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Processing and Technology for Millet Based Food Products: A Review

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Abstract

Millets are nutritionally rich and occupy an important place in the diet of people in many regions of the world. Although millets are nutritionally superior to cereals their utilization as a food is still mostly confined to the traditional consumers and population of lower economic strata. The climate change, water scarcity, population increase, declining yields of major cereals, adequate access to enough food, strengthening local agro-food systems present a challenge to scientists and nutritionists to investigate the possibilities of producing, processing, and utilizing other potential food sources to end hunger and poverty. However, the special features of the millets, their beneficial uses and health consciousness of the consumer have made food scientists and engineers to develop various food products and mechanize the processes. The present paper reviews the processes, various traditional and convenience foods including ready-to-eat (RTE) food products developed from millets and product characteristics.

Keywords: Millets, processing, puffing, fermentation, malting, weaning, nutrition, glycemic index.

Introduction

Millet is a generic term used for small sized grains that form heterogeneous group and referred along with maize and sorghum as 'coarse cereals'. Millets are of minor importance in the west but a staple food in the diets of African and Asiatic people. Their agricultural importance arises from their hardiness, tolerance to extreme weather and could be grown with low inputs in low rainfall areas. *Bajra* or pearl millet (*Pennisetum americanum*), *ragi* or finger millet (*Eleusine coracana*), *navane* or foxtail millet (*Setaria italica*), *samai* or little millet (*Panicum miliare*), *haraka* or kodo millet (*Paspalum scrobiculatum*), *panivaragu* or proso millet (*Panicum miliaceum*), banti or barnyard millet (*Echinochloa frumentacea*) are the important millets cultivated largely in the Asian and African countries. Fonio (*Digitaria exilis*) and Tef (*Eragrostic tef*) are specific to Nigeria and Ethiopia respectively. Most of the millets are grown in different regions of the world from east to west. The world total production of millet grain was 762712 metric tonnes and India top ranking with a production of 334500 tonnes in 2010 (FAO, 2012).

Millets are considered as crop of food security because of their sustainability in adverse agro-climatic conditions (Ushakumari *et al.*, 2004). These crops have substantive potential in broadening the genetic diversity in the food basket and ensuring improved food and nutrition security (Mal *et al.*, 2010). Along with nutrition millets offer health benefits in daily diet and help in the management of disorders like diabetes mellitus, obesity, hyperlipidemia, etc. (Veena, 2003). Millets offer unique advantage for health being rich in micronutrients, particularly minerals and B vitamins as well as nutraceuticals. Though millets are not the important part of daily diet of American and European people, now these countries have recognized the importance of millets as ingredient in multigrain and gluten-free cereal products. However, in many Asian and African countries millet is the staple food of the people in millet producing areas and used to prepare various traditional foods and beverages like *idli*, *dosa*, *papad*, *chakli*, *porridges*, breads, infant and snack foods (Chandrasekara and Shahidi, 2011). Whilst a number of traditional foods are made in the domestic household, the lack of large-scale industrial utilization discourages the farmers raising millet crops

(Subramanian and Viswanathan, 2003). Therefore, many countries Including India, China, USA etc. have now started research projects to study and develop process technology for nutritional improvement and harvest health benefits and promote their utilization as food on large scale.

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 (Saleh *et al.*, 2013). Typical grain texture and hard seed coat of millets increases their keeping quality but makes them difficult to process as well as cook in convenient form. Absence of appropriate primary processing technologies to prepare ready-to-use or ready-to-cook (RTC) products 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 (Malleshi, 2014). Millets have relatively poor digestibility and low bio-availability of minerals due to presence of inherent anti-nutritional factors. An increasingly important determinant in food choice is the growing consumer concern about nutrition and health (Nehir and Simsek, 2012). The difficulties in millet grain processing present a challenge but nutritional as well as health benefits and consumer demand for health foods provide opportunities in processing, development of suitable technology for newer products and process mechanization. This change in technology and consumer food preference would help in increasing the area under millets, maintaining ecological balance, ensuring food security, prevent malnutrition and increase the scope for utilization of millet grains on industrial scale.

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 (Malleshi, 1986). Extrusion of weaning foods of pearl millet increases the protein digestibility (Cisse *et al.*, 1998) whereas germination and probiotic fermentation causes significant improvement in protein profile and in-vitro mineral availability (Arora *et al*., 2011).

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, specialties of ingredients, different food products from millets, processing techniques, their effect on nutrients and product characteristics.

Nutrient Composition of Millets

Most of us find health at risk due to malnutrition of vital nutrients. Therefore, everyone is conscious of his/her daily diet and so are the food product development teams around the world striving to provide missing pieces to health puzzle. So nutrition is at the core of the diet of people. Millet grains are nutritionally comparable and even superior to major cereals with respect to protein, energy, vitamins, and minerals (Sehgal and Kawatra, 2003). Millets are the rich source of minerals, nutraceuticals, and higher dietary fibers than rice or wheat and contains 9-14% protein, 70-80% carbohydrates (Hadimani and Malleshi, 1993). These are rich sources of phytochemicals and micronutrients (Singh *et al.*, 2012b). The nutritional status of a community has therefore been recognized as an important indicator of national development (Singh and Raghuvanshi, 2012).
In the face of increasing population and stagnant wheat and rice productions, millets can be a promising alternative in solving the problem of food insecurity and malnutrition. The quality of protein is mainly a function of its essential amino acids. Finger millet contains 44.7% essential amino acids (Mbithi *et al.*, 2000) of the total amino acids, which is higher than the 33.9% essential amino acids in FAO reference protein (FAO, 1991). The characterization of the proteins of millet grains shows that prolamin fraction constitutes the major storage protein of the grain and lysine is the most limiting amino acid followed by cystine but millets are relatively high in methionine (Monteiro *et al.*, 1987; Sudharshana *et al.*, 1987; Kumar and Parmeswaran, 1999). The true digestibility and biological value of these millets ranges between 95.0 to 99.3 and 48.3 to 56.5 respectively (Geervani and Eggum, 1989b). Among the millets, pearl millet (*Bajra*) has the highest content of macronutrients, and micronutrients such as iron, zinc, Mg, P, folic acid and riboflavin, significantly rich in resistant starch, soluble and insoluble dietary fibres (Antony *et al.* 1996; Ragaee *et al.*, 2006). Finger millet seed coat is an edible material and contains good proportion of dietary fibre, minerals and phytochemicals. The seed coat matter (SCM) forms a by-product of millet milling, malting and decortication industries and can be utilized as composite flour in biscuit preparation (Krishnan *et al.*, 2011). Finger millet (*ragi*) is an extraordinary source of calcium. Kodo millet and little millet are also reported to have 37% to 38% of dietary fiber, which is the highest among the cereals and though low in fat -

Table 1: Nutrient composition of sorghum, millets and other cereals (per 100 g edible portion; 12 percent moisture)

Food	Protein[a] (g	Fat (g)	Ash (g)	Crude fibre (g)	Carbohydrate (g)	Energy (kcal)	Ca (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Rice (brown)	7.9	2.7	1.3	1.0	76.0	362	33	1.8	0.41	0.04	4.3
Wheat	11.6	2.0	1.6	2.0	71.0	348	30	3.5	0.41	0.10	5.1
Maize	9.2	4.6	1.2	2.8	73.0	358	26	2.7	0.38	0.20	3.6
Sorghum	10.4	3.1	1.6	2.0	70.7	329	25	5.4	0.38	0.15	4.3
Pearl millet	11.8	4.8	2.2	2.3	67.0	363	42	11.0	0.38	0.21	2.8
Finger millet	7.7	1.5	2.6	3.6	72.6	336	350	3.9	0.42	0.19	1.1
Foxtail millet	11.2	4.0	3.3	6.7	63.2	351	31	2.8	0.59	0.11	3.2
Common millet	12.5	3.5	3.1	5.2	63.8	364	8	2.9	0.41	0.28	4.5
Little millet	9.7	5.2	5.4	7.6	60.9	329	17	9.3	0.30	0.09	3.2
Barnyard millet	11.0	3.9	4.5	13.6	55.0	300	22	18.6	0.33	0.10	4.2
Kodo millet	9.8	3.6	3.3	5.2	66.6	353	35	1.7	0.15	0.09	2.0

[a]All values except protein are expressed on dry weight basis; protein = N x 6.25.
Sources: Hulse, Laing and Pearson, 1980; United States National Research Council/National Academy of Sciences, 1982; USDA/HNIS. 1984; FAO, 1995

content, it is high in PUFA (polyunsaturated fatty acids) (Malleshi and Hadimani 1993; Antony *et al.* 1996). It is also rich in essential amino acids, like lysine, threonine, valine, sulphur containing amino acids and the ratio of leucine to isoleucine is about 2 (Ravindran, 1992; Antony *et al.,* 1996). Kodo millet has the highest free radical (DPPH) quenching activity followed by great millet (sorghum) and finger millet (Hegde and Chandra, 2005). Sorghum is exceptionally high in antioxidant activities followed by millets. Millets are valued for their high content of vitamin B, folic acid, phosphorus, iron and potassium. Finger millet contains 16 times more calcium than maize. The niacin content in pearl millet is higher than all other cereals. In addition, millets are gluten-free, easy to digest and are a great source of antioxidants and might have anti-carcinogenic properties (Dykes and Rooney, 2006).

The lipid content is generally high (3–6%) for pearl millet, higher than for sorghum and most other common cereals. About 75% of the fatty acids in pearl millet are unsaturated and linoleic acid is particularly high (46.3%). For this reason energy content of millet is greater than sorghum and nearly equal to that of brown rice. Finger and teff millet are good source of dietary calcium and magnesium and iron content is significant. The overall average nutrient composition of millet and other cereal grains is given in the Table 1.

Processing of Millets

Technology used for converting the grain into edible form and thereby enhancing its quality is known as processing. Processing of cereals and millets plays significant role during its utilization as food. Minor 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 are hard seed coat grains, their processing starts with the task of removal of husk.

Decortication/ Dehulling

Millets were earlier decorticated at household level by hand pounding. Now a day these are milled in rice milling machinery with slight modification of the process. Centrifugal sheller can be used to dehull/decorticate the small millets. The fractions of husk in pearl millet and small millet varied from 1.5 to 29.3% (Hadimani and Malleshi, 1993). Soaking of pearl millet grain in 300 ml (w/v) 0.2 N HCL for 15 hr and washing twice with water helps in removing the hull. Then grains are scarified in laboratory scarifier (Osawa make) for 1–3 min can remove 8.10–15.84% hull (Pawar and Parlikar, 1990). The polyphenolic pigments and phytate phosphorus were reduced to 66.9-71.3% and 60.0-74.0% respectively. Decortication decreases the total mineral contents, but increases the bio-accessibility of calcium, iron and zinc by 15, 26 and 24 g/100 g respectively (Krishnan *et al*., 2012). It significantly decreases total phytic acid, polyphenols, dietary fibre and the amount of tannins with corresponding increase in protein digestibility. Dehulling coupled with hydrothermal treatment affect the phenolic content and antioxidant potential of millet grains. Antioxidant activity of phenolic extracts was in the order of hull > whole grain >dehulled grain > cooked dehulled grain (Chandrasekara *et al*., 2012).

Milling

Most of the millets produced in India are used as staple food and less in ready-to-use and convenient food products due to non-availability of proper milling technology. 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 (Desikachar, 1975). Pearling, debranning and chemical treatments of millets overcome some of these constraints; improve nutritional quality and consumer acceptability (Akingbala, 1991). In milling, the milling efficiency and shelling index are the important parameters that influence the head yield and further processing.

Hadimani *et al.* (1995) milled thirty eight cultivars of pearl millet in McGill mill for 30 s under 1.4 kg pressure and glumes separated by aspiration. The yield of pearled grains and brokens varied from 80.0 to 96.8% and 0.9 to 30.3%, respectively. Similar studies on head yield and bran of minor millets and pearl millet grains found to vary from 63.2 to 90.0%, and 5.0 to 11.0%, respectively. Millet contain appreciable amount of dietary fibre (9-16%) even after removal of husk and major portion of bran (Hadimani and Malleshi, 1993). There is significant and positive correlation between milling breakage and thousand kernel weight which indicates that bolder grains and varieties of lower protein contents break easily during milling. The milling efficiency of little millet, kodo and kutki (*Panicum miliaceus* L.) is 83.38, 76.43 and 74.10%, respectively whereas their respective head yields after polishing are 71.5, 56.25 and 54.57% (Mandhyan *et al.*, 1987). Lohani and Pandey (2008) observed still lower milling percentage in barnyard millet (70.77) at 10% moisture level and found that the degree of polish increased with increase in time of milling but at the cost of linear decrease in milling yield and exponential decrease in the head yield. Thus, there is significant difference in milling percentage and head yields among the milled millet types and this may be attributed to the intact hard seed coat and relative difference in size of grains of particular millet.

The milling and polishing of millet grains was tried with other processing equipments or machines which were specifically not designed for millets for a long period. The successful effort in this direction was made by Singh (2010) who tried to mechanize the milling process by developing dehuller for barnyard millet and optimized the machine parameters for maximizing efficiency, minimizing specific energy consumption and broken grains. The actual dehulling efficiency (88.3±2.8%), specific energy consumption (0.078± kW h/kg grain) and broken grain (6.1±1.1%) were obtained with the optimized machine parameters (9 canvas strips and 3 mm over hanging width) and operational parameters (8.6 m/s peripheral speed; 5 passes and 8.4% db moisture content). After applying steaming (9 min) mustered oil (31 g/100 kg) as pretreatment, the actual dehulling efficiency, specific energy consumption and broken grains were 76.3±3.6%, 0.018±0.004 $kWhkg^{-1}$ and 7.3±1.5%, respectively in single pass of dehulling.

Composite Flour

Although millets are nutritionally superior to cereals, yet their utilization is not wide spread. One possible way of extending their utilization could be by blending them with wheat flour after suitable processing (Singh *et al.*, 2005). On addition of millet flour there would be changes in physico-chemical, nutritional and functional characteristics. In developed countries many convenience products including extruded products are popularly consumed. Extruded products include spaghetti, macaroni, vermicelli and noodles, pasta, etc. The products are made using refined durum wheat flours or semolina as their main ingredient. Many research workers have attempted to produce composite millet flours by replacing conventional cereal flours to some extent in making the traditional foods, ready-to-use or RTE food products or in the production of pasta.

Multi-grain flour by combining wheat and finger millet in the ratio of 7:3 is one of the simple semi-finished products suitable for making *chapatti* (roti). Kamaraddi and Shanthakumar (2003) incorporated the small millet flours to commercial wheat flour and studied the effect of incorporation of refined millet flours on chemical, rheological and baking characteristics. It was found that substitution of wheat flour with millet flours was possible from 10 to 20% level. Barnyard millet and proso millet can be added 20 and 15% respectively. The optimum level of addition of finger millet, foxtail millet and little millet was 10%. The increase in level of millets in blends increased the ash content and decreased the gluten and sedimentation value; loaf volume of dough; per cent damaged starch and protein whereas crust colour and shape of bread remained unaffected but colour of crumb changed from creamish white to dull brown.

Singh *et al.* (2005) prepared composite flours of foxtail, barnyard and finger millet with wheat flour by adding 10-30% millet flour and observed that addition of milled millet flour to wheat flour increased the concentration of protein, fat and ash but decreased the carbohydrates. Addition of milled barnyard millet flour increased significantly ($p<0.01$) the level of protein, crude fat and total ash contents but whole barnyard flour decreased significantly ($p<0.01$) the level of protein. With the increase in the level of finger millet flour in the blend, protein content decreased from 11.59 to 10.99% whereas fat and ash contents increased from 1.06 to 1.37 and 0.55 to 1.37% respectively with non-significant variation in carbohydrate content.

Singh *et al*. (2012a) formulated two millet–wheat composite flours, CF1 and CF2, based on the rheological and textural properties of dough using response surface methodology. The optimized contents of composite flour CF1 were 61.8% barnyard millet flour, 31.4% wheat flour, and 6.8% gluten and that of CF2 were 9.1% barnyard millet flour, 10.1% finger millet flour, 10.2% proso millet flour, and 70.6% wheat flour. The specific loaf volume of CF1 bread (3.3 cm^3/g) was at par with that of the control (wheat bread; 3.5 cm^3/g) and significantly higher than CF2 (2.9 cm^3/g) at 5% level of significance. Irradiation of pearl millet flour with gamma rays followed by cooking improved significantly ($P \leq 0.05$) the sensory quality of the flour during processing and storage. Radiation process alone had no effect on tannin and phytate contents but when followed by cooking, it significantly ($P \leq 0.05$) reduced the level of anti-nutrients for the whole and dehulled flour (ElShazali *et al*., 2011).

Puffed/Popped and Flaked Millets

Puffing or popping of cereals is an old traditional practice of cooking grains to be used as snack or breakfast cereal either plain or with some spices/salt/sweeteners. Starch is the main carbohydrate in human nutrition and offers a range of desired technological properties. The nutritional quality of starch strongly depends on starch structure and on its processing (Lehmann and Robin, 2007). Puffing or popping process brings about such structural changes in starch or starch-protein matrix of the millet grain or preconditioned pasta that leads to expansion of the grain or pasta pieces and produce a puffed product with high crisp and other textural attributes. The high temperature short time (HTST) treatment exploits the thermo-physical properties of starch and prepares expanded grains or flakes. During this process the Millard reaction takes place in which the sugars present in the aleurone layer react with amino acids of the millet and gives a pleasant and highly desired aroma to the puffed product. In also reduces anti-nutrients like phytates, tannins, etc., increase bio-availability of minerals, give pleasing texture to the product, and enhances protein and carbohydrate digestibility (Nirmala *et al*., 2000). The engineering properties like moisture, porosity, bulk density, kernel size and ingredient like salt or sugar used in popping affect popping volume and ratio. Ushakumari *et al.* (2007) prepared expanded finger millet as ready-to-eat new generation product using HTST. Flattening the grains to desired shape factor and moisture content are the critical factors for maximum expansion ratio. The optimal conditions for expansion are moisture content of about 40%, shape factor 0.52 to 0.58, drying time 136 to 150 min. The expanded millet had expansion ratio of ≥4.6, hardness ≤5.0 N and with overall acceptability of **≥ 7**.2.

The cereal processing technologies can be successfully applied to foxtail millet to prepared RTE or ready to use products in the form of flaked, extruded and roller dried decorticated and popped grains by subjecting native grains (12% mc) to HTST treatment at 230+/- 5 ^{o}C (Ushakumari *et al.*, 2004). The degree of starch gelatinization was the highest in the case of roller-dried millet followed by popped, flaked and extruded products. The microstructure of puffed starch granules becomes spherical (Fujita *et al.*, 1996) and that of popped and extruded product a honey comb like structure. The cooking of finger millet and foxtail millet flour at 80–100 ^{o}C at different levels of water (100–130 ml) and time (1-3 min) to form dough and extrusion through hand extruder and then flaking to a thickness of 0.6 mm, roasting at 90-110 ^{o}C for 5–15 min can be used to prepare expanded flakes (Viswanathan *et al.*, 2009).

Wadikar *et al.* (2007) prepared puffed grains of different varieties of finger millet by conditioning grains for 2 hours with 20% moisture content and puffed the grains using hot sand at a temperature of 220–230 ^{o}C and observed that the changes in fatty acid composition were non-significant. However, in puffing neutral lipids decreased by 9.3% with an increase in glycolipids of 21.92% and phospholipids 33.3%. Popping of conditioned pearl millet using heated sand (250 ^{o}C) resulted with yield and expansion ratio of popped grains ranging from 8.3-77.1% and 2.3-11.3% respectively (Hadimani *et al.*, 1995). Puffing process reduces phytic acid (21-50 %) and tannins (3–18%) (Wadikar *et al.*, 2006) whereas popping significantly increases bio-accessibility of Zn (18 g/100 g) in native millet (Krisnan *et al.*, 2012).

The varietal effect of finger millet on puffing quality shown that brown seeded varieties are more suitable for puffing whereas white seeded varieties yielded organoleptically superior quality puff (Shukla *et al.*,1986b). The brown seeded variety 'PR 202' gave the maximum puffing yield followed by 'JNR 852' with medium expansion. Premavalli *et al.* (2005) studied the effect of hydration and pan roasting pretreatments on the puffing characteristics of ragi (finger millet) variety 'MR1' and found that water and buttermilk hydration influenced puffing yield and bulk density but water conditioning was more economical.

Jaybhyae and Srivastav (2010a; 2010b) prepared a ready-to-eat (RTE) barnyard millet (*Echinochloa frumentacea*) based snack food by forming thin rectangular shaped, steam cooked cold extrudate (cut pieces of dough) samples and puffing them with HTST puffing process. It was observed that proper level of ingredients and moisture content were the critical factors for forming and cutting the dough in desired shape through dolly pasta machine. The samples prepared from barnyard millet, potato mash and tapioca powder dough in the proportion of 60:37:3 were steam cooked and puffed in hot air at optimum temperature (238^o C) and time (39.35 s) to produce puffed product with an expansion ratio of 2.05 having moisture content of 0.09 kg/kg dry matter. After puffing the product was oven toasted at optimum toasting temperature and time combination of 116.26^o C and 20.23 min respectively to obtain toasted snack food with moisture content (0.0464 kg/kg), colour (L-value - 69.79), crispness (18.45 +ve peaks) and hardness (362.64 g). During the process popped/puffed grains/products are dehydrated to the extremely low level of moisture content (3-5%), which helps to enhance the shelf-life. Now days modern air puffing machines have been developed which can be used for mass production of puffed or popped millet grains (Verma and Patel, 2013).

Pasta, Noodles and Other Products

Pasta or papad are made from the flours of cereals or legumes as main ingredient and the dried products are used as RTC. Noodles are the pasta products also known as convenience foods prepared through cold extrusion system which become hard and brittle after drying. The cooking of these noodles is very convenient and requires few minutes. Noodles of different combinations are prepared such as noodles exclusively made of finger millet, finger millet and wheat in the ratio of 1:1 and finger millet blended with wheat and soy flour in the ratio of 5:4:1. Pasta can be prepared with finger millet, refined wheat and soy flour/whey protein concentrate composite flour formulated (50, 40 and 10%) (Devaraju *et al.,* 2006) or proso millet and wheat flour blend with appreciable shelf life (Sudhadevi *et al*., 2013). Pasta was extracted in dolly pasta machine.

Noodles are one of the most preferred food items among all age groups having longer shelf life and good commercial importance. Barnyard millet has relatively low carbohydrate content (58.56%) having slow digestibility of 25.88% (Veena, 2003). This health benefit of millet was exploited by preparing value added low glycaemic index noodles from barnyard millet flour by incorporating sago flour, pulse flour and bengal gram leaf powder at different levels to develop plain, pulse and vegetable noodles respectively (Surekha *et al.,* 2013). The findings indicated significant increase in nutrient composition in pulse and vegetable noodles. The glycaemic index of pulse noodles (35.65) and vegetable noodles (38.02) were significantly less than plain noodles (42.07).

Punia *et al.* (2003) prepared *ladoo (*sweet balls*)* and *shankarpara* (from dough and formed into flakes*)* from *kanagini* or foxtail millet (*Setaria italica*) by substituting *maida* with 50% *kangini* flour and observed that *kangini ladoo* had protein 13.13%, ash 4.92% and iron and zinc13.83 and 2.35 mg/100 g respectively. It was also found that both the products prepared were acceptable and appearance, texture, and taste of the product were in the category of 'liked very much'. Srivastava *et al.* (2003) prepared popped grains from barnyard, foxtail and little millet using common salt as heating medium in an open iron pan containing sample and salt in the ratio 1:20 at 240-260 ^{o}C for 15-25 s. Two types of *ladoos* (sweet balls of 5 cm dia) first one using individual popped millet grains and *jaggery* and second type by using millets, roasted groundnut and coconut powder were prepared. The sensory scores on nine point hedonic scales for first and second type *ladoo* were 5.0-6.9 and 7.2-8.1 respectively. Products based on foxtail millet had higher values of protein and calcium than those based on barnyard millet. Incorporation of groundnut and coconut in the formulation increased the contents twice in protein (7.27-8.39 g/100 g), energy, calcium and iron compared to those containing only millets and *jaggery (*made from sugarcane juice*)* in the first type of *ladoo.*

Geervani and Eggum (1989a) prepared fortified minor millets by supplementing with lysine to overcome deficiency of amino acid on heat treatment. The italian, french, barnyard, kodo and little millet grains were autoclaved and then supplemented with lysine at 0.6 g/100 g dry matter and observed an increase of both biological value (BV) and net protein utilization (NPU). The beneficial effect of supplementation was demonstrated by Eggum *et al.* (1985) who reported an average increase of 0.016 in true digestibility (TD), 0.154 in BV and >144 in NPU values with the provision of methionine to diets based on casein, skim milk powder, meat and brown beans. In a rat bioassay Ifon (1980) observed much improvement in the nutritive value of millet porridge after fortification with soy proteins as reflected in the significant increases in PER (protein efficiency ratio), NPR, NPU and BV.

Jowar crunch, a snack food with a light crunchy texture, prepared by deep-fat frying of dried kernels (pellets) of alkaline-cooked whole sorghum was developed by Suhendro *et al.* (1998). The optimized process for sorghum were autoclaving for 60 min at 120^o C, rinsing, drying to 9% moisture content (room temperature and then 50^o C) and deep fat frying at 220^o C.

Baked Products

Bakery products are popular all over the world and the production has risen by many folds due to their low cost, varied taste and textured profiles with attractive package and longer shelf-life to suit easy marketing (Patel and Rao, 1996). The use of millets in bakery products will not only be 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 (Verma and Patel, 2013). These are mostly prepared from the wheat flour but efforts are being made to replace few portion of it with millets in order to provide an alternative and reduce over dependence on wheat and make gluten free bread. Finger millet and foxtail millet flour can be incorporated in bakery items like biscuits, *nan-khatai*, chocolate, cheese, cakes, muffins, etc. Research findings have revealed that substitution of 40% wheat flour with finger millet flour in baked products like cake and biscuits is possible (Begum *et al.*, 2003; Yenagi *et al*., 2013). The chocolate cup cake, gel cake, masala cake, carrot cake, soup sticks, *rusk* and muffins prepared with finger millet have good appearance, texture, flavour and overall acceptability scores. Attempts have been made to improve the nutritional quality of cakes with respect to the minerals and fibre content by supplementing with malted finger millet flour (Desai *et al*., 2010).

Sehgal and Kawatra (2007) prepared sweet, salty and cheese biscuits using pearl millet flour (40-80%), refined wheat flour (10-50%) and green gram flour (10%) and found highly acceptable with non-significant difference. Biscuits prepared from maida-finger millet flour blend (80:20) can have self life period of 120 days at 65% RH at 27^{o} C when packed in double pack of polypropylene/pearlised BOPP and metalised polyester/polylaminate packs (Selvaraj *et al.*, 2002). More nutritious sweet and salty biscuits prepared from refined wheat flour, blanched pearl millet and green gram in the ratio of 50:40:10 (Type I) and 30:60:10 (Type II) than those with refined wheat flour alone but with higher anti-nutrient (polyphenol and phytic acid) content in Type II biscuits (Sehgal and Kwatra, 2007). Saha *et al.* (2010) prepared biscuits from flour composites containing 60:40 and 70:30 (w/w) finger millet : wheat flour and found that hardness of biscuit dough was more in 60:40 combination than in 70:30 level. The adhesiveness and resistance of biscuit dough increased with the increasing levels of wheat flour but expansion of biscuit and breaking strength after baking was more in 70:30 composite than in 60:40. Wheat composite flour (40 g/100 g) had higher water absorption capacity than in 30 g/100 g composite.

Krishnan *et al.* (2011) tried to explore the possibility of using seed coat matter (SCM) of finger millet in preparation of biscuits using the composite flour with comparable crisp texture, breaking strength (1480–1690 g), higher protein, dietary fibre and calcium contents compared to control biscuits (1560 g). The sensory evaluation of the biscuits indicated that 10% of SCM from native and hydrothermally processed millet and 20% from malted millet could be used in composite biscuit flour.

Production of wheat-free sorghum or millet bread still remains the challenge (Taylor *et al.*, 2006). Some researcher also tried production of cookies from 100% sorghum or pearl millet. Such cookies could be produced, but were tough, hard, gritty, and mealy in texture and taste. These products also lacked spread and top surface cracks, both traits being regarded as desirable. The lipid composition may be partly responsible for this inferior quality.

Extruded Products

A majority of world population suffers from qualitative and quantitative insufficiency of dietary protein and calories intake. In all such cases physiological maintenance and growth are impaired, and malnutrition results. In this context extrusion is a beneficial process. Extrusion cooking is a HTST cooking process, which could be used for processing of starchy as well as proteinaceous materials. The use of extrusion cooking has distinct advantages like versatility, high productivity, high product quality, increase in in-vitro protein digestibility (Dahlin and Lorenz, 1992) and production of new food without effluents. Extrusion Cooking is accomplished through the application of heat either directly by steam injection or indirectly through jacket or by dissipation of mechanical energy through shearing occurring within the blend.

Onyango *et al.* (2005) used lactic and citric acids as alternatives to backslop fermentation in the manufacture of extruded *uji* (a thin porridge of maize-finger millet from eastern Africa). Acidity of the blends was reduced by fermentation or progressively lowered with 0.1, 0.5, and 1.0 mol/l lactic or citric acids before extrusion. The extrusion solubilizes starch without formation of maltodextrins. In vitro starch digestibility increased from 20 mg maltose/g in the raw blend to about 200 mg/g after extrusion. Fermentation of lactic/citric acid treated blends before extrusion increased in-vitro protein digestibility and the nitrogen solubility index (by 20%). The tannin content decreased from 1677 mg/100 g in the raw blend to between 551 and 1093 mg/100 g in the extrudates whereas phytate content remained unaffected by extrusion (248-286 mg/100 g). Extrusion process increases the iron availability of the extruded weaning foods based on pearl millet, cowpea and peanut or milk powder by 3.5 to 6.5 times higher than the corresponding roasted weaning foods (Cisse *et al.*, 1998).

Millet based extruded snack foods are prepared using twin-screw extruder from kodo millet-chickpea flour blend (70:30) (Geetha *et al*., 2012); pearl millet, finger millet and soybean flour blend (Balasubramanian *et al*., 2012) or ragi, sorghum, soy and rice (42.03,14.95,12.97 and 30%) flour blend (Seth and Rajamanickam, 2012) with desired quality. Expansion index (2.31) and sectional expansion index (5.39) was found to be maximum for feed rate and screw speed combination of 9.5 kg/h and 250 rpm for pearl millet (81.68%), finger millet (7.02%) and decorticated soy bean (11.29%) composite flour. The barrel temperature significantly affects all the product attributes like expansion ratio, bulk density, hardness and crispiness significantly. Kodo-chickpea flour blend gives desirable crispy extrudates at higher screw speed of 280 rpm, lower feeder speed 20 rpm, and medium to high temperature of 123 °C. About 15% moisture content of the millet-pulse or millet-soy feed at 10 to 15% blend ratio appears to be acceptable level (Singh *et al.,* 2008). Microwave cold extrudated puffed barnyard millet based ready to eat fasting foods with comparable sensory quality was developed by Dhumal *et al.* (2014).

Pelembe *et al.* (2002) developed a protein rich composite Sorghum-Cowpea porridge by extrusion cooking at 130^0 C and water content of 200 g/kg and was similar to commercial instant maize–soy porridge in terms of functional properties. Increase in cowpea resulted in increase in protein content, water absorption index (WAI) and decrease in Expansion ratio (ER). Sumathi *et al.* (2007) blended pearl millet with grain legumes (30%) and also with defatted soy (15%) separately and prepared nutritious extruded ready-to-eat food. The foods based on millet and the millet-soy blend contained 14.5% and 16% protein with 2.0 and 2.1 protein efficiency ratio values, respectively. Devi and Narayanasamy (2013) explored the possibility of preparation of composite millets milk powder with the combination of finger millet and pearl millet to prepare RTC extruded product from composite of millet powder and maida (50:50) within the acceptable range in terms of nutrient content, color, texture and cooking quality and sensory characteristics.

Fermented Products

Fermented foods like Dosa and Idli are popular and common breakfast foods and even as the evening meals in many parts of India. Millets are good source of protein but the protein quality in terms of lysine and tryptophan content is low, hence there is growing emphasis on the improvement of protein quality. Fermentation not only improves the taste but at the same time enriches the food value in terms of protein, calcium and fibre, B vitamins, in vitro protein digestibility and decreases the levels of anti-nutrients in food grain (Chavan and Kadam, 1989; Maha *et al.*, 2003; Verma and Patel, 2013). Fermentation of the ground germinated pearl millet grains gives higher protein digestibility (>90%). Khetarpaul (2003) fermented the pearl millet by inoculating the micro flora namely, *S. diastaticus, S. cerevisiae, L. brevis and L. fermentation* and incubated at 30^o C for 72 h in single culture, mixed culture and sequential culture fermentation. The samples were oven dried and ground to fine flour and found that controlled pure culture fermentation did not change the protein and ash content of pearl millet (sprouted and flour) and increased the starch digestibility of flour significantly. High dietary calcium and phytic acid reduces bio-availability of zinc by Zn-Ca-phytate or Zn-phytate complex. Fermentation is one of the most economic and effective measure for reducing polyphenols and phytic acid significantly and improves HCL-extractability of zinc (Sripriya *et al.,* 1996b; Murali and Kapoor, 2003), iron, copper, calcium and manganese but maximum reduction is brought out by sequential fermentation. Dry heating and acid treatment of pearl millet also increases the mineral availability significantly (Arora *et al.*, 2003). Germination and probiotic fermentation causes significant improvement in the contents of thiamine, niacin, total lysine, protein fractions, sugars, soluble dietary fibre and in vitro availability of Ca, Fe and Zn of food blends (Arora *et al.*, 20011).

Fermentation of finger millet flour using endogenous grain microflora showed a significant reduction in phytates by 20%, tannins by 52% and trypsin inhibitor activity by 32% at the end of 24 h resulting in increase in percent mineral availability of calcium (20%), phosphorous (26%), iron (27%) and zinc (26%) (Antony and Chandra, 1998). The various recipes were prepared including cutlets, weaning mixtures, vermicelli and biscuits from naturally and mixed fermented pearl millet flour and were highly acceptable. The findings indicated that pure culture fermented products can be safely included in the diet of the people for improving starch digestibility, increase bioavailability of minerals and proteins. The availability of zinc during pure culture fermentation was found to be more effective than natural fermentation. A highly significant ($p\leq0.05$) improvement in the in vitro protein digestibility of pearl millet genotypes can be achieved if fermented for 14 h (Maha *et al.,* 2003).

Onyango *et al.* (2004) prepared high energy density fermented *uji* from different combinations of maize, finger millet, sorghum and cassava using alpha-amylase and extrusion. It was observed that fermentation alone was not able to reduce viscosity of *uji* but addition of 0.1-2.1 ml/100 ml alpha-amylase to the fermented slurry or extrusion of the fermented and dried flour at 150-180^o C and a screw speed of 200 rpm reduced viscosity of *uji* from 6000-7000 to 1000-2000 cp with acceptable energy densities (0.6-0.8 kcal/g) for child feeding.

Malting and Weaning Foods

Traditionally, the millet malt is utilized for infant feeding purpose. Finger millet possesses good malting characteristics and its malting is popular in Karnataka and part of Tamil Nadu. Malting helps to increase significantly the nutrient composition, fibre, crude fat, vitamins B, C and their availability, minerals (Sangita and Srivastav, 2000), improve the bioavailability of nutrients, sensory attributes of the grains. Millet malt is used as a cereal base for low dietary bulk and calorie dense weaning foods, supplementary foods, health foods and also amylase rich foods. Malting reduce paste viscosity of flour than many other heat treatments (Malleshi and Desikachar, 1981). The millets, like sorghum, have high-starch gelatinization temperatures, pearl millet (*Pennisetum glaucum(*L.*)* 61-68 ^{o}C and finger millet (ragi) 65-69 ^{o}C (Serna-Salsivar and Rooney, 1995). Hence, they are subjected to same constraints in terms of conservation of enzyme activity during brewing. Brewing process for millets has not been extensively investigated. Like sorghum, arabinoxylans seem to be the major cell wall component of pearl millet and finger millet (Subba Rao and Muralikrisna, 2004). As with sorghum, the arabinoxylans of pearl millet are also substituted with uronic acids. However, uronic acid was not reported in analysis of finger millet non-starch polysaccharides (Subba Rao and Muralikrisna, 2001). The optimum malting conditions for pearl millet seem to be essentially same for sorghum. In malting germination is an important unit operation which needs greater attention. The germination temperature normally suggested is greater than 22 ^{o}C. Pelembe *et al*. (2002) found 25-30^o C to be optimal with a germination period of 3-5 days. Malting finger millet reduces tannin (brown millet) and phytic acid content, and improves ionisable iron and soluble zinc significantly but malting, steaming and roasting of little millet increase the nutraceutical and antioxidant properties in terms of total phenolic, flavonoid and tannin contents (Pradeep and Guha, 2011). The amylase activity of malt flour from brown finger millet seed was higher than white seed varieties (Shukla *et al.*, 1986a). Malting of pearl millet and finger millet reduces protein content, but improves protein efficiency ratio (PER), bioavailability of all minerals and has pronounced effect in lowering anti-nutrients (Desai *et al*. 2010; Krishnan *et al*., 2012).

Asma *et al*. (2006) prepared weaning blends composed of 42% sorghum supplemented with 20% legumes, 10% oil seeds, and 28% additives (sugar, oil, skim milk powder, and vanillin) as per FAO/WHO/UNU recommendations and processed in a twin-roller drum dryer. The blends were found to contain good proportion of protein 16.6% to 19.3%, fair fiber content of 0.9% to 1.3%, satisfactory energy level 405.8 to 413.2 kcal per 100 g and a healthy iron content of 5.3 to 9.1 mg/100 g. The calcium content ranged from 150 to 220 mg/100 g and lysine content improved considerably ($p <$ or $= 0.05$) for all blends. The paste of this blend was comparable to commercial weaning foods in terms of water-holding capacity, wettability and bulk density.

Malleshi and Klopfenstein (1998) tried to use seed germination as a tool to improve the nutrient potential of millets. The malted flour was prepared from germinated, dried and milled fractions of sorghum, pearl millet and finger millet. Moist-conditioning the malt and milling the same in roller mill are reported to be promising in preparation of low fibre malt flour. The amino acid profile of low fiber malt flour from sorghum as well as millets was comparable to barley malt flour. Thus the essential amino acid pattern of finger millet malt flour is superior and bran fraction is a rich source of proteins and minerals and may be useful in high fibre health foods and feed formulations. The yields of refined malt flour from sorghum, pearl and finger millet were 86, 85 and 78% respectively and their protein and crude fiber contents were 10.4, 15.5, 4.5% and 1.2, 1.0, 1.8% respectively. The lysine content of finger millet (3.4%) malt flour protein was higher than pearl millet (2.16%) and sorghum (1.45%) malt flour protein. Nirmala *et al*. (2000) found that Indaf-15 variety of finger millet develops high levels of amylases during germination, and its malt form is a rich source of reducing sugar which increased from 1.44 to 8.36% at 96 h of germination period. Adewale *et al*. (2006) extracted starch-digesting enzymes from malted maize, finger millet and sorghum and found that the α-amylases extracted were heat sensitive but the sorghum amylases were slightly more resistant proving more suitable for commercial malt production. In case of malted weaning food (MWF) prepared by mixing refined malted ragi with malted green gram flour in the ratio of 70:30, there was significant increase in amylase activity and decrease in paste viscosity with progressive germination (Malleshi and Desikachar, 1981). Hot paste viscosity of MWF was much lower than that of several proprietary brands of weaning foods. There was lower cooked (hot) paste viscosity and high cold paste viscosity of the extruded precooked RTE weaning food from sorghum, pearl millet, finger millet flour (60%) blended with roasted mung bean flour (30%) and nonfat dry milk (10%) (Malleshi *et al.,* 1996). The soluble dietary fiber content of foods was 10% higher than that of the corresponding blends with increase in the in-vitro protein digestibility but no marked difference in carbohydrate digestibility. The NPR, PER and BV were higher for the finger millet flour than for pearl millet food. Similar effort was made by Thathola and Srivastava (2002) to prepare weaning food based on malted flours of foxtail (30%), Barnyard (30%), roasted soybean (25%) and skim milk powder (15%). There was no significant difference in sensory quality of un-weaned mix and marketed weaning mix and well acceptable.

Health and Functional Foods

Small millets are important coarse grains and rich in nutrients. The term functional foods has been commonly used for foods that promote health through prevention of specific degenerative diseases like diabetes, cancer, Parkinson's disease, cataract etc. due to the effect of health-promoting and bioactive phytochemicals in plant foods. The term nutraceuticals (like pharmaceuticals) is used for such bioactive compounds like vitamins, minerals, essential fatty acids having protective effect against degenerative diseases, in isolated form. Epidemiological studies reflect that persons on millet based diet suffer less from degenerative diseases such as heart diseases, diabetics, hypertension, etc. Millets have received attention for their potential role as functional foods due to health-promotive phytochemicals. Millets are safe for people suffering from gluten allergy and celiac disease. They are non-acid forming and non-allergenic hence easy to digest (Saleh *et al*., 2013).

Finger millet, foxtail millet, pearl millet and sorghum are the potential sources of antioxidant compounds which can quench the free radicals (Sripriya *et al*., 1996a). The total phenolics and tannin content of pigmented type of finger millet; moderate reducing ability and high free radical scavenging activity of pearl millet serve as a source of antioxidants in our diets (Muthulisi *et al.,* 2007; Odusola *et al*., 2013). The presence of flavonoids, like tricin, acacetin, 3, 4 Di-OMe luteolin, and 4-OMe tricin in traditional recipes, indicate the chemo-preventive efficacy of pearl millet (Nambiar *et al*., 2012). They may be inversely related to mortality from coronary heart disease and to the incidence of heart attacks in the pearl millet consuming belts of the world similar to lower incidence of diabetes reported in millet consuming populations (Saleh *et al*., 2013). The diabetes preventing effect of millets is primarily attributed to high fibre content. Some antioxidant phenols in millets also tend to have anti-diabetic effect. Among minor millets, fox tail and barnyard millet have low glycaemic index (40-50). University of Agriculture Sciences, Dharwad (and others) have prepared ready to eat foods from these minor millets and demonstrated their anti-diabetic effects. Biscuits prepared by substituting 50% of refined wheat flour with barnyard millet flour had lower glycemic index, GI (50.17) compared to the GI of wheat biscuits (73.58) without much difference in the nutrient composition (Srivastava and Singh, 2003). The *burfi* was prepared by substituting Bengal gram flour with foxtail millet flour upto 57% and a control. It was found that both types of *burfi* had similar sensory score (8.2) but millet *burfi* had less GI (51) than control (68). It was also observed that there was significant reduction in serum glucose and serum cholesterol due to foxtail millet biscuits and *burfi*. Shobana *et al.* (2007) prepared diabetic food formulations based on finger millet, popped and expanded rice each blended separately with legumes, non-fat dry milk, oil, spices and a few hypoglycemic ingredients and found that millet based food (93.4+/-7) produces less glycemic index (GI) values than rice based formulation (109+/-8). Finger millet vermicelli prepared from mixed blend of finger millet flour (45%) with wheat flour (40-45%), defatted soy flour (10%) and hypoglycemic ingredient *amruth balli* (5%) recorded lowest cooking loss and ashwagandha showed higher sensory score for different storage periods (Mamatha *et al.,* 2003). Millets being high in fibre and antioxidant have beneficial effect on serum lipid profile besides blood sugar.

Thakkar and Kapoor (2007) found *roti, upma* and *idli* (Indian breakfast recipes) prepared from gum acacia and finger millet showed lowest glycemic index (41–48%). Similarly Arora *et al.* (2003) found that finger and barnyard millet preparations with legumes and fenugreek seeds (Sharma and Raghuram, 1990) reduce the GI with non-significant difference between them. The hypoglycemic effect of millet based diets has been observed by Gopalan (1981) and Kamath and Belavady (1980). The native starch (NS) extracted from rice and minor millets when subjected to five autoclaving and cooling (4 °C) cycles contain higher resistant starch (RS) than NS. Rats fed with NS and RS from barnyard millet had the lowest blood glucose, serum cholesterol and triglycerides than rice and other minor millets (Kumari and Thayumanavan, 1997). However, new slowly digestible carbohydrates (SDC) such as Isomaltulose/Palatinose, which claim a slow and sustained blood glucose level after intake, have been commercialized. But no such commercial product made of entirely millet is reported.

Traditional Foods and Beverages

Addition of finger millet as one of basic ingredient to the tune of 15-20% (w/w) along with other essential ingredients such as black or green gram, rice and spices has become a tradition in millet growing areas of South India (Verma and Patel, 2013). Addition of finger millet up to 60% in papad is possible and practiced in some parts of Karnataka (Begum, 2007). Vidyavati *et al.* (2004) prepared millet *papad* (rolled, circular and thin sheets) by substituting 50% of mixture of black gram dhal flour and sago flour with finger millet flour and compared with black gram (*Phaseolus mungo*) dhal *papad*. The finger millet flour *papad* had higher sensory score of 4.7 on a five point hedonic scale and were rich in Ca (102 mg% in roasted and 109 mg% in fried) compared to black gram dhal *papad* (82 mg% in roasted and 99.6 mg% in fried). There was a slight reduction in nutrient composition but the protein quality improved due to supplementary effect of millet and pulse proteins. Consumer acceptability of finger millet *Papad* was very good after long storage and hence finger millet can be good substitute in traditional *papad*. Similar effort was made by Naikare *et al.* (2003b) to prepare *papad* from malted sorghum and finger millet flour as well as from composite flours in different proportions of 80:20, 60:40, 40:60. The finger millet *papad* scored the highest rank with acceptability score of 4.6 on five point hedonic scale with highest crisp, palatable taste and excellent in appearance.

Sorghum and minor millets are poor source of protein which can be fortified by incorporating pulses or cereals. Badi *et al.* (1990) tried to improve quality of *Kisra*, a staple food of Sudan, by addition of chickpea and peanuts. This type of *kisra* can be used as a well-balanced sorghum and millet based baby food for infants above the age of one year. This formulation and way of processing is well suited for commercial production of sorghum/millet based baby food. Brown bread for infants should not exceed ten percent wheat or sorghum bran as it affects the digestibility in a negative way.

Millet and sorghum flours are essentially composed by starch. In fact, starch granule has a very complex structure, built around change in the composition and structure of the components (Tester *et al.,* 2004). Hydrothermal treatments (soaking up to moisture $30 \pm 2\%$, steaming $1.05\ \mathrm{kg\ cm^{-2}}$, 20 min) reduce anti-nutritional factors ($p \leq 0.05$) and inactivate lipase activity significantly (Balasubramanian, 2014). Ndiaye (2008) attempted to reduce the cooking time of rolled flour products Arraw using germinated millet and sorghum flours separately from 37 min without any treatment to 9 min. Malt prepared after grain germination of 3–4 days and dried at 50 °C and then ground to make flour. Rolled flour products Arraw were made by adding 5 and 10% shelled germinated flour.

Millets porridge is a traditional food in Russian, German and Chinese cuisines. In Southern Karnataka, both the rural and urban population consumes *Mudde,* a thick porridge of finger millet. Kodo millet is an important food crop for vast sections of the tribal community in Central India. The people in Himalayan foothills use millet as a cereal, in soups, and for making dense, whole grain bread called *Chapatti*. In Maharashtra state flat thin cakes called *Roti* are often made from sorghum/millet flour and used as the basis for meals. It is possible to incorporate 50–75% barnyard millet flour in preparation of *rotis*, *idlies*, *dosa*, *chakli* (Veena *et al*., 2004); *idli*, *pakora*, *vedai*, *adai* and sweet *halwa, kolukattai* from finger millet; *Navane sampali*, *huggi*, *burfi* or *kabab* from foxtail millet; and *Samai dosa*, *porridge*, *paddu* and *paysam* from little millet as traditional recipes in different millet growing states in India.

'Kodo ko jaanr' is the most common fermented alcoholic beverage prepared from dry seeds of finger millet in the Eastern Himalayan regions of the Darjeeling hills and Sikkim in India. *Chhang* is also a fermented finger millet beverage popular in Ladakh region in India. *Koozh* is another fermented beverage made with pearl or finger millet flour and rice, and consumed by ethnic communities in Tamil Nadu (Ilango and Antony, 2014). The traditional, naturally fermented finger millet product is called *Ambali*. Finger millet is the cereal of choice for the preparation of porridges for children and for the sick and old in India. Millet malt is also used to prepare beverages either with milk of lukewarm water with the addition of sugar since pretty old times. *Mahewu* is a non-alcoholic beverage prepared in Zimbabwe from finger millet (1/3) and sorghum (2/3) malt by traditional fermentation (Gadaga *et al*., 1999). Some liquid foods with different local names prepared from millets are consumed in India. Ragi soup is also famous and prepared by mixing the ragi flour into water (one part ragi flour and 2.5 parts water). Vijayakumari *et al.* (2003) made a scientific effort to develop finger millet based ethnic common recipes. Two types of beverages namely *Ambli* and *malt* were prepared and found a good score for appearance, texture and flavour with overall acceptability scores from 4.0-4.5 in sensory evaluation. There was a non-significant difference between the control and experimental products in all the parameters of sensory attributes. Modern products incorporating finger millet like *ragi* health drink (baby vita) are now available in the market. Extrusion of malted pearl millet grains can be used to prepare instant beverage powder from pearl millet and it reduces the peak viscosity of the starches significantly

($p \leq 0.05$) (Obilana *et al.*, 2014). Similarly Naikare *et al.* (2003a) reported that sweet sorghum millet cultivars are most suitable for preparation of syrup, *jaggery* and *khandsari*. It was also reported that SSV-84 variety produced good quality *jaggery* (3.5-4.0 tonnes per hectare) containing non-reducing sugars 65.4% and reducing sugars 12.5%.

Conclusions

Advances in post-harvest processing and value addition technologies have made it possible to process and prepare value added products acceptable to both rural and urban consumers. Millets and sorghum have huge potential for wider use. With finger millet this potential is much harnessed. The other millets particularly minor millets remain un-researched and their potential untapped in diversified ways. Processing and utilization of millets in product development have promising prospects with regard to nutrition, quality and health benefits and can be an alternative to cereals but its full scope and utilization is yet to be established. More studies using state of art techniques and different methods of cooking are needed to examine the bioavailability of micronutrients including minerals and B-vitamins to assess their nutritional advantage *in vivo*. Although some of the studies mentioned above did address the processes and health benefits of minor millets, it appears that information on scientific reasoning, beneficial characteristics and development of health foods needs further research for large scale use of these millets.

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