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9. Processing Technologies for Millets

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Millets is a general term for group of nutritiously rich, drought tolerant small, seeded grain belonging to diverse set of grass species that are mostly grown in the arid and semi-arid regions. They belong to the botanical family Poaceae along with other cereals like wheat, rice jowar etc. They constitute an important source of food and fodder for millions of resource-poor farmers and play a vital role in ecological and economic security. The millets are also known as "coarse cereals" or "cereals of the poor". Millets are nutritionally superior to wheat and rice as they are rich in protein, vitamins and minerals. They are also gluten-free and have a low glycemic index, making them ideal for people with coeliac disease or diabetes.

Table 9.1: Difference Between Millet and Cereals:

Definition	Grass crop with small edible seeds	Grass crop with large seeds and the grains are edible
Common crops	Pearl Millet, Foxtail Millet, Finger Millet, and Proso Millet	Wheat, Barley, Rice, Rye, Oats
Word origin	The term ‘Millet’ is used to describe cereal crops with small seeds	The word ‘Cereal’ is derived from the Roman Goddess Ceres
Nutritional value	Rich in carbohydrates, fat, magnesium, potassium, and phosphorous	60-70% carbohydrates, vitamins, fat, and proteins
Rainfall requirement	Low	Adequate
Drought resistance	Highly resilient to droughts	Poor drought resistance
Economic importance	Millets have less economic importance	Cereals have high economic importance
Grown as	Millets are grown as a mixed crop	Cereals are grown as the main crop

Digestibility	easy to digest	relatively tough to digest
Soil requirement	Grown in poor soil	Grown in good soil

Different millets are grown and consumed both by men and animals in different regions. They contribute significantly in the food and economic security of the farmers.

In spite of all the extraordinary qualities and capacities of millet farming systems, the area under millet production has been shrinking over the last five decades and rapidly, since the Green Revolution period due to relentless promotion of other crops such as rice and wheat for intensive farming (Gowri, Shivkumar, 2020).

Another major threat that millets are facing is in the form of an unnatural promotion of maize, which is resulting in maize invasion in various parts of the agricultural land owing to the corporate-induced demand for biofuels and poultry feed (Michaelraj and Shanmugam, 2013a, b).

But, during recent years people are recognizing the nutrient superiority and health benefits of millets compared to fine cereals. So, the focus on utilization of millets is on an upward swing given the proven understanding that they are good source of phytochemicals and dietary fibre.

Many initiatives are taken to promote acceptability of millet among the population, infact United Nations General Assembly (UNGA) declared 2023 as the International Year of Millets.

Table 9.2: Botanical Names of Millets

Millet	Botanical name
Pearl Millet	*Pennisetum glaucum.L.*
Sorghum	*Sorghum bicolor*
Finger Millet	*Eleusine coracana*
Small Millets:	
I. Foxtail Millet	*Setaria italica*
II. Barnyard Millet	*Echinochloa frumentacea*
III. Kodo Millet	*Paspalum scrobiculatum*

IV. Proso Millet	*Panicum miliaceum L.*
V. Little Millet	*Panicum sumatrense*
Two Psuedo millet-	
I.Buck wheat (Kuttu)	*Fagopyrum esculentum*
II. Amaranthus (Chaulai)	*Amaranthus viridis*

9.1 Millets Can Be Processed to Maintain Beneficial Characteristics:

Millets and other refined cereals are not eaten as uncooked whole seed after harvesting. They undergo processing before they are consumed. Since millets are not widely grown and consumed so their post harvesting processes are not completely developed and used.

The challenges millets face post-harvest impacts farmers and entrepreneurs both, from the small-scale subsistence farmer to the large-scale industrial processing facility. Additionally, the processing of millets can dramatically impact their nutritional value.

Traditional processing methods like hand milling methods retain more nutrients but are slow and cannot be done at scale and mechanical milling creates a more easily used flour with an improved shelf life but results in less nutrients. Processing of millets is also tedious as the large number of species of millets means many different types of processing are needed for different millets.

Also, there are alarmingly high losses in post-harvest stages of processing and storage of millets. According to FAO 2017, the average loss for sorghum in four different areas in Ethiopia during the drying, threshing and storage stages, for example, was almost one-third of the entire crop harvested.

The nutrients composition and technological properties of millet grains provide a number of opportunities for processing and value-addition. Thus, millets can be used as next generation foods to satisfy the consumers' choice of different culture, location, choice and society.

Like other grains, millets require basic processing such as threshing, cleaning, grading and sorting (separation to remove materials such as stones and chaff remaining after harvest, and the leftover grain from previous crops, etc.), which can be achieved through appropriate mechanization activities.

In general, processing of cereal or millet involves the separation of dirt material, pericarp and sometimes the germ from the edible portion.

Millet popularity is limited by the factor like the outer tough seed coat of millets, characteristic flavour, cultural attachments and non-availability of processed millet products of millet (Gowri and Prabhu, 2017).

Unfortunately, primarily only the traditional processing practices are prevalent in millet-based products and there has been limited well-proven industrial process available for making white visually acceptable products from coloured small millets. Infact, if the produce is processed well then, the price of produce will increase giving economic benefits to farmers.

It is reported that the farmers get very less price (Rs.15-20/kg) to their un-processed produce compared to processed one (Rs.80-100/kg). Difficult and not well-developed processing is the key challenge that hinders consumer demand and upscaling potential for millets.

Several interventions can be made to facilitate access by value chain actors to processing plants on the one end and by consumers to processed millet products on the other. Millets would probably be more widely used if processing is improved.

9.1.1 Advantages of Millets Processing:

- Digestibility - Processing is required to make dried grains edible and digestible.
- Food safety - Cooking inactivates natural toxins and heat prevents bacterial and food spoilage.
- Organoleptic properties - Processing optimizes the appearance, taste and texture of foods to meet the needs of consumers.
- Ready to eat (RTE) and convenience - To meet consumer demand for quick and easy meal solutions and also nutritional supplement.
- Maximize nutritional availability - Processing can make it easier for nutrients from grains to be digested. Nutrients lacking in the diet can be added to staple grain-based foods (food fortification) (e.g., thiamin added to flour).
- On de-hulling, phytin phosphorus decreased by 12% in proso millet, 39% in little millet, 25% in kodo millet and 23% in barnyard millet. De-hulling of sorghum can remove 40 to 50% of both phytate and total phosphorus (Krishnan *etal*, 2012). The phytate content of proso millet varieties ranged from 170 to 470

mg/100 g whole grain, and dehulling leads to a 27 to 53% reduction in phytate content.

- The de-cortication reduces total protein and lysine by 9% and 21%, respectively, but improves the remaining protein utilization. Decortication increases the biological availability of nutrients and consumer acceptability.
- Fortification resulted in many innovative 'Ready-to-Eat and Ready-to-Serve' millet based processed products. Although Wheat has the unique property of forming an extensible, elastic and cohesive mass when mixed with water. Millet flours lack these properties when used alone. Hence, Processing makes possible to fortify malted finger millet (70%) weaning food with green gram (30%) having low cooked paste viscosity and high energy density.

9.1.2 Primary Processing Methods:

Millets have good grain qualities for processing. Millets are processed before they are consumed. Primary processing mainly involves destoning, cleaning, dehusking, dehulling, grading and pulverizing. Millets can be used both for traditional as well as novel value-added foods. Unprocessed or processed millet can be cooked as whole or decorticated and if necessary, ground to flour by traditional or industrial methods. However, these traditional processing practices resulted in loss of nutrients and also leads to less yield hence there is a need to look into the possibilities of alternative and improved practices (Pawar and Machewad, 2006).

- **De-cortication:**

De-cortication is partial removal of outer layer of the millet grain. It is accomplished by hand pounding and using rice de-hulling or other abrasive de-hullers.

- **Pounding:**

Traditionally, dry, moistened or wet grain is pounded with a wooden pestle in a wooden or stone mortar. Moistening the grain by adding about 10% of water promotes not only the removal of fibrous bran but also the separation of germ and endosperm, if desired. However, this practice produces slightly moist flour. In hand pounding, fairly dry grain, is crushed and pulverized by the backward and forward movement of the hand-held stone on the lower stone. Generally, women perform this laborious work.

- **De-hulling:**

De-hulling is achieved by using rice de-hullers or other abrasive de-hullers.

- **Parboiling:**

Parboiling is the process of partial cooking of grain along with husk or bran. The raw grain is steamed for short duration. The resultant product is dried, de-husked and decorticated. Parboiling increases the de-hulling efficiency of kodo millet and also eliminates stickiness in cooked finger millet porridge.

- **Milling:**

Milling is the process of separating bran and germ from the starchy endosperm so that the endosperm can be ground into flour and rawa using different kinds of sieves in a hammer mill. Milling is to separate the seed coat that lowers the protein, dietary fibre, vitamins and mineral contents of the grains. But this is compensated by better consumer acceptability, improved bioavailability of the nutrients and enhanced product making qualities. The bran fraction from the millets is a very good source of dietary fibre and edible oil. The de-oiled millet bran can be used as source of dietary fibre in formulating high- fibre foods as it contains negligible or less of silica compared to de-oiled rice bran.

- **Impact of Processing on Antioxidant Activity of Millets:**

Antioxidants are substances that scavenge free radicals that may cells in our body. Antioxidants are found in many foods, including millets, fruits and vegetables. Antioxidants help to neutralize free radicals in our body, and this is enabled to boost overall health (Pasha *etal*, 2018). Different processing methods of foxtail millet made an effect on the total phenolic content (TPC), total flavonoid content (TFC), and the six kinds of phenolic acids (Chanderasekara, 2013).

Compared with whole millet, the TPC of dehulled millet decreased and TFC of dehulled millet increased. Compared with dehulled millet, the TPC and TFC of cooked and steamed millet decreased. However, the total phenolic content and cinnamic acid content were rich in cooked millet. In addition, cooked millet demonstrated remarkable radical scavenging capacity, which was associated with its high contents of natural antioxidants found in the samples, such as phenolic compounds, cinnamic acid, and phytic acid.

9.1.3 Secondary Processing of Millets:

Secondary processing is a process converting primary processed raw material into product which is suitable for food uses or consumption such as ready-to-eat (RTE) and ready-to-cook (RTC) products, minimize cooking time and make it convenient foods.

The traditional (popping and flaking) as well as contemporary methods (roller-drying and extrusion-cooking) of cereal processing could be successfully applied to millets to prepare ready-to-eat products, thereby, increasing its utilization as a food.

The pop making technology significantly reduces crude fat and crude fibre contents than raw millet, while the carbohydrate and energy values increase significantly (Gowda *etal*, 2022). This is mainly because, fat and fibre contents are higher in outer coat of grains, thus more affected by processing compared with nutrients located in inner layer (Amadou, 2011).

Therefore, the use of new technology optimization of puffing conditions, popping technique can be used as a strategy or in combination with other pre-treatments to produce ready-to-eat (RTE) millet grains on a commercial scale, thus promoting utilization of millet grains. However, because of the rigid endosperm texture, nearly spherical shape and smaller size, heavy duty roller-flaker is essential for flaking unlike the edge runner used for flaking of rice.

The hydrothermal treatments exploit the thermo-physical properties of starch and prepare flakes. During this process the Maillard reaction takes place in which the sugars present in the aleurone layer react with amino acids of the millet and gives pleasant and highly desired aroma to the puffed product. It also reduces anti-nutrients like phytates, tannins, etc., increase bioavailability of minerals, give pleasing texture to the product, and enhances protein and carbohydrate digestibility.

In addition to these, baking technologies are also developed for the value-added products (NAAS, 2022). Several studies recommended (Rai *etal*, 2008), millets as the nutritional composition, biological and sensory characteristic values are found to be on par with wheat-based products.

This has come as a morale-booster and has boost-up the demand for millet-based food products. Different value-added food products of millets Instantly ready-to-eat (RTE) products can be prepared by new technology.

A. Malt from Finger Millet:

Well, cleaned good quality ragi having good germination should be used for the preparation of malt. The grain should be first washed in water then steep (soak the grains) in clean, soft water in a vessel of appropriate size for a period of 18-24 hrs. Change the water twice or thrice. After soaking for the required period, the grains are taken out and again washed. After draining the excess water, the grains are spread over a gunny bag or thick cloth, spread thinly and allowed for germination for 36-48 hrs depending upon the temperature and humidity. It is desirable to cover the grain kept for germination with another cloth so as it facilitates uniform germination. During germination, water should be sprinkled as and when necessary to keep the sprouts moist. Two days of germination period is sufficient for ragi, if germination is allowed too long, root and shoot will grow very long causing high malting loss. During germination set of enzymes that promote digestion of food develops. Important among them are starch, protein and fat digesting enzymes. In finger millet, starch content is more and amylase is the most important enzyme produced. After, required period of germination the grains are dried in sunlight by spreading thinly on a cloth. Total 6-8 hrs of sun drying should be sufficient. Soon after drying, the rootlets are removed by rubbing grains gently against dry, clean cloth. The separated rootlets are aspirated leaving malted ragi. Malted ragi should be gently toasted or kilned at 65 - 70°C in an iron pan heated at low flame. Malting enhances carbohydrate and protein digestibility and in addition, the water-soluble vitamins is also enhanced along with increase in the bio-available minerals and other nutrients. The roasted grain is grinded into fine flour and sieved through 80 to 100 size mesh or through a muslin cloth. The malt obtained has improved nutritional quality, increased digestive enzymes and is an ideal base to prepare weaning foods, baby foods, malted milk foods, well - being foods, medical foods, etc. The Central Food and Technological Research Institute (CFTRI), Mysore has developed ragi malt based weaning food nourishment formulation.

B. Millets Puffs:

Millet puffs are product which is a resultant of explosive puffing or gun puffing where the millets (sorghum, pearl millet, foxtail millet) grain is expanded to maximum expansion consistent with the grain identity (similar shape of the grain). It is the RTE (ready-to-eat) snack which is processed using puff gun machine.

The puff gun machine is filled with dehulled millets grain onto a rotating barrel and the mixture is roasted for and fired leading to a puffed millets product.

C. Extruded Snacks:

Extruded snacks are ready-to-eat products prepared using twin-screw hot extruder which combines heating with the act of extrusion. Commercially, most of the extruded snacks are prepared from corn; but nowadays extruded snack is also made from millets. The grain mixture is combined and passed through twin screw extruder to produce expanded snacks which are ready to eat. The snack can be coated with desired spices to create variations in the taste and flavor. Snacks yield is 90% and by-product yield is 10% obtained.

D. Extruded Flakes:

Extruded flakes are ready-to-eat 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 snack can be coated with desired spices to create variations in the taste and flavor. Flakes yield is 88% and by-product yield is 12% obtained (Extruded by-product, un-flattened flakes) which varies according to millets.

E. Instant Mix:

Instant Mix like sorghum idli mix, Instant upma mix, Instant dosa mix and also Instant Pongal mix are also prepared using advanced processing techniques. These instant mixes are gaining popularity thus making the millets more widely acceptable.

F. Millet Semolina:

Semolina is ready to cook food. Millet grains (Pearl millet, Finger millet and Foxtail millet) are processed by dry milling. The dry milling process starts with the cleaning of grains. The cleaned grain is milled by the hammer mills to separate the endosperm, germ and bran from each other to get semolina. Millet's semolina has three variants. Millet grain is pulverised to get semolina; variants differ with particle size. According to the variant, need to use mesh size in the mill is adjusted. Coarse semolina (Kichidi rawa) yield is 68-72% and by-product yield 32-28% (contains medium/fine semolina, flour and bran). Medium semolina (Upma rawa) yield is 71-76% and by-product yield is 29-24% (contains coarse/ fine semolina, flour and bran). Fine Semolina (Idli rawa) yield is 74-80% and by-product yield is 26-20% (contains coarse/medium semolina, flour and bran). The output varies according to millets.

G. Millet's Vermicelli /Pasta:

Vermicelli and pasta are prepared using cold extrusion. This is very useful as it is low cost and has continuous processing capability. It has been accepted as one of the most useful technologies during the recent years in the field of food processing. Finger millet /Foxtail millet /Pearl millet semolina and refined wheat semolina are blended in the mixing compartment of the vermicelli-making machine and blended with water for 30 minutes and extruded using a round die.

The vermicelli is allowed to temper in room temperature for 8 hours and then dry in a cabinet drier for 6 hours. Vermicelli yield is 99% and by-product yield is 1% (negligible) which varies according to millets. Also, pasta is made in the similar manner.

H. Bakery Products of Millets:

Millet cookies, Millet bread/bun, Millet cake and Millet pizza have been introduced in the market. These are alternatives to the existing products and are used widely by the people.

Thus, it can be concluded that Local and traditional knowledge integrated with nutritional information based on modern science can help communities choose appropriate processing techniques to maintain or enhance nutritional value, maximize nutrient bioavailability, improve palatability and enhance the shelf life of millets.

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