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## Post harvest processing of millets: A review on value added products

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### Abstract

Millets play an important role in nutritional diet in many regions of the world. Despite the fact that millets are nutritionally better than other cereals, their involvement as food in diet is still generally limited to the poor and conventional people. Millets are good source of carbohydrates, energy and protein, fat iron, calcium and dietary fiber, which helps to prevent from many diseases like diabetes, cataract genesis and cardiovascular diseases. The environmental changes, water shortage, population increment, decreasing yields of major cereals, present a challenge to nutritionists and researchers to examine the potentials of production, processing and using another prospective food sources to end the poverty and hunger. The present paper reviews different postharvest technologies, processing and convenience food products prepared from millets.

**Keywords:** Millets, processing, nutritional diet

### Introduction

A group of annual grasses called millets are mostly found in arid and semiarid regions. Millets have its place to five genera: *Penisetum*, *Eleusine*, *Setaria*, *Paspalum* and *Panicum*. Small seeded grains are produced from these grasses and are often cultured as cereals. Millets have highest significance in Africa, Russia, China and Asia (Balasubramanian *et al.*). India is one of the biggest producer and consumer of millets in the world. In India, different types of crops including pearl millet (Bajra), sorghum (Jowar), finger millet (Ragi/Mandua) and small millets viz; barnyard millet (Sawa/Jhangora), lile millet (Kutki), kodo millet (Kodo), foxtail millet (Kangni/ Kakun), proso millet (Cheena) all together comes under millets, because of their high nutritive value now these are called as 'Nutri-cereals'. In case of India, during 1965-66 these crops were cultivated in 36.90 million ha, producing 16.4 million tones grains, but in 2017-18 cultivation area was decreased to 14.25 million ha around 61.4% of reduction which produced 16.4 million tones. However, an increase in production during 2017-18, has been noticed regardless of more than 61.4% reduction in area under Nutri-Cereals during this period. In certain constituent millets are highly nutritious than rice and wheat. They are significant sources of important nutrients like phosphorus, niacin, magnesium, manganese, potassium and iron and also a rich source of protein, lecithin, fiber, methionine, essential amino acids and vitamin E. Because of these nutrients, millets have calming benefits like to control the diabetic heart disease, migraine, asthma, atherosclerosis, blood pressure and heart attack. Whole grains like millets have comparable and even superior health promoting effects than fruits and vegetables with a shielding effect against different diseases like, heart disease, insulin resistance, diabetes, obesity, many types of cancer, premature death and asthma.

Consumption of millet and its products is decreasing due to rapid rate of urbanization, the change in consumer habits, inadequate domestic structure, energy and time required to prepare the foods based on millets, processing techniques, underprivileged facilities of marketing, and relative unavailability of millets and its products, unstaple supplies, comparison of millet with other foodstuffs. The commercial processing mechanical polishing or pearling is unknown for millet but for rice, maize and wheat is well known. Large imports of rice and wheat and subsidized production policies of those crops in some countries also affect the millets production. If technologies for millets are developed in industries for millets in future then Millets could be in great demand.

Generally, food has three important functions: (i) to constitute humans body, (ii) to control the physical functions and (iii) to provide energy to human body for to be used in internal combustion. Potassium cools and relaxes the body while Sodium warms and strains the body. Calcium Magnesium and potassium increase alkalinity of blood. Sulfur and Phosphorus increase acidity (Devgan *et al.*, 2019) <sup>[9]</sup>. Weak alkaline nature of blood, neutralize the poisonous acids produced in the human body. We need to eat foods containing sodium to keep the body temperature normal. Eating the animal food in excess makes the blood acidic. The processed foods and muscle have acidity. The plant food especially tropical plants neutralize your blood. Millets as whole grains are considered as neutral foods. Millets are good at keeping the physical balance of the body.

### Structural features of millet grains

The basic anatomical components and structure of millets are comparable to sorghum. The significant principal structural components are: germ (oily part), endosperm (starchy part), and the pericarp (outer covering). The pericarp is common in finger millets and foxtail and it is loosely attached at one point only to the endosperm. The pericarp easily breaks away in case of utricule-type kernels, leaving the seed coat to uncover the inner endosperm. In sorghum and pearl millet, the kernels type is cryopsis, in this pericarp requires higher

energy to break because pericarp is completely fused to the endosperm. All the three main components of kernel varies reasonably. In pearl millet, the shares of endosperm, germ and pericarp are 75.0, 16.5, and 8.4 %, respectively (Abdelrahman *et al.*, 1984) <sup>[1]</sup>. The proportion of endosperm to the germ in the sorghum kernel is 8.4:1, whereas in pearl millet it is 4.5:1 and the endosperm to the germ ratio, 11:1 to 12:1 in common and finger millets because the germ is very small, but is greater than that of the sorghum. Protein content of the millets varies from 5.6 to 14.8 %.

### Nutritional composition of millets

Millets are nutritionally equivalent and even superior to most of the cereals in respect of protein, vitamins, minerals and energy (sehgal and Kawatra, 2003). Millets are abundant in minerals, nutraceuticals and have higher dietary fibers as compare to wheat and having protein (9-14%), carbohydrates (70-80%) (Hadimani and Malleshi, 1993) <sup>[14]</sup>. Millets are good sources of micronutrients and phytochemicals (Singh *et al.*, 2012). The nutritional compositions of different types of millets are given in table 1. The table shows that highest protein among the millets is found in common millet followed by pearls millet and foxtail millet. Barnyard millet is a good source of iron having (18.6mg/ 100g) followed by pearl millet and little millet. Finger millet is an amazing source of calcium having 350 mg calcium per 100 g of finger millet.

**Table 1:** Nutritional composition of millets, per 100g edible portion

Crop	Fat (g)	Carbohydrates (g)	Ash (g)	Crude fibre (g)	Protein (g)	Ca (mg)	Energy (kcal)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Maize	4.6	73.0	1.2	2.8	9.20	26	358	2.7	0.38	0.20	3.6
Sorghum	3.1	70.7	1.6	2.0	10.4	25	329	5.4	0.38	0.15	4.3
Finger Millet	1.5	72.6	2.6	3.6	7.70	350	336	3.9	0.42	0.19	1.1
Pearl Millet	4.8	67.0	2.2	2.3	11.8	42	363	11.0	0.38	0.21	2.8
Foxtail Millet	4.0	63.2	3.3	6.7	11.2	31	351	2.8	0.59	0.11	3.2
Little Millet	5.2	60.9	5.4	7.6	9.70	17	329	9.3	0.30	0.09	3.2
Common millet	3.5	63.8	3.1	5.2	12.5	8	364	2.9	0.41	0.28	4.5
Barnyard Millet	3.9	55.0	4.5	13.6	11.0	22	300	18.6	0.33	0.10	4.2

Sources: FAO, 1995

### Processing of Millets

Why millets should be processed? It is difficult to eat the coarse cereals as uncooked whole seeds (Hulse *et al.*, 1980) <sup>[16]</sup>. To make them fit for consumption and to extend the shelf life and nutritional value, millets are processed (Rai *et al.*, 2012) <sup>[29]</sup>. Originally, we come to know that millets have calorie and energy contributions and good for us; then we find that millets are rich source of fibres too, and now we emphasis that millets are good source of phytochemicals also. Three major components of millets – Protective pericarp, endosperm containing starch and germ are partially separated or modified in processing.

In general, the primary operation of processing the coarse cereals and cereals, is to separate the offal (part which is not suitable for consuming). Offal consist pericarp and sometimes also the germ. Dehulling or decortication is the term used for the process of removing offal. The main reason of less popularity of the millets food among the wheat and rice eaters are that millets have tough outer coat, related characteristic flavor, unavailability of processed products of millets similar to rice and wheat. For processing of cereals many machines are available but there is no well verified method or process is available for making white products from coloured millets. Sometimes rice dehullers or other abrasive dehullers are used for decortication. A decrease in total lysine and protein by 21

and 9% respectively is found due to decortication, but it also improves the remaining use of protein reported by Pushpamma (1990) <sup>[28]</sup>. The minerals loss was very less. Also decortication improves the consumer acceptability and the availability of nutrients.

In the form of processed or unprocessed grain, millets can be used as traditional as well as novel foods by cooking decorticated or whole and may be converted into flour using industrial or traditional methods. Though, it is required to find alternative uses possibilities. Due to lack of gluten, millet flours lack in forming elastic, cohesive and extensive dough when mixed with water unlike other flours i.e, wheat flour and rice flour. Due to absence of these properties millet flours cannot be used therefore fortification is a method to prepare ready to eat or ready to serve processed products using millets. A possibility of mixing the malted finger millet weaning food (70%) with green gram (30%) having high energy density and low viscosity (Malleshi *et al.*, 1986) <sup>[26]</sup>.

For the significant utilization as food, inedible grains are converted into consumable form and also improving its quality by the processing. Millets can be processed into flour, porridges, popped, salted ready to serve grains, sprouted cereals, roasted and malted foods. Processing of millet grains initiate with the husk removal as it consists of hard seed coat. For further processing traditional methods are used. Cracked

or broken grains, coarse meal, grits and fine flour are the products of dry-milled whole grain. The flour can be used by mixing with other flour to produce simple to complex food products like soft and stiff porridges.

### Primary processing of millets

Unit operations carried out on the grains at producers' level or in the vicinity of farm which improves grain quality / transforms the grain into more useful form.

- Cleaning
- Dehulling
- Sorting
- Polishing / Pearling
- Grading
- Size reduction /Grinding
- Drying
- Storage

### Dehulling/ Decortication

Traditionally, millets were decorticating by hand pounding at domestic level. These days, with slight modification of the process these are milled in rice milling machinery. Decortication of finger millets similar to other cereals is not possible, so its use is confined to flour based products. The endosperm texture hardened by hydrothermal treatment of millet and enabled its decortication. For soft texture like rice in 5 min, decorticated millet can be cooked which was not possible before (Saleh *et al.* 2013) [35]. Centrifugal sheller can be used to dehull/decorticate the small millets. The fractions of husk in small millet varied from 1.5 to 29.3% (Hadimani *et al.* 1993) [13].

As the decortication enhances the bio-accessibility of iron, zinc and calcium by 26, 24 and 15g/100g respectively but decreases the total mineral contents (Krishnan *et al.* 2012) [17]. With corresponding increase in protein digestibility it significantly decreases dietary fibre, polyphenols, total phytic acid, and the amount of tannins. To increase the appearance of millet grains food products and to improve their edible and sensory properties they are decorticated before consumption though some nutrients such as fiber and minerals were found to be reduced due to decortication. Refinement of millet grains includes major process of milling, which separate anatomical parts of the grain to produce a palatable foodstuff (Hoseney *et al.* 1994) [15].

### Milling

Milling generally involves removal of bran, i.e., the pericarp, the seed coat, the nucellar epidermis, and the aleurone layer. Both rice and Wheat milling techniques are used for milling the small millets. The seed coat of the finger millet is tightly bound with the friable and soft endosperm. The finger millet contains coloured pigments. Use of abrasive type milling machinery to debran finger millet are found ineffective. Flour of finger millet seeds and whole meal is used for food products. However, adding 3-5 % moisture and tempering of half an hour (the bran will toughened and friability will reduced without affecting the endosperm qualities, due to moisture gain), sieving after crushing yields fairly white flour and separates most of the bran (Kurien *et al.*, 1962) [20]. The roller flour mill can be used to obtain the fully refined millet flour.

Milling of grains includes removal of husk and bran and sometimes grinding if desired, in case of other small millets are to be processed (Kumar *et al.*, 2015) [18]. Hand operated pestle or denki method of dehulling and debranning still

continues. The machines used for rice milling, rice huller like centrifugal sheller and disc huller can be also used effectively for milling the small millets (Desichakar *et al.*, 1975) [8]. Dehusking of millets can also be carried out in plate mill by adjusting the plates' clearance.

Semolina or flour can be obtained by pulverizing the polished grains. Alternately the grains can be processed for flaking or could be used for cooking like rice. Composite flours can be produced by milling of small millets by mixing with wheat and other cereals as reported by Crabtree and Dendy, (1977) [6]. The bran obtained by milling the millets could be used with rice bran as an extender for oil extraction as the percent oil content of millet bran ranges from 15-20. In addition, it makes the product become rancid faster, thereby decreasing its palatability. While milling may reduce the mineral and vitamin content of cereal grains, a related concern is that whole cereal grains may contain biologically unavailable forms of these nutrients (Roderuck *et al.*, 1987) [34].

### Secondary Post harvest operations

Unit operations that are carried out on grain either directly or after primary processing, that transform the grain into products generally for direct consumption. They are done usually away from farm either in unorganized or in organized sectors.

- Puffing
- Baking
- Milling
- Flaking
- Value Added Products of Millets

### Machines for post-harvest handling of millets

#### For primary processing

1. Grain Pre-Cleaners
2. Destoner – Grain Cleaner
3. Jowar Polisher
4. Ragi Pearler
5. Millet Rice Polisher
6. Flour Mills
7. Dehuller
8. Separator
9. Sorter

#### For secondary processing

1. Twin Screw Extruder Machine
2. Flaking Machine
3. Grain Roaster
4. Pasta Machine
5. Food Blender

### Conventional food products

**Roti (unleavened pan cake):** The main food products of millets are roti, porridge and mudde as stated by (Devi *et al.*, 2014) [10]. Millet as a sole material for bakery products is unsuitable as millet protein lacks gluten. Hot water is mixed with millet flour that partially gelatinizes the starch that imparts binding properties in dough. Dough flattened into thin sheet and baked on hot metal plate. Roti be similar to maize tortilla or chapatti of wheat flour. Mudde is prepared by steaming the dough and converting it in balls.

**Multigrain flour:** Multigrain flour/composite flour is made from blended flours of millets, and pulses are rich in nutrients such as protein, minerals, vitamins, and dietary fiber and meet the emerging nutritional needs of people in face of preference

for modern and healthy food habits for mass feeding and social program. The use of sorghum rich multigrain flour offers a good opportunity to improve the taste and nutritional quality of sorghum roti (Rao *et al.*, 2014) <sup>[30]</sup>. For making chapatti of finger millet flour, multigrain flour by mixing the finger millet and wheat in proportion of 3:7 is found suitable. In the proposed blend, the gluten content was reduced significantly and the colour of the chapatti was turned to slightly dark. Fortification of finger millet improves the taste in chapattis and also beneficial for diabetic patients by controlling glucose levels (Ravinder *et al.*, 2008) <sup>[33]</sup>.

**Fermented foods:** Fermentation improves the taste and lowers the antinutrients but increases the value of food in terms of calcium fiber and protein.

Idli and Dosa are fermented food, commonly used in breakfast and also in evening meals in southern states of India. Idli and Dosa are prepared by rice which can be completely substitute by millets (Desikachar, 1975) <sup>[8]</sup>. Blackgram and Millets mixed in 1:3 proportions and are ground wet, then fermented overnight. Prepared batter is baked to prepare wet pancakes or Dosa and steamed to prepare idli. The Enjera, a popular food item of Euthopia, is prepared by baking the batter on hot pan similar to dosa (Gebrekidan *et al.*, 1982) <sup>[12]</sup>.

**Parboiling of millets:** Parboiling is a traditional process used for hardness of endosperm of rice to lower the losses during milling. The parboiling of finger millet hardens the endosperm, reduces the sliminess of mudde and allows the grits production as reported by Desikachar (1976). Milling quality of kodo millet improved by parboiling as reported by Shreshta (1972) <sup>[38]</sup>. It is well known that parboiling of rice reduces the loss of thiamine during milling and improves milling quality. Precooked ready to eat product of rice is also prepared by parboiled rice.

**Papad:** In south India, papad is a conventional product, made by mixing the finger millet flour up to 15-20% with other ingredients such as spice, rice and black gram. In Karnataka, finger millet flour is mixed upto 60% as reported by Begum, (2007) <sup>[3]</sup>. For preparation of papad, finger millet flour is first cooked in water to gelatinize. The gelatinized dough is then rolled into thin sheets and cut into the desired size and shape, after that drying is done upto a moisture content of 7. A little dark colour of papad is because of pericarp of finger millet. After frying the dark color of papad turns to lighter (Varma *et al.*, 2012) <sup>[41]</sup>.

### Non-conventional food products

Processing of millets, in different studies, results in utilization of traditional health foods. Many researchers tried to develop processed products like puffed, popped, extruded, roller dried product and flaked products; malted, composite flours and fermented; weaning foods, etc.

**Millet flakes:** Quick cooking cereals should be developed by using the beneficial property of millets to cook soft within 5-10 min when dropped in boiling water. For preparing the flakes pearled grains are cooked at high pressure, to gelatinize the starch completely, after drying to moisture content as 18% it pressed between heavy duty rollers (Rao *et al.*, 2016) <sup>[31]</sup>. The small size of millets is suitable for flakes production. When flakes are added to milk or water they hydrate quickly.

**Puffing or popping:** For preparing the ready to eat products puffing or popping is a simple processing technique. Popped grain is a porous, precooked and crunchy product and also has a good taste by adding flavour. On popping, a highly acceptable flavor is developed by finger millet. Popping temperature of about 250° C and 19 % grain moisture content is maintained then that to obtained expanded millets as reported by Malleshi and Desikachar (1986) <sup>[25]</sup>. For preparing expanded millet decorticated finger millet required a high-temperature short-time treatment. For maximum expansion ratio the two factors play an important role first is flattening the grains to the desired shape and second is the moisture content. The shape factor ranging from 0.52 to 0.58, 40% moisture content prior to flattening, and drying time of 136 to 150 min are optimum conditions for highest expansion ratio of any product. (Ushakumari *et al.*, 2007) <sup>[40]</sup>.

**Weaning/Malting food:** Malting of barley and sorghum is practiced on industrial level for brewing in African countries. In certain parts of India finger millet malting is a traditional process. Finger millet is superior in amylase activity than sorghum and other millets (Senappa, 1988) <sup>[37]</sup>. Malleshi and Desikachar (1986) <sup>[22]</sup> reported that with adequate starch hydrolyzing enzymes finger millet malt has highly agreeable flavour. The maximum activity of amylase develops after 4 to 5 days of germination. It is rich in calcium and sulphur amino acids and forms an ideal base for formulations of weaning food. The millet malt is use to develop the beverages either with milk or lukewarm water by addition of sugar and for production of infant food. Malting of finger millet grains improves its sensory nutritional and digestibility, quality as well as pronounced effect in lowering the antinutrients (Desai *et al.*, 2010) <sup>[7]</sup>.

**Noodles-vermicelli:** Kurkure is the best example of Extrusion technology. Extrusion technology is transforming ingredients into value added products. Extruded foods being RTE products have become a good choice as snack foods with the change in the food habits (Varma *et al.*, 2012) <sup>[41]</sup>. Due to change in food habits the demand for noodles has been increasing in India and abroad. Due to awareness of finger millet's nutritional value the demand is growing for it. Noodles, also known as convenient foods, prepared through cold extrusion. Noodles which are prepared by using the mixture of legume and millet flours are nutritionally balanced food, which can be used as weaning food or supplementary. The pearled grains are soaked in water for 24-48 hours than wet ground and are cooked, extruded and dried; develop the excellent crispy product when fried. The capital investment required is also low, as the equipment needed are very simple so these products could be economically produced (Kumate *et al.*, 1983) <sup>[19]</sup>.

**Bakery products:** Millet flour is widely used for the preparation of bakery products like nankhatai, biscuits, bread and muffins. To give the dough extensible and elastic properties, gluten is very important but millet grains lacking in Gluten, makes it unsuitable for easy handling of pure millet solid food products particularly noodle products or bakery. The entry in bakery world creates good potential for millets with superior in terms of micronutrients and fibre content. Finger millet flour has received attention in recent years and attempts have been made to provide it to the consumers in convenient forms (Singh *et al.*, 2012) <sup>[39]</sup>. Breads have been



prepared with millet based composite flour and it has equal acceptability as wheat flour bread (Singh *et al.*, 2012) [39]. Eneche, (1999) [11] prepared biscuits from pigeon pea and millet flour blends with different blending ratios millet/pea. Sensory evaluation results also indicated that all the biscuits had high sensory ratings and the recipe with the 35% pea /65% millet blend resulted in the highest scores for texture, flavor and general acceptability.

### Conclusion

Milletts are nutritionally rich as compare to other cereals, so product development by processing and using millets have undisputable prospects with respect to health benefits, nutrition and quality. It can also be an alternative to the other cereals like rice and wheat, but is not fully established among the population. Millets are cheaper but less convenient to use as it is not so popular among the people and its use in food is limited to only poor and traditional people. There are different methods and processes for preparing the products from millets only and mixing the millets with other ingredients, these methods can same as that of wheat and rice and may be different from that as the physical chemical properties of the millets are different from the other cereal grains.

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