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Review Article

A Potential Review on Millet Grain Processing

Kulkarni DB*, Sakhale BK and Giri NA
Department of Chemical Technology, Dr. Babasaheb Ambedkar Marathwada University, Maharashtra, India

***Corresponding author:** Kulkarni DB, Department of Chemical Technology, Dr. Babasaheb Ambedkar Marathwada University, Maharashtra, India

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Abstract

The enormously increasing population is raising needs for solving the problem of food scarcity. It presents a challenge to scientists and nutritionists to investigate the possibilities of processing and utilizing other potential food sources to end hunger and poverty. Millets are a major food source in arid and semi-arid arid parts of the world. Although India is the top most producers of millets, observed a steady decline in its production and utilization. Millets provide nearly all essential nutrients. Millets are safe for people suffering from gluten allergy and celiac disease. Improved techniques applied for value addition are giving out more products of wide acceptance in rural as well as urban areas. The techniques include milling, decortication, germination/malting, fermentation, popping, baking, extruding, etc. Commercialized use will increase the ease of adopting their products at wide scale. The aim of this work is to review the processes, various traditional and convenience foods including Ready-To-Eat (RTE) food products developed from millets to promote millet utilization as food for a growing population.

Keywords: Millets; Nutritive value; Decline and fall of millets; Processing; Value addition

Highlights

1. India is top most producers of millets and still lack in consumption of millets.

2. Millets are the set of complete nutrients and hence provide nutritional security.

3. Although processing of millets seems to be difficult, it gives number of conventional as well as non conventional foodstuffs.

4. Value addition is one of the ways to increase consumption of millets in daily diet.

Introduction

21st century challenges like climate changes, water scarcity, increasing world population, rising food prices, and other socioeconomic impacts are expected to generate a great threat to agriculture and food security worldwide, especially for the poorest people who live in arid and sub-arid regions [1]. Hence there is need of alternative nutritive food source. Millet is a generic term used for small sized grains and it includes grasses like finger millet, (*Eleusine coracana* (L.) Gaertn), pearl millet (*Pennisetum glaucm* (L.) R.Br), foxtail millet (*Setaria italica* (L.) *P. Beauvois*), kod o millet (*Paspalum scorbiculatum* L.), little millet (*Panicum sumatrense* Roth ex Roem. & Schult.), proso millet (*Panicum miliaceum* L.), barnyard millet (*Echinochola crusgalli* (L.) P. Beauv), guinea grass (*Panicum maximum* Jacq), elephant grass (*Pennisetum purpurium* Schumach.) that belong to the family Poaceae of the mono-cotyledon group. Most of the millets are grown in different regions of the world form east to west. Millets are important crops in the semi-arid tropics of Asia and Africa (especially in India and Nigeria), with 97 percent of millet production in developing countries. Millets share a set of characteristics which make them unique amongst cereals. The crop is favored due to its productivity and short growing season under dry, high-temperature conditions. Millets can survive in areas with as little as 300mm or less of seasonal rainfall. The minimum water requirement is 400mm for sorghum and 500-600mm for maize. These millets possess unique nutritional characteristics specifically, they are gluten-free, have complex carbohydrates, rich in dietary fibre as well as unique in phenolic compounds and photochemical having medicinal properties. It is well recognized that, the incidence of diabetes mellitus and gastro-intestinal tract related disorders are minimal among the population using these grains as staple food. Millets are safe for people suffering from gluten allergy and celiac disease. They are non-acid forming and non-allergenic hence easy to digest [1]. Millets are considered as crop of food security because of their sustainability in adverse agro-climatic conditions [2]. Although these crops have genetic diversity and difficulties in millet grain processing, ensures improved food and nutritional security [3].

Different studies on processing of millets have yielded promising results in their successful utilization for various traditional as well as convenience health foods. Accordingly different researchers have tried to develop processed products like popped, flaked, puffed, extruded and roller dried products; fermented, malted and composite flours; weaning foods, etc. For example, exploratory studies on popping and milling of millets have been promising [4]. In India, because of their potential contribution to national food security, millet grains as a food resource receiving increasing attention from agriculture and food security policymakers. In order to understand the miracle of millet grains, their process ability, present status of range of food products and future scope for development of millet based health, functional and RTE products, it is attempted to review the composition, different food products from millets, processing techniques to increases consumption of millets in daily diet of people from rural as well as urban areas.

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Table 1: Top 5 millet producing states of India.

Millet crops	Vernacular names	Total production in lakh tonnes
Sorghum	Jowar, Jondhla, Jola, Jonna, Cholam, Juara, Rotla	Maharashtra (35.87), Karnataka (16.29), Madhya Pradesh (5.74), Andhra Pradesh (4.36), Tamil Nadu (2.14), India (72.46)
Pearl millet	Bajra, Bajri, Sajja, Sajje, Cumbu	Rajasthan (42.83), Uttar Pradesh (13.02), Haryana (10.79), Gujarat (9.61), Maharashtra (6.62), Tamil Nadu (0.84), India (88.87)
Finger millet	Ragi, Mandua, Keppai, Kaelvaragu,Nagli,Nachni, Mandiya, Marwa	Karnataka (13.94), Uttarakhand (1.93), Tamil Nadu (1.70), Maharashtra (1.25), Andhra Pradesh(0.52), India (20.40)
Barnyard millet	Koni, dhan, Shyama, Banti, Sanwa, Khira, Oodalu, Kutdiravali	Uttarakhand (0.91), Arunachal Pradesh (0.16), Nagaland (0.14), Madhya Pradesh (0.12), Uttar Pradesh (0.07), Tamil Nadu (0.03), India (1.65)
Little millet	Gajrao, Kuri Kutki, Sava, Same, Save, Sama, Sava, Suan, Samalu, Swank, Sama	Madhya Pradesh (0.37), Tamil Nadu (0.32), Karnataka (0.20), Chhattisgarh (0.12), Jharkhand (0.11), India (1.42)
Kodo millet	Kodra, Kodon, Harika, Varaku, Kodra, Kodua, Arika, Varagu	Madhya Pradesh (0.50), Chhattisgarh (0.17), Tamil Nadu (0.12), Maharashtra (0.08), Uttar Pradesh (0.07), India (0.98)
Foxtail / Italian millet	Kaon, Kang, Kakun, Kangni, Navane, Thena, Rala, Kangam, Kanghzu, Kangani, Korra, Tenai	Andhra Pradesh (0.17), Karnataka (0.14), Arunachal Pradesh (0.05), Maharashtra (0.05), Rajasthan (0.05), Tamil Nadu (0.01), India (0.58)
Proso millet	Cheena, Cheno, Bari, Baragu, Vari, Bachari, Panivaragu	Maharashtra (0.17), Bihar (0.05), Orissa (0.01), Rajasthan (0.01), Tamil Nadu (0.004), India (0.26)

Seetharam *et al*.,(1986).

Table 2: Nutrient composition of millets compared to fine cereals (per 100g).

Food gain	Carbo-hydrates (g)	Protein (g)	Fat (g)	Energy (KCal)	Crude fibre (g)	Mineral matter (g)	Ca (mg)	P (mg)	Fe (mg)
Finger millet	72.0	7.3	1.3	328	3.6	2.7	344	283	3.9
Kodo millet	65.9	8.3	1.4	309	9.0	2.6	27	188	0.5
Proso millet	70.4	12.5	1.1	341	2.2	1.9	14	206	0.8
Foxtail millet	60.9	12.3	4.3	331	8.0	3.3	31	290	2.8
Little millet	67.0	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	5.0
Sorghum	72.6	10.4	1.9	349	1.6	1.6	25	222	4.1
Bajra	67.5	11.6	5.0	361	1.2	2.3	42	296	8.0
Wheat (whole)	71.2	11.8	1.5	346	1.2	1.5	41	306	5.3
Rice (raw, milled)	78.2	6.8	0.5	345	0.2	0.6	10	160	0.7

(Source: Nutritive value of Indian foods, NIN, 2007).

Decline and Fall of Millets

Millets and particularly small millets are in a situation of crisis in India. The period between 1961 and 2009 saw a dramatic decrease in cultivated area under millets (80% for small millets, 46% for finger millet, 59% for sorghum and 23% for pearl millet); a 76% decrease in total production of small millets; a significant decrease in per capita availability of all millets (despite high productivity gains for some varieties); and a steep fall in overall millets consumption. Similar trends can be seen in Tamil Nadu too (Table 1). At the same time, India is the biggest producer of millets in the world and millets remain a staple crop for numerous households. The change in climatic conditions, water scarcity, increasing world population, rising food prices, and other socioeconomic impacts are expected to generate a great threat to agriculture and food security worldwide, especially for the poorest people who live in arid and sub-arid regions of the world [1].

The major influence of "urban culture" in the country changes nutrition habits are apparent all across world, even in rural populations resulting from increasing migration to urban areas [5]. After Green Revolution, there been a systematic decline in the production of millets can be understood from the production trends of millets and other crops such as rice and wheat that were relentlessly promoted for intensive farming under irrigated conditions.

Millets possesses typical grain texture and hard seed coat that increases their keeping quality but makes them difficult to process as well as cook in convenient form. Also there is absence of appropriate primary processing technologies and also secondary as well as tertiary processing to prepare ready-to-eat value added products have been the major limiting factors for their diversified food uses and better economic status with respect to other cereals [6]. The major constraints for widespread utilization of millet are its coarse fibrous seed coat, coloured pigments, astringent flavour and poor keeping quality of the processed products [7].

On an average, some of the main underlying barriers limiting the production and consumption of millets are (1) Lower or near absence of production support, (2) lack of reach of improved methods of production and technologies, (3) Lack of appropriate post-harvest processing technologies, (4) Competition from other market friendly remunerative crops, (5) Changes in preference patterns in consumption, (6) Lack of public procurement and marketing support, (7) Absence of public or private funded promotion [8].

Although there are some of the difficulties in millet grain processing but nutritional as well as health benefits and consumer demand for health foods provide opportunities in processing, development of suitable technology for value added products and process mechanization.

Nutritional Composition of Millets

Cereal grains and plant nutrients are largely used as a major

Table 3: Essential Amino acid profile of Millets compared to fine cereals (mg/g of N).

Millet	Arginine	Histidine	Lysine	Tryptophan	Phenyl Alanine	Tyrosine	Methionine	Cystine	Threonine	Leucine	Isoleucine	Valine
Foxtail	220	130	140	60	420	-	180	100	190	1040	480	430
Proso	290	110	190	50	310	-	160	-	150	760	410	410
Finger	300	130	220	100	310	220	210	140	240	690	400	480
Little	250	120	110	60	330	-	180	90	190	760	370	350
Barnyard	270	120	150	50	430	-	180	110	200	650	360	410
Sorghum	240	160	150	70	300	180	100	90	210	880	270	340
Bajra	300	140	190	110	290	200	150	110	140	750	260	330
Rice	480	130	230	80	280	290	150	90	230	500	300	380
Wheat	290	130	170	70	280	180	90	140	180	410	220	280

(Source: Nutritive value of Indian foods, NIN, 2007).

Table 4: Vitamin profile of Millets and major cereals (mg/100g).

Millet	Thiamin	Niacin	Riboflavin	Vit A	Vit B6	Folic Acid	Vit B5	Vit E
Foxtail	0.59	3.2	0.11	32	-	15.0	0.82	31.0
Proso	0.41	4.5	0.28	0	-	-	1.2	-
Finger	0.42	1.1	0.19	42	-	18.3	-	22.0
Little	0.3	3.2	0.09	0	-	9.0	-	-
Barnyard	0.33	4.2	0.1	0	-	-	-	-
Kodo	0.15	2.0	0.09	0	-	23.1	-	-
Sorghum	0.38	4.3	0.15	47	0.21	20.0	1.25	12.0
Bajra	0.38	2.8	0.21	132	-	45.5	1.09	19.0
Rice	0.41	4.3	0.04	0	-	8.0	-	-
Wheat	0.41	5.1	0.1	64	0.57	36.6	-	-

(Source: Nutritive value of Indian foods, NIN, 2007; MILLET in your Meals, http://www.sahajasamrudha.org/)

source of dietary nutrients worldwide. The millets contain 7-12% protein, 2-5% fat, 65-75% carbohydrates and 15-20% dietary fibre in general. Being the rich source of calcium, dietary fiber, polyphenol and protein contents in millets make them unique among the cereals [9]. Generally, millets show significant amounts of amino acids (methionine and cysteine) and also have high fat content than maize, rice, and sorghum [10].

Foxtail millet which is rich in essential amino acid lysine can be used as a supplementary protein source to most cereals and the millet protein characterization showed that its protein concentrate is a potential functional food ingredient [11]. The millets when compared to the protein of wheat and grain, proso millet showed significantly higher content 11.6% (dry matter) and was also rich in essential amino acids (leucine, isoleucine and methionine) than wheat protein [12]. The use of millets as whole grain makes the essential nutrients such as dietary fiber, minerals, phenolics and vitamins concentrated in the outer layer of the grain or the seed coat form the part of the food and offer their nutritional and health benefits [13].

Among them, pearl millet contains considerably high proportion of proteins (12-16%) as well as lipids (4-6%) whereas; finger millet contains lower levels of protein (6-8%) and fat (1.5-2%). The essential amino acid profiles of the millet proteins is better than maize. The niacin content in pearl millet is higher than all other cereals whereas, finger millet proteins are unique because of the sulphur rich amino acid contents. Similar to cereal proteins, the millet proteins are poor sources of lysine, but they complement well with lysine-rich vegetable (leguminous) and animal proteins and form nutritionally balanced composites of high biological value. Small millets are more nutritious compared to fine cereals. Finger millet is the richest source of calcium (300-350mg/100g) and other small millets are good source of phosphorous and iron (Table 2).

The millet grain contains about 65% carbohydrate, a high proportion of which is in the form of non-starchy polysaccharides and dietary fibre which help in prevention of constipation, lowering of blood cholesterol and slow release of glucose to the blood stream during digestion. Lower incidence of cardiovascular diseases, duodenal ulcer and hyperglycemia (diabetes) are reported among regular millet consumers. Millet grains are also rich in important vitamins *viz.*, Thiamine, riboflavin, folin and niacin. Millets are comparable to rice and wheat or rich in some of the minerals as well as fatty acids. Millets vary largely in composition of carbohydrates as proportion of amylose and amylopectin content vary from 16-28% and 72-84%, respectively (Table 3).

The edible component of millet kernel is the rich source of phytochemicals, such as dietary fiber and polyphenols (0.2-0.3%) [14]. Also millets contribute to antioxidant activity with phytates, polyphenols and tannins present in it having important role in aging and metabolic diseases [15]. The highest calcium content is present is finger millet with 344mg/100g among the cereals; Also rich in phytates 0.48g/100g, polyphenols, tannins 0.61% [16]. Kodo millet

Table 5: Micronutrient Profile of Millets compared to fine cereals (mg/100g).

Millets	Mg	Na	K	Cu	Mn	Mb	Zn	Cr	Su	Cl
Foxtail	81	4.6	250	1.40	0.60	0.070	2.4	0.030	171	37
Proso	153	8.2	113	1.60	0.60	-	1.4	0.020	157	19
Finger	137	11.0	408	0.47	5.49	0.102	2.3	0.028	160	44
Little	133	8.1	129	1.00	0.68	0.016	3.7	0.180	149	13
Barnyard	82	-	-	0.60	0.96	-	3	0.090	-	-
Kodo	147	4.6	144	1.60	1.10	-	0.7	0.020	136	11
Sorghum	171	7.3	131	0.46	0.78	0.039	1.6	0.008	54	44
Bajra	137	10.9	307	1.06	1.15	0.069	3.1	0.023	147	39
Rice	90	-	-	0.14	0.59	0.058	1.4	0.004	-	-
Wheat	138	17.1	284	0.68	2.29	0.051	2.7	0.012	128	47

(Source: Nutritive value of Indian foods, NIN, 2007; MILLET in your Meals, http://www.sahajasamrudha.org/)

Table 6: Fatty acid composition of millets compared to fine cereals.

Millets	Palmitic	Palmoleic	Stearic	Oleic	Linoleic	Linolenic
Foxtail	6.40	-	6.30	13.0	66.50	-
Proso	-	10.80	-	53.80	34.90	-
Finger	-	-	-	-	-	-
Little	-	-	-	-	-	-
Sorghum	14.0	-	2.10	31.0	49.0	2.70
Bajra	20.85	-	-	25.40	46.0	4.10
Rice	15.0	-	1.90	42.50	39.10	1.10
Wheat	24.50	0.80	1.00	11.50	56.30	3.70

(Source: Nutritive value of Indian foods, NIN, 2007; MILLET in your Meals, http://www.sahajasamrudha.org/).

and little millet were also reported to have 37% to 38% of dietary fiber, which was once considered as 'anti nutrient' and is now termed as a neutraceutical and highest among cereals [14]. Thus, it makes millets a complete food ingredient suitable for large scale utilization as processed products, snacks, baby foods etc., and also plays a major role in propagating food security among under developed and developing countries (Table 4-7).

Refinement of the Millet Grains

Processing is the method used for converting the inedible grain into edible form and thereby enhancing its quality. Processing of cereals and millets plays significant role during its utilization as food. Millets can be consumed by processing them into rice, flour, sprouting, roasted, popped, salted ready-to-eat grains, porridges and fermented products. As millet grains consists hard seed coat, their processing starts with the task of removal of husk. Traditional methods are usually applied to decorticate millet grains partially or completely before further processing. Whole grains may as well be directly dry-milled to give a range of products: broken or cracked grains, grits, coarse meal and fine flour. The flour thus obtained is used in the preparation of an extensive variety of simple to complex food products. They can also be mixed with other flours to form composite flours for soft and stiff porridges.

Decortication/Dehulling

Millets were earlier decorticated at household level by hand pounding. Now a day with slight modification of the process these are milled in rice milling machinery. It has been reported that the food uses of finger millet, being small in size, are confined to flour based products because it has not been possible to decorticate millet similar to other cereals. The hydrothermal treatment of millet hardened the endosperm texture and enabled its decortication. The decorticated millet could be cooked as discrete grains similar to rice to obtain soft edible texture within 5 min, which was not possible before [17]. 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% [14]. As the decortication decreases the total mineral contents, but increases the bio-accessibility of calcium, iron and zinc by 15, 26 and 24g/100g respectively [18]. It significantly decreases total phytic acid, polyphenols, dietary fibre and the amount of tannins with corresponding increase in protein digestibility. Although decortication of millet grains was found to reduce some nutrient contents such as fiber and minerals, but usually they are decorticated before consumption to improve their edible and sensory properties and to increase the appearance of their food products. Refinement of millet grains includes major process of milling, which separate anatomical parts of the grain to produce a palatable foodstuff [19].

Table 7: Amylose & Amylopectin content of millets.

Cereal grain	Amylose (%)	Amylopectin (%)
Proso millet	28.2	71.8
Foxtail millet	17.5	82.5

Milling

Milling generally involves removal of bran, i.e., the pericarp, the seed coat, the nucellar epidermis, and the aleurone layer. Milling of small millets is done by adoption of both wheat and rice milling techniques. The finger millet seed coat, contains coloured pigments tightly bound with the soft and friable endosperm. Efforts made to debran finger millet using abrasive type milling machinery have not been successful. Generally, finger millet seeds are powdered, and the whole meal (sometimes a small portion of coarse bran is sieved off) is utilized for food preparations. However, moistening the seed with 3-5 per cent moisture, tempering for about 30 min (moistening toughens the bran and reduces its friability without affecting the endosperm property), grinding followed by sieving separates most of the bran and yields fairly white flour [20]. The roller flour mill, universally used for wheat milling, could be used to obtain fully refined millet flour. However [21], in the case of other small millets, milling process includes dehusking and debranning (decortication) and grinding if desired. The traditional method of dehusking and debranning by hand operated pestle or denki still persists. The Rice milling machinery, such as disc sheller, rice huller and centrifugal sheller also dehusk the small millets effectively [22]. Dehusking can be carried out even in the plate mill by suitably adjusting the clearance between the plates. The dehusked or decorticated grains (`brown rice') are polished in a rice polisher to get `millet rice'. Polished grains may be pulverized in a plate mill or hammer mill to obtain semolina, or flour, as required. Alternately the grains could be used for cooking like rice, or can be processed for flaking. Co-milling of small millets with wheat and other cereals to produce composite flours has also been reported by Crabtree and Dendy, (1977) [23]. It may be worthwhile

to mention here that the millet bran contains nearly 15-20 per cent oil. In case milling of these grains is carried in an organized sector, the bran could be used as an extender of rice bran for extraction of oil. In addition, it makes the product become rancid faster, thereby decreasing its palatability [19]. 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 [24].

Value Added Products of Millets

Conventional food products

Roti (unleavened pan cake): Roti (unleavened pan cake), mudde (dumpling) and porridge are the main food products prepared from millets [9]. Millet protein lacks gluten, hence it is unsuitable as the sole material for preparation of bakery products. For preparing roti, millet flour is mixed with hot water to partially gelatinize the starch. This imparts the necessary binding of particles and helps to roll the dough into thin sheets. The flattened dough is baked on a hot plate. Roti resembles wheat chapathi or maize tortilla. Mudde from millet flour is prepared by steaming the dough and making it into balls. Mudde is similar to `TO' of Africa. Millet flour suspended in cold water containing a little buttermilk is left overnight for mild fermentation. Next morning the slurry is cooked to prepare porridge.

Multi-grain flour: Multigrain flour also known as the composite flour. Multigrain flour made from blended flours of millets, and pulses are rich in nutrients such as protein, vitamins, minerals, 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 [25]. Multigrain flour by combining wheat and finger millet in the ratio of 7:3 (wheat: finger millet) is one of the simple semi-finished products suitable for making chapatti. In the proposed blend though the gluten content is reduced significantly the making of chapatti while flattering is not affected. However the colour of the chapatti turns to slightly dark. Fortification of finger millet in chapattis not only improves the taste but also helpful in controlling glucose levels in diabetic patients very efficiently [26]. High fiber content of multigran flour is further helpful to the individuals having the problem of constipation [27].

Fermented foods: Fermented foods like Dosa and idli are popular in many parts of India and they are very common as breakfast foods and even as the evening meals in southern part of the India. Fermentation lowers the antinutrients and improves the taste but enriches the food value in terms of protein, calcium and fiber [28]. Millets can substitute rice completely in the preparation of idli and dosa (steamed and baked preparations) [22]. Millets and blackgram mixed in the ratio of 3:1 are wet ground, and the mixed batter is fermented overnight. The batter is steamed to make idli or baked on hot pan to prepare dosa or wet pancakes.

Enjera, a popular food item prepared in Ethiopia [29] is prepared by wet grinding teff, fermenting the batter and baking on hot pan similar to dosa. Enjera is nutritionally inferior to dosa as the former is prepared out of teff only.

Parboiling of millets: Parboiling of rice is a well-known traditional process of processing of rice. Desikachar (1976) reported that steam treatment of finger millet hardens the endosperm, enables the production of grits, and reduces the sliminess of mudde. Shreshta (1972) [30] reported that parboiling of kodo millet improved its milling quality. It is well known that parboiling bf ric improves milling quality and reduces the loss of thiamine during milling. Parboiled rice is also used to prepare expanded rice, which is a precooked ready to eat product. The same may hold well with millets too.

Papad: Papad is a traditional product in south India. Finger millet flour (15-20%) added in other essential ingredients such as black gram, rice and spices. Begum, (2007) [31],reported that addition of finger millet flour (upto 60%) is possible and practiced in Karnataka. During papad preparation finger millet flour is first cooked in water up to gelatinized. A thin sheet is prepared by rolling and cutting the dough into desired shapes and sizes followed by drying of these papad pieces to desired moisture content of 7. Since the pericarp of finger millet grain is not separated out from the starch so that it gives a little dark colour to the papad. The dark colour of papad turns to lighter after frying [28].

Non-conventional food products

Different studies on processing of millets have yielded promising results in their successful utilization for various traditional as well as convenience health foods. Accordingly different researchers have tried to develop processed products like popped, flaked, puffed, extruded and roller dried products; fermented, malted and composite flours; weaning foods, etc. For example, exploratory studies on popping and milling of millets have been promising [4].

Millet flakes: Debranned small millets, when dropped in boiling water, cook soft within 5-10 min. This beneficial property of millets needs to be exploited for developing quick cooking cereals. Pearled grains are soaked in water, steamed or cooked under pressure to effect complete gelatinisation of the starch, dried to about 18 per cent moisture and pressed to requisite thickness between heavy duty rollers and dried to prepare flakes [32]. Flakes hydrate quickly when added to warm water or milk and are used to prepare sweet or savoury dishes. Flakes, when deep fried, expand and form crispy products. The relatively smaller size and quick hydration of millets make them most suitable for the production of flakes.

Popping/puffing: Popping or puffing is a simple processing technique of cereals to prepare ready to eat products. Popped grain is a crunchy, porous, precooked product. Popping invariably improves taste and flavour. Among the cereals finger millet develops highly agreeable flavour on popping. The volume of popped millets ranges from 8-10ml/g. Popped grains find extensive usage as snacks. Popped finger millet flour is often consumed after mixing with jaggary (brown sugar) and milk is traditionally called hurihittu. Popped finger millet flour is now produced and is marketed at cottage industry level in some places. Popped millets are also used as adjuncts in brewing. Malleshi and Desikachar (1981) [33] reported thatto obtain fully expanded millets, the grain moisture content should be around 19 per cent and popping temperature of about 250°C. They also studied the varietal differences in popping [34]. Decorticated finger millet was subjected to a high-temperature short-time treatment to prepare expanded millet, a ready-to-eat new-generation product. It was observed that flattening the grains to the desired shape and moisture content were

critical factors for obtaining millet with maximum expansion ratio. The optimum conditions for preparing a product with the highest expansion ratio were found to be about 40% moisture content prior to flattening, with the shape factor ranging from 0.52 to 0.58 and drying time varying from 136 to 150 min [35].

Weaning food: Malting of barley in temperate countries and that of sorghum in African countries is practised on industrial level for brewing. Malting of finger millet has been a traditional process in certain parts of India [36,37]. Studies have shown that finger millet develops higher amylase activity than sorghum and other millets [38,39]. Malleshi and Desikachar (1986) reported that finger millet malt has highly agreeable flavour with adequate starch hydrolyzing enzymes. 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 weaning food formulations [37]. Generally the millet malt is utilized for production of infant food and also to prepare beverages either with milk of lukewarm water with the addition of sugar since old times. Malting of finger millet grains improves its digestibility, sensory and nutritional quality as well as pronounced effect in lowering the antinutrients [40].

The food was nutritionally comparable to proprietary weaning foods and was readily accepted and tolerated by children [41]. Use of malted finger millet for preparation of malt extract and malt syrups [42] and in brewing [43] has also been reported. Malts from other small millets are also acceptable; however the development of amylases is low in them as compared to finger millet. Refined finger millet malt flour blended with milk powder, sugar and a flavouring agent, forms a thickener for milk-based beverages. In addition, malt flour blended with barley malt hydrolysed to dextrin, flavoured with cocoa and vacuum self-dried, forms a fluffy product, for use in milk-based beverage formulations (CFTRI Ann. Report, 1982).

Noodles-vermicelli: Extrusion technology is another novel way of transforming ingredients into value added products. One of the best examples is Kurkure very popular among children. The change in life also bringing a drastic change in the food habits and the extruded foods being RTE products have become a good choice as snack foods [28]. Due to the changing food habits of children and teenaged groups have created a good market for noodles in India and abroad. The demand for millet noodles particularly the noodles made out of finger millet is growing due to awareness of its nutritional properties. Noodles are also known as convenience foods prepared through cold extrusion system which becomes hard and brittle after drying. Noodles prepared from blends of millet and legume flours form nutritionally balanced food which could be used as supplementary or weaning foods. Finger millet and wheat flour in the ratio of 1 and finger millet blended with wheat and soy flour in the ratio of 5:4:1 [28]. The pearled grains soaked in water for 1-2 days, wet ground and the mash cooked, extruded and dried, make excellent crispy product when deep fried. The quality of these products is equal to that prepared from rice. These products could be economically produced as a cottage industry, as the equipment needed are very simple, and the capital investment required is also low [44].

Bakery products: Millet flour is widely used for the preparation of bakery products like biscuit, nankhatai, muffins and bread. Although millet grains lack in gluten, which is very important to give dough with elastic and extensible properties, makes them unsuitable for the preparation of easy-to-handle pure millet solid food products, particularly bakery or noodle products. The use of millets in bakery products will not only superior in terms of fibre content, micronutrients but also create a good potential for millets to enter in the bakery world for series of value added products. In a recent study attempts have been made to improve the nutritional quality of cakes with respect to the minerals and supplementing with malted finger millet flour [40]. In recent years, finger millet has received attention and efforts are under way to provide it to the consumers in convenient forms [45]. For the preparation of breads, millet-based composite flours were optimized. Barnyard millet plus wheat composite flour was formulated and prepared. The results of sensory analysis showed that the acceptability of bread samples prepared from composite flours was almost equal to that of the wheat bread [45]. Furthermore, the suitability of oat, millet, and sorghum in bread making was assessed in which wheat flour was replaced from 0% to 60%. The results indicated that oat, millet, and sorghum represent a viable alternative [46]. Eneche, (1999) [47] prepared biscuits from millet flour and pigeon pea 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 65% millet/35% pea blend resulted in the highest scores for flavor, texture, and general acceptability.

The study conducted by Saha et al., (2011) [48] in production of biscuits from flour composites containing 60: 40 and 70:30 (w/w) finger millet: wheat flour was evaluated for dough characteristics and biscuit quality. It was indicated that a composite of finger millet and wheat flour (60: 40) was best, particularly regarding biscuit quality. In addition, the finger millet seed coat is an edible material and contains a good proportion of dietary fiber, minerals, and phytochemicals. The Seed Coat Matter (SCM) forms a byproduct of the millet milling, malting, and decortication industries and can be utilized as composite flour in biscuit making [49]. Millets can substitute wheat up to 20 per cent in bakery flours. Incorporation of higher levels of millet flours affects the texture of the products, without affecting the nutritive value [50].

Conclusion

In conclusion, it may be stated that small millets can be processed to diversify their uses, to improve their nutritive value and consumer acceptability. Millets contain many nutritional and health benefits. Nutritionally important components in millets such as dietary fiber, minerals, vitamins, and phytochemicals that include phenolic compounds are important contributors for positive health benefits in humans. Processing of the grain for many end uses involves primary (dehulling and milling) and secondary (fermentation, malting, extrusion, popping, baking) operations. The emerging principal uses of millets as an industrial raw material include production of biscuits and confectionery, beverages, weaning foods and beer. Soft biscuits and cookies are being made using sorghum, maize and wheat composites, while cakes and non-wheat breads have become a subject of increasing scientific and technological inquiry, showing encouraging results. Also novel approaches and models should be proposed to improve the effectiveness of the millet consumption. Being a staple and consumed at household levels, processing must be

considered at both traditional and industrial levels, involving small, medium and large-scale entrepreneurs. Preparation and distribution of millets and millet products should be propagated more to promote food security which includes nutritional security.

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