drying with lower operating costs than mechanized driers. Numerous designs have been proven technically; however none yet is widespread in use. An extensive study has been conducted on different types of direct solar dryers such as box/cabinet-type, tent-type, and polyhouse solar dryers for drying of agricultural produce. Polyhouse dryers are now being increasingly used since they are better and more energy efficient option.

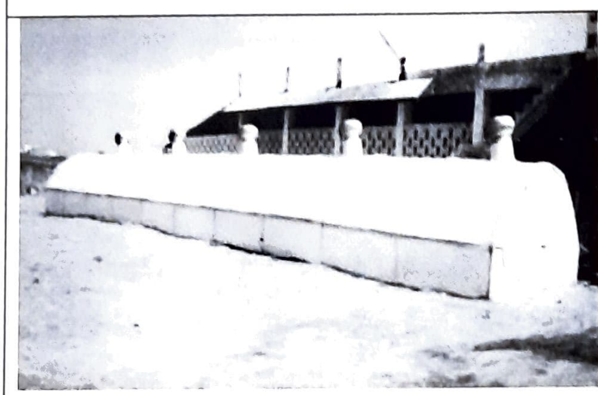
A polyhouse dryer is a unique and cost efficient method of drying agricultural products on commercial scale. It consists of a drying chamber, an exhaust fan and a chimney. The roof and the wall are made by transparent plastic films that are mounted on a metal frame. The sheet has a transmissivity of approximately 92% for visible radiation which traps the solar energy during the day and maintains optimum temperature for drying of produce. UV-stabilized films play an important role in polyhouse dryers. UV-radiation in the sun rays tends to cause changes in the organoleptic properties such as texture, color and flavor of food materials. Hence UV-stabilized polyethylene sheets are used to prevent such deterioration. The sheet allows only short wavelength which is converted into long wavelength when it strikes on the surface of product or a blackbody. Since the long wavelength cannot move out, it increases the temperature inside the dryer. Apart from the above mentioned advantages, the sheet has superior properties in terms of transparency, transmissivity, anti-corrosion property, self-adhesive, retraction ratio, tensile properties, tear-resistant, anti-puncture, water-proof, moisture-proof and dust-proof. A black surface inside the PHD improves the effectiveness of converting light into heat. Plastic sheets and glass covers have the distinct property to allow light to enter the dryer and retaining it inside the chamber. The trapped light is converted into heat energy to remove moisture from the produce. The objective of a polyhouse dryer is to maximize the utilization of solar radiation. Based on the mode of heat transfer, it is classified into passive and active polyhouse dryer. The passive mode dryer works on the principle of thermosyphic effect i.e. the moist air gets ventilated through the outlet provided at the roof or through the chimney of the dryer. For active polyhouse dryer, there are two energy sources namely the air saturation deficit and the incident global solar radiation. Both natural and forced convection methods circulate the hot air to the food material. One of the differences is that, at the initial stage of drying, the value of mass transfer coefficient is double in the active mode than in passive polyhouse dryers.

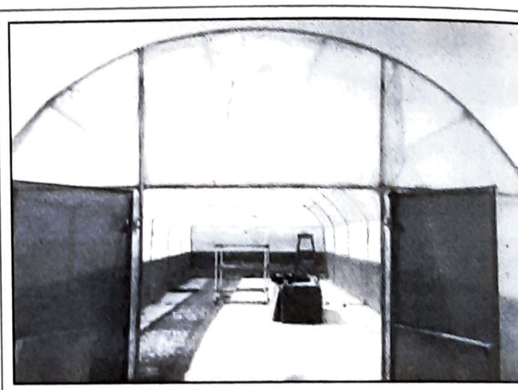
Drying by use of polyhouse proved to be economical and only viable option in rural areas which is evident from the studies carried out by AICRP on PET centre at farmers' field. They have dried all type of commodities and standardized design of their dryer according to their climatic condition for different food products of plant and animal origin.

- One of centre developed dryer was used to dry fruits and vegetables. The dryer was used for drying of grapes and cauliflower. Approximately 100 hr were required to obtain the equilibrium moisture content (17.62%) for grapes. About 16.00 hr were required to obtain the equilibrium moisture content (14.99%) for sample of 10 mm length and 8% for sample of 15 mm length of cauliflower.
- Designed and developed portable solar dryer also tested for its performance. Capacity of the solar poly tunnel drier with two trays was 4-6 kg/batch. Cost of unit is Rs. 3500/- and the operating cost is negligible as it uses solar energy (renewable source) for its operation and just 6 volt battery to operate the exhaust fan as and when needed. The polyhouse use during summer (when the inside temperature reaches 50-60°C) for drying of vegetables was investigated by centre. Package for drying chilli in poly house have been developed which is impurity free, and took less than 1-2 days in open sun drying. The capsaicin was also recorded 10% more for polyhouse dried chillies.
- A single span arc type G.I. pipe framed greenhouse tunnel dryer of size 21.3 m*4.6 m*2.2 m covered with single layer 200µ thick UVS polyethylene sheet was developed and installed at M/s Jose and Bros., Veraval (a fish processing industry) by ACRP on PET centre in 2008. Freshly available marine fish of the variety Croaker, Anchovy and Ribbon fish were tested for drying with and without salt treatment, by loading the fish on the wire net or jute net inside the dryer between 9:00am to 17:00pm under two temperature regimes i.e. 40-45°C and 45-49°C. At no load conditions, inside temperature was 5-15°C higher than ambient for different vent openings. However, temperature remained below 50°C with any single side full vent opening. In salt treated fish moisture content was reduced up to 42.85% - 66.66% db in 1 or 2 days of drying, whereas in

Portable polytunnel dryer







Types of dryer developed under AICRP on PET for drying of fruits, vegetables and fish products.

➤ unsalted fish moisture content was reduced up to 17.64% - 25% db in 3 or 4 days of drying. For salted Croaker, average drying rate was found to be 1.55 g/hr/100g bone dry weight in solar drying as compared to 1.31 g/hr/100g bone dry weight in sun drying. Similarly, for salted Golden Anchovy fish the corresponding figures were found to be 0.56 and 0.41. The capital cost of the dryer with and without three tier trolley was worked out to be Rs.1.50 lakh and Rs.1.10 lakh, respectively. Considering major maintenance cost of replacement of UV stabilized polyethylene to be Rs 13,000/year including labour, the drying cost per tonne for raw croaker, golden anchovy, and ribbon fish was worked out to be Rs. 770, Rs. 571 and Rs. 1000, respectively. Whereas for salted fish it was Rs. 857, Rs. 514 and Rs. 1028 respectively. The drying cost of these varieties of raw and salted fish could be reduced to 60% by using three tier trolleys.

Conclusion

India is at a crucial juncture when it needs to tackle the issue of food security by optimizing the use of resources, which traditionally has been taken for granted.

Plasticulture is a viable solution for India, to launch 2nd Green revolution. Application of plastics or plasticulture technologies played an important role in post-harvest sector. Post-harvest losses can be minimized by intervention of plasticulture technologies such as innovative film packaging, storage in plastic derived bags/containers. Food processing sector in India is also at a nascent stage. The use of plastics in food processing is currently one of the lowest in the world. As plastics are majorly used for packaging such products, their demand is also expected to grow. North India is already a hub for food processing companies with major international players running their operations thereby promoting the consumption of plastics. From the work carried out to date on polyhouse drying of agricultural produce, it is inferred that the solar dryers can be used to a great extent. It is recommended that the farmers should use polyhouse solar dryers in their farms. Hence the polyhouse dryer is a boon to small scale farmers

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