Processing of Foods for Addressing Malnutrition

K. Bembem, Renu Balakrishnan, Yogesh Kalnar, Vikas Kumar and Th. Bidyalakshmi Devi

ICAR-CIPHET, Ludhiana-141004, Punjab

"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.

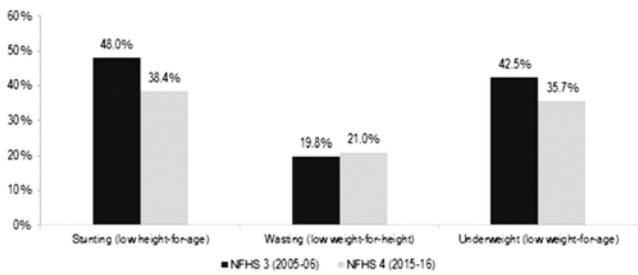

Fig. 1. Percentages of stunted, wasted and underweight children in India (Source: National Family Health Survey 3and 4)

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.

References

Borad G, Kumar A and Singh AK (2017) Effect of processing on nutritive values of milk protein, Critical Reviews in Food Science and Nutrition, 57:17, 3690-3702, DOI: 10.1080/10408398.2016.1160361

Development Initiatives, 2017. Global Nutrition Report 2017: Nourishing the SDGs. Bristol, UK: Development Initiatives.

Fillion Land Henry CJ (1998) Nutrient losses and gains during frying. International Journal of Food Science and Nutrition, 49(2): 157-68.

Gopalan C, Sastri B and Balasubramanium S (2016) ed. Nutritive Value of Indian Foods. National Institute of Nutrition, ICMR.

Kohajdova Z and Karovicova J (2007) Fermentation of cereals for specific purpose. Journal of Food and Nutrition Research. 46(2):51-57.

Miller D and Welch R (2013) Food system strategies for preventing micronutrient malnutrition. Food Policy. 42:115-128.

National Family Health Survey-3, 2005-06, Ministry of Health and Family Welfare. http;//rchiips.org/nfhs/pdf/India.pdf

National Family Health Survey-4, 2015-16, Ministry of Health and Family Welfare. http;//rchiips.org/NFHS/pdf/NFHS4/India.pdf

Oghbaei M and Prakash J (2016) Effect of primary processing of cereals and legumes on its nutritional quality: A comprehensive review. Cogent Food and Agriculture, 2:1136015.

Ranhotra G.S., Bock M.A. (1988) Effects of Baking on Nutrients. In: Karmas E., Harris R.S. (eds) Nutritional Evaluation of Food Processing. Springer, Dordrecht.

Singh S, Gamlath S and Wakeling L (2007) Nutritional aspects of food extrusion: a review. International journal of food science and technology. 42:926-929.

Younis K, Ahmad S and Badpa A (2015) Malnutrition: cause and strategies. Journal of Food processing and Technology. 6(4):1000434

https://www.gktoday.in/academy/article/food-processing-industry-types-and-functions/

https://www.healthline.com/nutrition/cooking-nutrient-content#section7