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12. Post-Harvest Management in Millets

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Abstract:

Millets are an important part of many people's nutritional diets around the world. Despite the fact that millets are more nutritious than other cereals, their use as a food in the diet is still mostly limited to the poor and traditional people. Millets are high in carbohydrates, energy, and protein, as well as fat, iron, calcium, and dietary fibre, all of which help to prevent diseases such as diabetes, cataract genesis, and cardiovascular disease. Environmental changes, water scarcity, population growth, and decreasing cereal yields present a challenge to nutritionists and researchers to investigate the potentials of production, processing, and using other prospective food sources to end poverty and hunger. The current paper examines various postharvest technologies, processing, and convenience food products made from millets.

Keywords:

Millets, Post-harvest management, Value addition, Nutritional values.

12.1 Introduction:

Millets are group of small grained cereal food crops which are highly nutritious and are grown under marginal/low fertile soils with very low inputs such as fertilizers and pesticides. These crops largely contribute to food and nutritional security of the country. Most of millet crops are native of India and are popularly known as Nutri-cereals as they provide most of the nutrients required for normal functioning of human body. Millets are rain fed crops and are grown in regions with low rainfall and thus resume greater importance for sustained agriculture and food security. Based on area grown and its grain size the millets are classified as major millet and minor millets.

The major millets include sorghum (jowar) and pearl millet (bajra). The finger millet (ragi/mandua), foxtail millet (kangni/Italian millet), little millet (kutki), kodo millet, barnyard millet (sawan/jhangora), proso millet (chena/common millet), and brown top millet (korale) are categorized under minor millets. In certain countries of Africa, other millets such as fonio and tef are grown. Millets were the first crops to be domesticated by the mankind in Asia and Africa which later on spread across the globe as critical food sources to the evolving civilizations.

All these millets have shorter growing duration complete their life cycle in 2-4 months, fit wide range of cropping systems and also adapt themselves to the changing environmental conditions especially during vagaries of monsoon. Millets are major energy source and staple foods for people living in the dry and arid regions of the world. The stover after harvest of grains is a source of nutritive fodder to animals apart from its industrial use as bird feed, brewing, potable alcohol etc.

Millets had been the lifeline of dry regions of Asia and Africa for food and fodder. Most of the millets are kharif season crops (sown during May-June) and come to maturity during September to October. Most of these crops give good yields during rabi season (October-March) and summer season (January-April). Millets require very less water as compared to rice and wheat and considered drought tolerant crops. These crops are majorly grown in regions receiving less than 450 mm rainfall (compared to about 700 mm minimum for maize). About 50% of sorghum and 80% of millet production is used for human consumption while the rest is used for poultry feed, potable alcohol and other industrial purposes. Millets are sometimes referred to as famine crops since they are the only crops that assure yields in famine situations. Earlier, these crops were also called as orphan crops since they are the last option for cultivation as they have less demand in the market and profits earned are also lower than other crops.

However, these neglected crops are important by virtue of their contribution to the means of livelihood, food and nutritional security of the poor in various parts of the world and they diversify our food basket. Before getting to more about the utility of millets and the story of their domestication, let us know briefly about each of the common millets grown today. Millets were the oldest foods known to humans but their importance and cultivation reduced due to large scale cultivation of rice and wheat because of urbanization and industrialization.

With diabetes, hypertension and cardiovascular disease becoming more prevalent, as gifts of newly acquired life-styles and food habits, millets have returned as a viable option to live healthy life and can reduce the incidence of these lifestyle diseases. Millets have many nutritional, nutraceutical and health promoting properties especially the high fibre content, nature of starch has major role in reducing the risk of diabetes other related diseases. Indeed, millets act as a prebiotic feeding micro-flora in our inner ecosystem. Millet will hydrate our colon to keep us from being constipated. The high levels of tryptophan in millet produce serotonin, which is calming to our moods. Niacin in millet can help lower cholesterol. Millet consumption decreases triglycerides and C-reactive protein, thereby preventing cardiovascular disease. All millet varieties show high antioxidant activity. Millet is gluten free and non-allergenic. The beneficial effects of millets on human health are reported in many literatures and are available online.

12.2 Post-Harvest Technology:

Postharvest technology is interdisciplinary science and technique applied to agricultural produce after harvest for its production, conservation, processing, packaging, distribution, marketing and utilization to meet the food and nutritional requirements of the people in relation to their needs. Postharvest technology involves all treatments or processes that occur from time of harvesting until the foodstuff reaches the final consumer.

Efficient techniques for harvesting, conveying / transportation, handling, storage, processing / preservation, packaging, marketing and utilization etc. are components of the postharvest chain. Post harvest technology is inter-disciplinary "Science and Technique" applied to agricultural produce after harvest for its protection, conservation, processing, packaging, distribution, marketing, and utilization to meet the food and nutritional requirements of the people in relation to their needs.

12.2.1 Harvesting:

Many millets are harvested by removing the individual heads using sickles or small hand knives. This is sometimes preceded by the stems being broken (Aucland, 1921). According to Esele (1989), finger millet is harvested in Uganda with a sharp hand or finger knife.

The ears are trimmed to leave roughly 2 cm of stalk. The harvested ears are stored in a pile for a few days to further mature the grain and provide the desired flavour. They are then dried in the sun. Hulse et al. (1980) observed that proso (common) millet is harvested by taking out the entire plant by the roots as soon as the grain is ready to minimise excessive shattering and is threshed immediately.

Although there is no evidence of automated harvesting of millets in the literature reviewed, it is thought that combine harvesting of millets is possible. That may be especially true for millet types with uniform heights. Therefore, the screen in order to keep excellent seed in the combine harvester would have to be extremely compact, much smaller than the maize and rice.

12.2.2 Transport:

Millet transportation begins shortly after harvesting on the farm. Farmers who prefer not to dry their grain in the field take the millet in bags to their farmhouse, where the heads are laid out to dry in the sun.

Several farmers in Tanzania's central regions They convey their millet by wrapping it in fabric, which is then loaded onto donkeys and hauled to the homestead. Alternately, the entire harvest can be roped together and delivered with donkeys.

12.2.3 Threshing:

Threshing is the process of removing grain from a harvested plant or plant component (Acland, 1921). Millet is threshed by hand by both men and women. It requires repeatedly striking the millet heads with wood or clubs until practically all of the grains are separated from the heads. Depicts the beating method of threshing millet.

The beating action can be performed on a mat, canvas, or the bare ground. Millet heads may be placed into bags prior to beating to facilitate grain collection after beating. Tanzania, Kenya, Malawi, Mozambique, Zimbabwe, and Uganda are all familiar with this approach. The straw that remains after threshing can be burned as fuel. Straw is used as a material for thatching.

Figure 16.1: Threshing

Figure 16.2: Winnowing

12.2.4 Drying:

There is little information available about millet drying (McFarlane et al., 1995). Millet grains picked during the rainy season can be kept to dry for up to two weeks in the field. If necessary, additional drying is conducted after threshing on sun-dried mats or plastic sheets. Many Africans believe that dishes produced from rain-beaten grains have higher quality and palatability (Vogel and Graham, 1928; McFarlane *et al.*, 1995). Mechanical drying can be used to dry millet grains, but it is expensive and should only be used when the returns are favourable. In addition to typical sun drying, unheated air drying could be used. This is a basic procedure that requires little attention to obtain uniform results.

12.2.5 Cleaning:

Cleaning is the process of separating contaminants from produce and completely removing the impurities so that the cleaned food is free of contamination. Sand (soil), small stones, leaves, shrivelled seeds, off-type seeds, broken seeds, and other pollutants may be present in millets.

Glumes, sticks, chaff, stem portions, insects, animal hair, animal excreta (e.g. rodent and bug faeces), and, most vexingly, metal fragments. Metal fragments that are not removed may damage the milling machine sieves if automated grinding is utilised. If sand and soil are not removed, secondary goods such as ugali, porridge, and other products will taste gritty. Contamination from small stones, sand, off-type seeds, and other contaminants may occur on the drying ground, where farmers in rural regions distribute the millet heads. Winnowing: A millet cleaning procedure in which around 2 to 3 kg of threshed millet grains are placed on a flat reed- or raffia-woven basket (known as ungo in Tanzania, Kenya, and Uganda) and winnowed by up and down strokes (known as kupepeta is Swahili). The basket is pulled up and down throughout this operation, causing the grains to fly into the air and then land back onto the basket. Sand and other light pollutants are separated to the front of the basket and tossed off with a jerky action or removed by hand. Light pollutants are frequently blown off by the mouth. Women in both rural and urban areas It's a little breezy, so the wind current sweeps the light pollutants away from the comparatively heavy grains (personal experience). Approximately 10 kg of threshed millet grains are placed in a tin or basket and spilled from above the head to fall on the ground, which is normally lined with either a cloth or a rug. Canvas or carpet? The chaff is blown away by the wind, leaving a pile of clean grains. This procedure is much faster than traditional winnowing, and it is possible to winnow up to 4 or 5 bags in 1 hour. The approach, however, is ineffective in separating sand, stone, and metal impurities that are as heavy as (or even heavier than) millet grains. Screening is another method of cleaning that uses a collection of sieves.

12.2.6 Storage:

Millets are often wrapped in 100 kilogramme hessian/sisal bags after threshing, drying, and washing and sealed for delivery to distant markets (personal experience). Millet grains are sometimes bundled in bags stitched from artificial polythene bags for either storage or transport. transportation or storage. Crop storage is a crucial component of the entire production chain.

It serves various farmer aims, including supplying food for the future and avoiding food shortages, providing seed for the following growing season, and allowing the farmer to sell at a time when the market is low.

The price is reasonable. Sorghum storage, particularly millets, has received far less scientific study than other grains (McFarlane, *et al.*, 1995). The fundamental reason for this is because sorghum and millets are considered minor grain crops, despite their importance as a food staple in many expanding countries. Another noteworthy factor is that farmers in arid and semi-arid locations where millets are grown accomplish pretty outstanding grain storage performance using quite basic conventional methods.

Figure 12.3: Traditional Millet Grain Storage Structures

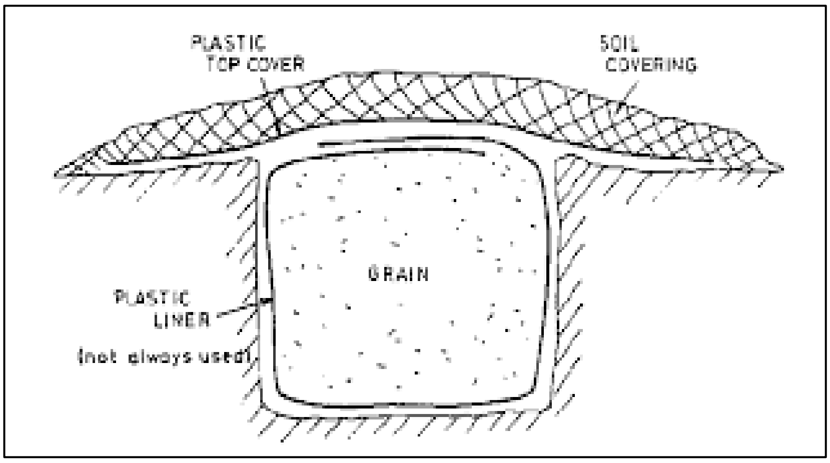

Figure 12.4: Traditional Underground Grain Storage Structures

Most millets have excellent storage qualities and can be preserved in modest storage facilities such as traditional granaries for up to 4-5 years. This is because the hard hull covering the endosperm protects the seeds from insect attack, and grain is often harvested and kept in a dry environment (FAO and ICRISAT, 1996). Consequently, despite huge year-to-year differences in production, stock can be easily built up over time. Millets can be stored as loose grain in bags or loose containers after drying and threshing (McFarlane *et al.,* 1995). Prior to threshing, they are sometimes left on the pitch in stacks or mounds of harvested plants. Detached heads can also be stored away from the field, either in an exposed stack or in typical storage containers. Nonetheless, the main requirements for millets storage are the same as those for other grains. According to Esele (1989), finger millet is stored in granaries made of reeds and mud walls in Uganda.

Other traditional millet storage structures include sealed storage drums, mud straw bins, and earthenware pot and jars. Underground grain storage of millet, sorghum, and maize has been documented in nations such as Somalia and Sudan.

Millets have an inverse relationship with storage temperature and relative humidity. Quality can be preserved by lowering the storage temperature, humidity, or moisture content (or all three) (McFarlane, 1995). Millet mould growth and inherent degradation When the grains are sufficiently dry, the losses in storage are insignificant. A relative humidity of 20% is slightly acceptable for storage, and a relative humidity of 60-65 percent is preferred. Less typically, millets can be stored via admixture with beans (as in Botswana), which minimises the intergranular spaces between the beans, preventing braccate beetle infestation and optimising storage space (McFarlane, 1995).

12.3 Dehulling and Milling:

12.3.1 Machinery of Primary Processsing:

A. Dehulling:

Upon cleaning of millet grains, the grains are dehulled – the outer indigestible husk layer from the grains, improving its overall digestibility.

Increased: Protein digestibility Starch Digestibility Mineral Bioavailability

Decreased: Protein Dietary/crude fiber Fat Vit. E Iron Calcium Phenolic Content Ant-nutrients (phytate, tannins).

Figure 16.5: De-Stoning Cum Grader

Figure 16.6: Mille Single Stage

Figure 16.6: Single Stage Dehuller

Figure 16.7: Double Stage Dehuller

Advantages: Less labour required

De-hulling efficiency range - 50% to 70%

B. Milling:

Process of separating the bran and germ from the starchy endosperm so that the endosperm can be ground into flour and rawa using different types of sieves in a hammer mill.

Increased: Protein digestibility Starch digestibility.

Decreased: Protein Dietary Fiber Fat Vit. B, E Iron Calcium Phenolic Content Anti-nutrients (phytate, tannins)

Processing	Protein	Dietary	Fat	Vitamins	Iron	Calcium	Phenolic Content	Protein Digestibility	Starch Digestability	Anti-Nutrients	Mineral Bioavailability
De-hulling	↓	↓	↓	↓	↓	↓	↓	↑	↑	↓	↑
Soaking	-	-	-	-	↓	↓	↓	↑	↑	↓	↑
Germination	↑	↑	↓	↑	↑	↑	↑	↑	↑	↓	↑
Milling/Sieving	↓	↓	↓	↓	↓	↓	↓	↑	↑	↓	-
Cooking	↑ or ↓	↑	↑	-	-	-	↑	↓	↓	↓	-
Fermentation	↑	↓	↓	↑	↑	↑	↑ or ↓	↑	↑	↓	-
Roasting	↓	↑ or ↓	↓	-	↑	↑ or ↓	↑ or ↓	↑	-	↓	-
Parboiling	↑	-	↑	↑	-	-	-	-	-	-	-
Puffing	↑	↓	↓	-	↑	↓	↑	↑	↑	↓	-
Extrusion	-	-	-	-	-	-	-	↑	-	-	-
Irradiation	-	↓	-	-	-	-	-	-	-	-	-
Microwave cooking	-	-	-	↑	-	-	-	-	-	-	-
Nixtamalization	-	↑	-	↑	-	↑	↑	-	-	↓	↑

12.4 Value Addition of Millets:

Millets are renamed as "Nutri Cereals", since they are the powerhouse of nutrient, dispensing with the nomenclature "coarse cereals". The move is aimed at removing a lingering perception that these grains are inferior to rice and wheat, even as their health benefits are larger.

Millets hold great potential in contributing substantially to food, nutritional security, safety from diseases and economic security of the country and thus they are not only a powerhouse of nutrients, but also are climate resilient crops and possess unique nutritional characteristics.

12.5 Nutritional Quality:

Millets are highly nutritious, non-glutinous and not acid forming foods. They are soothing and easy to digest. They contain high amounts of dietary fibre, B-complex vitamins, essential amino and fatty acids and vitamin E.

They are particularly high in minerals, iron, magnesium, phosphorus, potassium and release lesser percentage of glucose over a longer period of time causing satiety which lowers the risk of diabetes. The millet grain is rich in fibre and minerals.

These grains are high in carbohydrates content varying from 60.9 to 72.6 percent, with protein content varying from 6 to 11 percent and fat varying from 1.5 to 5 percent. Nutritional compositions of different millets compared to fine cereals are mentioned in table 2. Starch is the major constituent of the grain.

The grain contains protein, albumin, globulin, prolamin and glutelin. Millets do not contain gluten and its slower hydrolysis makes it attractive to diabetics, celiac and ethnic groups. Particularly in developed countries, there is a growing demand for gluten free foods from people with celiac disease and other intolerance to wheat. Though millets nutritionally superior, its consumption has been decreased gradually due to the non- availability of processed clean grain in markets.

To increase millet consumption among the urban population, development of processing technologies is a prerequisite. As a step towards this, under the NAIP project, IIMR has taken up the millet processing, and developed value added millet products.

Around 30 machineries for different processes were procured and retrofitted. Millets have unique nutrients value which is good for physical and mental health as described in figure 16.1.

They have high fibre content, low sugar, vitamins and if consumed regularly they promote movement of the bowels, help detoxify the system, renders less blood sugar and cholesterol than eating fine flour or rice.

Millets are used for food, fodder, biofuel and alcohol. That's why millets are called smart foods because they are better for consumers, better for farmers and better for the planet.

Millets are very useful for human body development and control many diseases because they are gluten free. How different millets help human body development and make us healthy is shown below.

Table 12.2: Nutrient Composition of Millets Compared to Fine Cereals (Per 100 G)

Millets /Cereals	**Carbo-Hydrates (g)**	**Protein (g)**	**Fat (g)**	**Energy (Kcal)**	**Crude Fibre(G)**	**Mineral Matter (g)**	**Ca (Mg)**	**P (Mg)**	**Fe (Mg)**
Rice	78.2	6.8	0.5	345	0.2	0.6	10	160	0.7
Wheat	71.2	118	1.5	346	1.2	1.5	41	306	5.3
Sorghum	72.6	10.4	1.9	349	1.6	1.6	25	222	4.1
Bajra	67.5	11.6	5	361	1.2	2.3	42	296	8
Finger millet	72	7.3	1.3	328	3.6	2.7	34	283	3.9
Foxtail millet	60.9	12.3	4.3	331	8	3.3	31	290	2.8
Proso millet	70.4	12.5	1.1	341	2.2	1.9	14	206	0.8
Kodo millet	65.9	8.3	1.4	309	9	2.6	27	188	0.5
Little millet	67	7.7	4.7	341	7.6	1.5	17	220	9.3
Barnyard millet	65.5	6.2	2.2	307	9.8	4.4	20	280	5

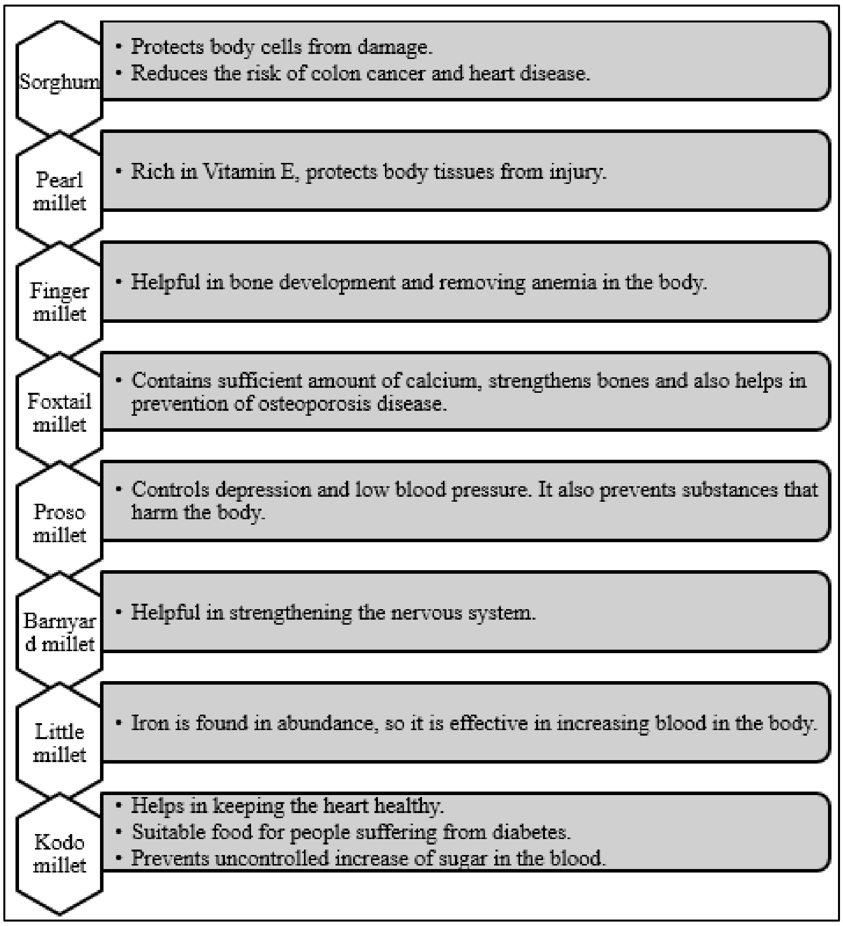

Figure 16.8: Millets Make the Body Strong

12.6 Value Addition Technologies:

A. Puffing technology
B. Flaking technology
C. Baking technology
D. Fortified food technology
E. Instant mixes

12.6.1 Puffing Technology:

Millet puffs are the products which is a result of gun puffing or explosive puffing where the millet grain is expanded to maximum expansion consistent with the grain identity.

These are the ready-to-eat snacks which is developed using this technique. The puff gun machine is loaded with dehulled millets grain onto a rotating barrel and the mixture is roasted and fried resulting in a puffed millets product. Puffs yield is 94%; by-product yield is 6% (small puffs and un-puffed grains) which varies according to millets.

A. Process of Puffing Technology:

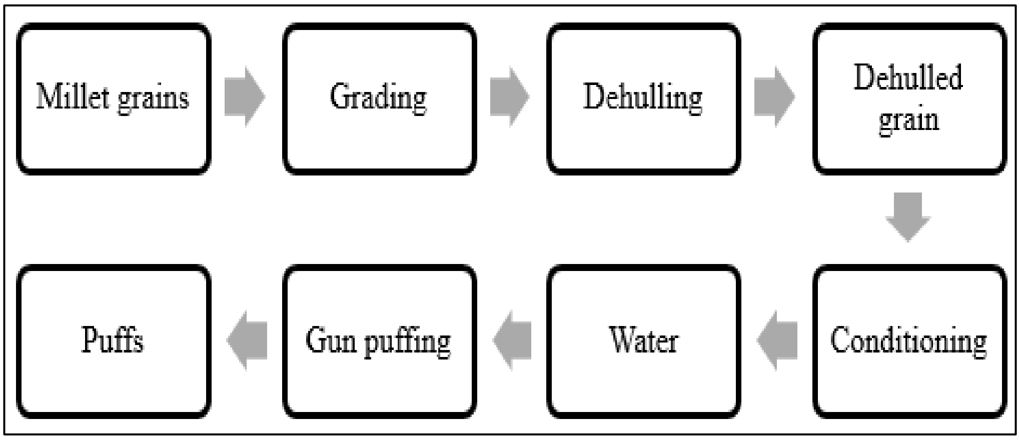

Figure 12.9: Process of Puffing Technology

12.6.2 Flaking Technology:

Extruded flakes are ready-to-eating products prepared using twin-screw hot extruder which combines heating with the act of extrusion to create round-shaped product which is further flattened in roller flaker machine. The extruded flakes are made from sorghum grits, wheat and corn flour. The snack can be coated with desired spices to create variations in the taste and flavour. Flakes yield is 88% and by-product yield is 12% obtained (Extruded by-product, un-flattened flakes) which varies according to millets.

A. Process of Flaking Technology:

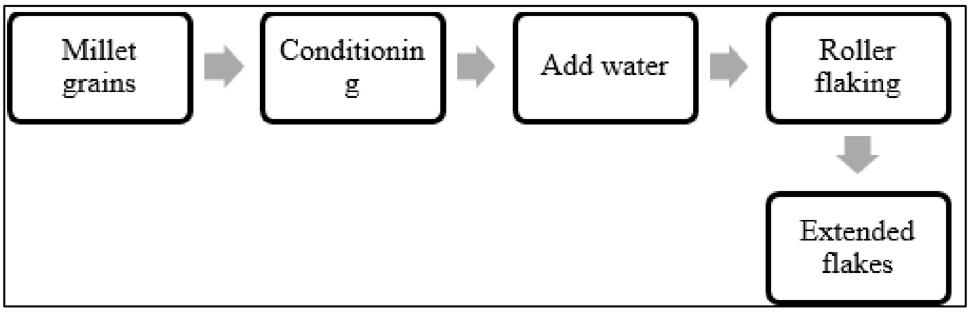

Figure 12.10: Process of Flaking Technology

12.6.3 Baking Technology:

Baking product are also ready-to-eating products which is prepared by mixing a mixture of flour, water, salt/sugar, yeast etc. Consumers prefer healthy products to conventional foods, hence are these days showing preference to millet-based bakery foods. The products like cookies, bread/bun, cakes, pizza base.

In the preparation of products different flavours and baking machines are used. Product yield is 92% and by-product yield is 8% obtained which varies according to millets. These products have different shelf-life. The entry in bakery world creates good potential for millets with superior in terms of micronutrients and fibre content.

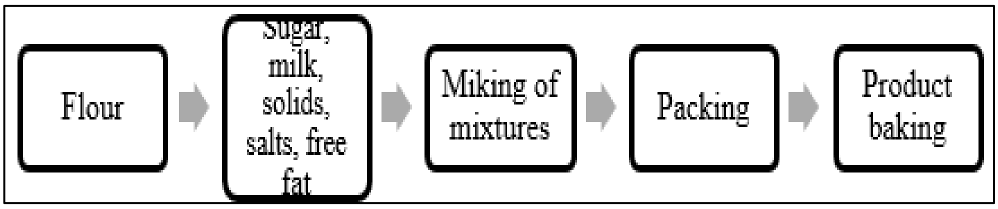

Figure 12.11: Baking Technology

12.6.4 Fortified Food Technology:

Increasing nutrient levels on food products by the process called bio-fortification. By incorporating millet seeds with gingelly seeds for enrichment of zinc ang garden cress for iron rich. Garden cress is rich in iron, magnesium, zinc, calcium and protein rich.

It helps recover from atony, reduces muscle tension, increases appetite, helps asthma sufferers, alleviates breathing difficulties and purifies the lungs. Gingelly seed is rich in iron, magnesium including vitamins, minerals, natural oils, and organic compounds which consist of calcium, iron, magnesium, phosphorous, manganese, copper, zinc, fiber, thiamin, vitamin B6, folate, protein, and tryptophan.

Gingelly incorporate Sorghum products are highly nutritional and digest slowly, which is why it is suitable for diabetics. It has a shelf life of 3 months and shelflife studies are in progress.

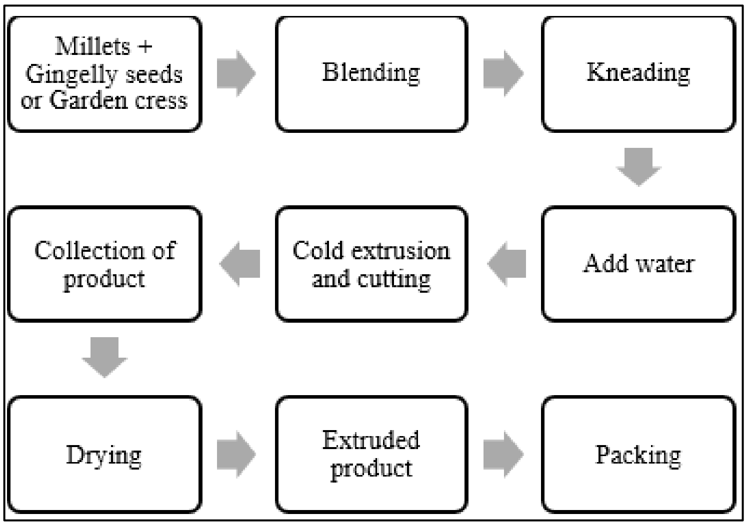

Figure 12.12: Fortified Food Technology

12.6.5 Instant Mixes:

In today's fast-paced world, where time is precious to everyone, "Instant Foods" play an important role in everyone's day-to-day life. In Western countries, instant and ready-to-reconstitute foods have become well-established products. It is critical to develop traditional foods as convenience foods, and IIMR has conducted research in developing millet-based instant mixes, such as Idle mix, Upma mix, Pongal mix, Laddu mix, etc are ready to eat foods.

12.7 Losses During Post-Harvest Management:

Postharvest loss can be defined as the degradation in both quantity and quality of a food production. Postharvest loss includes the food loss across the food supply chain from harvesting of crop until its consumption. The losses can broadly be categorized as weight loss due to spoilage, quality loss, nutritional loss, seed viability loss, and commercial loss. Magnitude of postharvest losses in the food supply chain vary greatly among different crops, areas, and economies.

In developing countries, people try to make the best use of the food produced, however, a significant amount of produce is lost in postharvest operations due to a lack of knowledge, inadequate technology and/or poor storage infrastructure. On the contrary, in developed countries, food loss in the middle stages of the supply chain is relatively low due to availability of advanced technologies and efficient crop handling and storage systems.

However, a large portion of food is lost at the end of the supply chain, known as food waste. “Food waste” can be defined as food discarded or alternatively the intentional non-food uses of the food or due to spoilage/expiration of food. In 2010, estimates suggested that about 133 billion pounds of food (31% of the total available food) was wasted at retail and consumer level in the United States.

Among different agricultural commodities, the studies estimated that on a weight basis, cereal crops, roots crops, and fruit and vegetables account for about 19%, 20%, and 44% losses respectively. On a calorific content basis, losses in cereal crops hold the largest share (53%). Cereal grains, such as wheat, rice, and maize are the most popular food crops in the world, and are the basis of staple food in most of the developing countries. Minimizing cereal losses in the supply chain could be one resource-efficient way that can help in strengthening food security, sustainably combating hunger, reducing the agricultural land needed for production, rural development, and improving farmers’ livelihoods.

Postharvest loss accounts for direct physical losses and quality losses that reduce the economic value of crop, or may make it unsuitable for human consumption. In severe cases, these losses can be up to 80% of the total production. These losses play a critical role in influencing the life of millions of smallholder farmers by impacting the available food volumes and trade-in values of the commodities. In addition to economic and social implications, postharvest losses also impact the environment, as the land, water and energy (agricultural inputs) used to produce the lost food are also wasted along with the food. Unutilized food also results in extra CO_2 emissions, eventually affecting the environment.

12.7.1 Main Stages Where Postharvest Losses Occur:

A. Harvesting
B. Transportation
C. Drying
D. Threshing/winnowing
E. Storage
F. Milling
G. Marketing

A. Harvesting: Time of harvest is determined by maturity. Millets should be harvested between maturity of straw, earheads, for all that affects successive operations, particularly storage and preservation. Mostly losses during this stage occur because edible crops left in field, ploughed into soil, eaten by pests; timing of harvest not optimal, crop damaged during harvesting. Bird damage also seen during this stage. Because of this yield and quality of grain decreases.

B. Transportation: Much care is needed in transporting a really mature harvest, in order to prevent detached grain from falling on the road before reaching the storage or threshing place. Collection and initial transport of the harvest thus depend on the place and conditions where it is to be stored, especially with a view to threshing.

C. Drying: The length of time needed for full drying of ears and grains depends considerably on weather and atmospheric conditions. In structures for lengthy drying such as cribs, or even unroofed threshing floors or terraces, the harvest is exposed to wandering livestock and the depredations of birds, rodents or small ruminants. Apart from the actual wastage, the droppings left by these marauders often result in higher losses than what they actually eat. On the other hand, if grain is not dry enough, it becomes vulnerable to mould and can rot during storage. Moreover, if grain is too dry it becomes brittle and can crack after threshing, during hulling or milling.

During winnowing, broken grain can be removed with the husks and is also more susceptible to certain insects (e.g flour beetles and weevils). Lastly, if grain is too dry, this means a loss of weight and hence a loss of money at the time of sale.

D. Threshing / Winnowing: Separation of grain from plant stalks is called threshing. During threshing some grains are wasted due to manual threshing. If a harvest is threshed before it is dry enough, and we heaped up or stored immediately then it will be more susceptible to attack by micro-organisms and this is all due to poor technique. During winnowing and cleaning loss of seed not that much than threshing.

E. Storage: Storage is the art of keeping the quality of agricultural materials and preventing them from deterioration for specific period of time, beyond their normal shelf life. Different millet crops are harvested and stored by various means depending on the end utilization. Whether the seed will be used for new plantings the following year, for forage being processed into livestock feed, or even for crops to be developed for a special use, the grower must be aware of harvesting and storage requirements toward a quality product.

After determining the prescribed use for the crop, timing for harvest and storage is of important consideration. Along with an assessment of when to harvest, the farmer needs to determine the method of harvesting. Pests and disease attacks, spillage, contamination; natural drying out of food. The grains of pearl millet are sufficiently large for the destructive attack by the major pests such as *Rhyzopertha dominica* and *Trogoderma granarium* (McFarlane *et al.*, 1995). For this reason, the popular concept that millets are hardly susceptible to damage by storage insect pests is erroneous, except for the very small grained millets such as tef and fonio. Another factor contributing to a general myth that millets are immune to susceptibility to insect pest attack is the fact that millets are grown in semi-arid climates, where stored grain is typically very dry, with moisture contents often in equilibrium with humidities below 40 percent. In such conditions, the warehouse moths and most secondary beetle pests do not thrive. However, the major pests *R. dominica* and *T. granarium* are relatively well adapted to extremely dry conditions and will cause serious damages (McFarlane, 1995). The control of such pests as *Rhyzopertha dominica* (Lesser grain borer) and *Trogoderma granarium* (Khapra beetle) may be achieved through sealed storage e.g. in drums or underground storage. In Sudan for example, an underground storage may carry up to 30 tonnes of grains. Alternatively, Khapra beetle may be controlled by dusting the grains with Pirimiphos Methyl (Actellic) which has a wide spectrum of activity against beetles, bruchids, moths and mites (Odogola and Henriksson, 1991).

Population control of *Rhyzopertha dominica* and *Trogoderma granarium* during drying of millet can be achieved by lowering the drying temperature. For example, the optimum reproduction temperature for *Rhyzopertha dominica* is 30-35 ^{0}C. Therefore, a temperature around 21 ^{0}C could check reproduction and therefore control the pest (Odogola and Henriksson, 1991). Likewise, *Trogoderma granarium* reproduces well in temperature range of between 33 and 32 ^{0}C. Lowering this temperature to around 22-25 ^{0}C during drying would check the reproduction.

F. Milling: Causes of post-harvest loss in this stage include limited availability of suitable varieties for processing, lack of appropriate processing technologies, inadequate commercialization of new technologies and lack of basic infrastructure, inadequate facilities and infrastructure, and insufficient promotion of processed products. During dehulling seeds are breaked and become flour and wasted.

G. Marketing: In this stage due to improper packing and damage during transport, spoilage at retailer level.

12.8 Conclusion:

In some ways, finding and developing economic uses for coarse cereals/millet is critical. The demand for pre-processed and convenience foods is increasing as urbanisation and disposable incomes rise. This is one of the reasons why commercially milled wheat and maize flour are becoming more popular. Millet is substantially less expensive, but it is unprocessed and so less convenient to use. As a result, markets for locally grown millet are shrinking, incentives for local production are worsening, and foreign exchange reserves are depleting to meet expanding pre-processed flour demand. As a result, in dry locations, processing facilities are especially important for the future of local cereal cultivation.

As a result, millets are appealing enough to agree on the need to educate consumers on the health benefits and encourage higher use. This will necessitate a collaborative effort by health, food, and nutrition professionals, as well as industry, government, and health promotion organisations.

As part of this endeavour, we need nutrition educators from industry, academia, and government to help us establish clear and consistent consumer messages about the health benefits of millets. Efforts to work with industry leaders to increase their understanding of the benefits of millets and encourage them to overcome barriers to including more whole grains in their products, as well as to continue developing fortified products to meet consumer needs. Commercial opportunities would emerge that had not previously been considered.

12.9 References:

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