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Review on finger millet: Processing and value addition

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Abstract
Finger millet (*Eleusine coracana*) is one of the rich sources of nutrients compared to other minor cultivated cereal crops. It contains dietary fiber (18%), calcium (344 mg/100g), tannins (0.04-3.47%), phytate (0.48%), oxalate (0.27%), cyanide (0.17%), saponins (0.36%), phenolics (0.3–3%) and polyphenols. It is also a rich source of amino acids (isoleucine, phenylalanine, leucine and methionine), minerals (calcium, phosphorous and iron) and vitamin including B (1.71 mg) and E (22 mg). Due to its high dietary nutritional content, it can provides numerous health as well as and medicinal benefits such as the anticipation of diabetes (Type 2 diabetes mellitus), anti-inflammatory, anti-tumerogenic (K562 chronic myeloid leukemia), antiulcer, atherosclerogenic effects, antimicrobial, anti-diarrheal and antioxidant capacity. Finger millet is crop reasonably sustainable for poor segment of the world's population. However, existence of anti-nutrients (Tannins, phytat & polyphenols) could reduce the accessibility of nutrients which restrict the application of finger millet in food preparations. Anti-nutritional factors can be reduced to permissible limits with the application of certain pre-treatments like roasting, soaking, boiling, parboiling, fermentation, milling, germination, decortications, and extrusion cooking. Pretreatments improves millet quality which could be beneficial in formulation of various value added food product such as pasta, vermicilli, noodles, papads, soups, Indian sweets (*Halwa*) and bakery items. Therefore, this review focuses on health benefits, value addition through processing technologies and its impact on properties of finger millet.

Keywords: finger millet, bioavailability, processing, fermentation, value addition

Introduction

Mandua and ragi are the common names of Finger Millet (*Eleusine coracana* L.) in India. It is cultivated broadly in major parts of India and Africa (Chandra *et al.*, 2016) [7]. Finger millet is a subtropical and tropical grain which can withstand in drought and high temperature environment which inferences its sustainability to be grown-up in those areas where maize, rice, wheat and other cereals are difficult to grow. Finger millet is used as poor man's crop due to its elongated sustainable strength as it could be kept securely for a number of years devoid of any insect and pests infestation (Purseglove, 1972) [61]. Several cultivars have been recognized. In Africa and India, two groups are familiar: Afro-Asiatic forms with full-grown grains visible outside the florets; and African highland types with grains enclosed inside the florets. Finger millet is native to the Ethiopian highlands and commonly cultivated in more than 25 countries; - Uganda, Nepal, India, Sri Lanka, Bangladesh, East China, Tanzania & Kenya etc. It is understood that Uganda or nearby areas are the primary centre of foundation of *E. coracana*, and it was brought into India probably over 3,000 years before. Karnataka leads the market of finger millet production in India accounting 58% global sharing, but only limited sections of population are aware about its nutritional and health importance (Chandra *et al.*, 2016) [7]. While concerning the production area in India, finger millet secures sixth rank after wheat, maize, sorghum, rice and bajra. It is world's fourth important millets after pearl millet, sorghum and foxtail millet (Devi *et al.*, 2014) [12]. Grains of finger millet are tiny deep red with seed smaller than that of pearl millet and the mean value of 1000 finger millet seed grain weight is approximate to 2.6 g. It has naked caryopsis with seed coat of brick red-colour and is mostly consumed in whole meal form during making of traditional products viz., roti (Unleavened breads or pancake), ambali (Thin porridge) and mudde (Dumpling). There are massive possibilities of processing the millets into value-added foods and beverages in developing nations. Moreover, gluten free millets grains are also suitable for the patients suffering from gluten intolerance. It is an essential cereal crop because of its incredible nutritive value, which is superior to rice and identical to the wheat (Van Wyk and Gericke, 2000) [85].

Nutritional importance and health benefits

The kernel of finger millet mainly consists of seed coat (testa), embryo and endosperm. It has five layer of seed coat which is high in antioxidant and dietary fiber. Finger millet contains carbohydrate 81.5%, dietary fiber 18% to 20%, starch 65% to 75%, protein 9.8%, fat 1% to 1.7%, minerals 2.7% and crude fiber 4.3% that is equivalent to other millets and cereals (Saleh *et al.,* 2013). Its mineral content & crude fiber are specifically higher than that of rice (minerals 0.6%, fiber 0.2%) and wheat (minerals 1.5%, fiber 1.2%); its protein content is reasonably well balanced; additionally it also contains lysine, valine and threonine than other millets (Ravindran, 1991; Sripriya *et al.,* 1997) [66, 77]. The black finger millet contains 8.47 g/g dry weight protein and 8.71 mg/g dry weight fatty acid (Glew *et al.,* 2008) [23]. Apart from containing proximate compositions finger millet is a rich source of calcium (344mg/100g), Phosphorous (283 mg), Iron (3.9 mg), Vitamin B (1.71mg), Vitamin E (22 mg) and other micronutrients. Due to rich in dietary nutritional profile it has numerous therapeutic effects. Finger millet seed coat portion hinder the intestinal pancreatic amylase and α-glucosidase which leads to control postprandial hyperglycemia. Therefore, regular intake of finger millet as a staple food and whole meal based product will help in administrating unusual disorders of our body by regulating the proper blood glucose level. Wound healing is impaired in diabetic patients due to damage in nerve growth factor and various research work have shown that finger millet extracts outcomes in ameliorating this impairment via improving the nerve growth factor production and antioxidant level (Chandra *et al.*, 2016) [7]. It contains tryptophan which controls our appetite, hence keeps weight under control (Kakade and Hathan, 2015) [78]. Ragi possesses high calcium and iron which strengthens body bones and prevent from anemic disorders respectively.

Anti-nutrient content

Despite of having numerous nutritional profiles, it contains certain anti-nutritional factors such as tannins (0.04-3.47%), phytate (0.48%), oxalate (0.27%), cyanide (0.17%), saponins (0.36%) and polyphenols. Occurrence of these anti-nutrients causes chelation of dietary minerals into the gastrointestinal tract, thereby these micronutrients losses its bioavailability for healthy diet (Harris and Burns, 1978). Moreover to get better shelf life of finger millet flour along with processed foodstuffs reduction of anti-nutritional features is essential. The amount of anti-nutritional factors can be reduced to permissible limits with the application of certain pre-treatments like roasting, soaking, boiling, parboiling, fermentation, milling, germination, decortications, and extrusion cooking. With the help of various processing techniques, this underutilized crop can be transformed into the variety of commercial and traditional value added products. Tannin content (0.04 to 3.47%) of finger millet is higher than that in any other millet (Kakade and Hathan, 2015) [78]. Tannin content finger millet varies among different varieties such as brown and a dark brown variety of finger millet contains 0.61 per cent of tannin while white variety of finger millet contains 0.05% tannin (Kumar *et al.,* 2016) [26]. Excess amount of tannin leads to reduce the iron intake in diet which ultimately lowers down the nutritional profile of the grains (Rao and Deosthale, 1988) [65]. Tannin content decreases protein digestibility, feed intake, growth rate and net metabolizable energy in experimental animals (Kumar *et al.,* 2016) [26]. High tannin in diet leads to sound effects on microbial enzyme activities even intestinal digestion and cellulose may be depressed. Tannin is also known as antioxidants. Tannins protect our body against cells damage through neutralizing chemicals. Tannins have antimicrobial, anti-cancer property and positive effect on cardiovascular system. Finger millet contains 0.48% of phytate, it is a naturally occurring phosphorus compound, interferes with zinc and calcium absorption and makes them unavailable for absorption in intestines (Doherty *et al.,* 1982) [14]. Phytate has a strong binding property and it also forms complexes with protein molecules and multivalent cations. Saponins (0.36%) are also present in finger millet having hemolytic activity. It affects the digestive system and the central nervous system. It also causes cardiovascular disease (CVD). Saponin causes a decrease in protein digestibility and absorption. Saponins may reduce occurrence of cancer and can help in lowering cholesterol & post-meal blood glucose responses (Kumar *et al.,* 2016) [26]. Finger millet contains 0.27% of oxalate anti-nutritional factor. It affects the calcium and magnesium metabolism (Oke, 1969) [60] and form complexes with protein inhibiting peptic digestion (Kakade and Hathan, 2015) [78] and prevents their absorption in human body. It can also cause kidney stones. Healthy people can consume oxalate-rich foods without facing any problems, but people suffering with altered gut function need to limit their intake (Kumar *et al.,* 2016) [26]. The permissible limit of oxalate for human diet is less than 50mg per day is applicable

Processing technologies

Processing methods

Processing is normally employed for enhancement of food grains quality through transforming them into edible form and reducing the antinutrients present in them. Consumption of millets can be improved via their processing into several forms such as rice flour, roasted, sprouting, popped, porridges, salted ready-to-eat grains and fermented foods.

Soaking and cooking

Soaking is the widely used technique in order to reduce anti-nutrients in food. Soaking of ragi for 1-2 days at room temperature (25˚C) in water (1:10; ragi: water) reduces polyphenols, phytate, saponins, oxalates and trypsin inhibitors (Hotz and Gibson, 2007) [34] which ultimately improve bioavailability and bio accessibility of minerals and also the nutrition quality. It has reported that ragi soaked in NaOH solution or distilled H_2O for 8 hours, which significantly reduces tannin content. It also reduces phytic acid content ranges from 39.47 to 24.17%. As like soaking, cooking upon boiling water or steam also inactivate heat labile antinutrients in ragi (Kakade and Hathan, 2015) [78]. Udayasekhara and Deosthale (1988) [65] has reported 30% reduction of tannin content in food legumes by Lestienne *et al.* (2005) [46] has conducted an experimental study on dehulled seeds, whole seeds & flour of millets which facilitates reduction of phytase activity, zinc, iron and phytates concentration in aqueous medium. Hithamani and Srinivasan (2014) [33] reported reduced total phenolic content (10.2 to 5.95 mg/g), bio-accessible polyphenol (2.65 to 1.84 mg/g), total flavonoids (5.54 to 1.78 mg/g), bio-accessible flavonoids (1.09 to 0.89 mg/g), tannin (5.93 to 3.57 mg/g) along with increased % bio-accessibility of polyphenols (25.5 to 30.9) and flavonoids (19.7 to 50.3) after pressure cooking of finger millet (15 psi for 15-20 min). The hydrothermal treatment of finger millet improved its protein and carbohydrate digestibility by 12%

over its native counter parts. The carbohydrate digestibility of finger millet increased from 61 to 73 g/100 g and protein digestibility from 79 to 91 g/100 g (Dharmaraj and Malleshi, 2011) [50].

Fermentation

Fermentation is a metabolic process which converts complex material into simpler form with the help of micro-organism. Davidek *et al.* (1990) [9] has reported changes during fermentation including destruction of inhibitors, breakdown of protein and increase in amino nitrogen. Michaelsen *et al.* (2008) [56] reported fermentation is the most effective and oldest method of processing and preserving foods. Fermentation reduces antinutrient factors in millets. Fermentation has great impact on enhancement of net protein utilization (NPU), niacin, thiamin, riboflavin and biological value (BV) of finger millet (Rajyalakshmi and Geervani, 1990; Aliya and Geervani, 1981) [621, 1]. Use of endogenous grain microflora in finger millet flour during fermentation shows a significant reduction in the amount of antinutrient factors such as trypsin inhibitor activity (TIA) by 32%, tannins by 52% and phytates by 20% (Antony and Chandra, 1998) [2]. Singh and Raghuvanshi (2012) [74] has reported fermentation also increases mineral availability and accessibility such as calcium 20%, zinc 26%, phosphorous 26%, iron 27%. Basappa *et al.* (1997) [4] reported significantly increased concentration of amino acid profile in fermented finger millet such as niacin-4.2 mg/100g, pantothenic acid-1.6 mg/100g, riboflavin-0.62 mg/100g, which is higher than raw finger millet. Fermentation also increases significant amount of lysine content in millets (Hamad and Fields, 1979) [30]. Since the ancient time finger millet is consumed in the form of baked & fried pancake (dosa, roti), thin porridge (ambali), thick porridge (dumpling or mudde) and beverages (jnard or chang). Fermentation is an important step for preparation of these products (Madhavi and Vaidehi, 1990; Hadimani and Malleshi, 1993; Gomez, 1993*)* [51, 52]. Fermentation using lactic acid bacteria has beneficial effect on amount of amino acids in legumes and cereals. *Lactobacillus salivaricus* increases lysine and tryptophan content by 7.1% and 17.8%, respectively, in fermented finger millet. Fermentation also improves vitamins B (niacin, riboflavin and thiamine) in cereals from it increased 0.19 to 0.36 μg/g (Elyas *et al.,* 2000; Kakade and Hathan, 2015) [78]. Fermentation improves the protein digestibility by degrading complex storage protein with the help of microbial enzymes. In vitro starch digestibility also reported increased by 43% after fermentation as a impact of soaking and weak acid production, which loosen the granules and made their active sides accessible to amylolytic attack.

Germination/malting

Germination of finger millet is the most familiar method in India and nutrition profile of germinated finger millet is measured better then germinated maize and germinated sorghum (Singh and Raghuvanshi, 2012) [74]. Malleshi and Desikachar (1986) [50] and Senappa (1988) [69] stated that amylase activity (AC) of finger millet is higher than sorghum and other millets which take 4-5 days to reach to maximum AC. Germination protects the grains from fungal infection and has dominant effect on number of biochemical changes which enhances the nutritional value of malted products. It leads to expansion of α and β-amylase throughout germination process, which develops desirable aroma during roasting/kilning and makes it a supreme grain for malt foods (Varma and Patel, 2013) [25]. Germination, malting and sprouting are the most commonly used terms to pass on to the method of soaking (Kakade and Hathan, 2015) [78]. Apart from enhancing the nutrients value, germination also helps to lowers down the antinutritional content of finger millet as tannin, phytic acid and trypsin inhibitors activity (TIA) which drastically improve bioaccessibility of dietary minerals such as zinc, iron and calcium (Desai *et al.,* 2010; Mwikya *et al.,* 2000; Mamiro *et al.,* 2001; Suma and Urooj, 2011b; Krishnan *et al.*, 2012) [11, 42, 52, 53, 54]. Malleshi and Desikachar (1986) [50, 52] stated increase in lysine & methionine content from 3.5 to 4.0 mg/100 and 1.3 to 1.5 mg/100 g, respectively in germinated finger millet. Malting also increases threonine, tryptophan and protein content of finger millet. Mwikya *et al.* (2000) [50] have reported an increase in amount of the sulfur containing amino acids such as cysteine and methionine during sprouting of finger millet. They also observed that tannin content of finger millet was reduced from 914 ± 14.4 mg/100 g to 20%, 45%, 62% and 72% after germination of 0, 24, 48, 72 h respectively. Rao (1994) [32] reported reduction of iron content in white and brown finger millet from 12.0 to 2.8 mg/100g and 4.4 to 1.8 mg/100 g respectively. It was also reported that malted white finger millet and brown finger millet had significantly higher amount of soluble zinc (25 & 81%) and ionisable iron (55 & 27.1%). Further, reduction of 54% tannin content in brown finger millet and 65% & 58% reduction of phytin phosphorus in white and brown finger millet were also found in their study. Singh and Raghuvanshi (2012) [74] stated that sprouted finger millet contains 5 mg iron, 230 mg phosphorus and 323.85 mg calcium. Germination of finger millet for 48 hours has improved significantly in *vitro* extractability of calcium, zinc and iron (Mamiro *et al.,* 2001) [50]. Malted finger millet contains 88.3% ionisable iron which is much higher than that of raw finger millet contain (7.4% ionisable iron) at pH 7.5 (Deosthale, 2002) [10]. Deosthale (2002) [10] and Mamrio *et al.* (2001) stated malting leads to reduction of 41 to 33% phytate in finger millet. Varadaraj and Horigane (1998) have reported beneficial changes in traditional foods throughout sprouting due to growth of lactic acid bacteria and a desirable microflora. Malted flour of finger millet contains 2.9 to 9.9 mg/100g soluble sugar and 73.7 to 83.1% total carbohydrate (CHO) (Shukla *et al.,* 1986) [73]. Malting process decreases certain amount of dietary fiber and increases reducing sugar content from 1.44 to 8.36% and total sugar content from 1.5 to 16.0%. Malting and germination reported to have a significant improvement in protein content. It was found that malting of finger millet carried out at 48 h/30 ^{0}C increase the protein content from 6.42 g/100 g to 7.32 g/100 g (Hejazi and Orsat, 2016). Swami *et al.* (2013) also reported similar trends of increased protein percentage for germinated finger millet grains (24 h). They also found a 25% improvement in protein availability of germinated finger millet (from 14 to 17.5%). Malting has improved Protein Efficiency Ratio (PER) of brown finger millet significantly ranges from 0.9 to 1.06 (Malleshi and Desikachar, 1986) [50].

Decortication

Decortication is a technique in which debranning of the grains takes place through mechanical removal of outer layer of seed coat of the grains (Michaelsen *et al.,* 2008; Malleshi, 2006) [8]. Gull *et al.* (2016) [56, 28] has stated that decortication of finger millet is difficult due to presence of seed coat attached to fragile endosperm. Therefore, decortication of finger millet is done through hydrothermal treatment such as hydration, steaming & drying which increases hardness of endosperm texture and nutritional contents of finger millet grains (Malleshi, 2006; Dharmaraj and Malleshi, 2011) [8, 13]. Thus decortications has a significant effect on reduction of phytate phosphorus and polyphenols contents by 39.8% and 74.7%, respectively which ultimately enables the nutritional bioavailability of protein and minerals (Michaelsen *et al.*, 2008; Kakade and Hathan, 2015) [56, 78]. Shobana and Malleshi (2007) [8] stated that scutellum & aleurone cells of finger millet losses phytate phosphorous during decortications. McDonough *et al.* (2000) [55] reported reduction in amount of tannin and polyphenols content in testa layer of finger millet. Liu *et al.* (2012) stated finger millet can be cooked like rice with soft texture within 5 minutes and can also be consumed as main course meal due to its edible quality and sensory characters. Study was conducted on different methods of decortications such as traditional (hand-pounding methods) verses mechanical methods (Abrasive methods) in the laboratory using finger millet. The nutritional composition and characteristics of traditional and mechanical decorticated millets were compared and result indicates the improved nutritional composition with reduction in antinutritional factors in mechanical decorticated millets and they have also shown in results that no significant differences were found in traditional decortications method (Hama *et al.*, 2011) [30]. Bagdia *et al.* (2011) and Lestienne *et al.* (2005) [46] has reported that decortications reduces antioxidant activity, minerals content, dietary fiber & crude fiber value and total phenols content of millets and has no effect on fat and protein content of millet. We can conclude that decortications of millets have several benefits on apperance, edible quality, organoleptic properties and antinutritional content. Losses of nutrients such as antioxidants, fibers and minerals were due to the removal of peripheral part (aeurone layer & pericarp) of grain in decortications process. Thus the decortications have several benefits over some losses which can be prevented with the innovative decortications techniques (Ahmed *et al.*, 2013). Dharamaraj and Malleshi (2011) [12] also stated that decortication increases the carbohydrate digestibility by 5% and protein by 8%. The presence of partially gelatinized starch backed up by the loss of granular rigidity could be the reason of increasing carbohydrate digestibility and increased protein digestibility may be due to the reduction in polyphenol content (34%). Removal of seed coat during decortication reduced dietary fiber and polyphenol content resulted in increased in protein and carbohydrate digestibility.

Parboiling

Parboiling is the hydrothermal treatment given to cereals and millets prior to decortications in order to achieve maximum recovery of grains without nutrients losses. Parboiling treatment was initially developed in some Asian countries to cut down milling losses. It is done through soaking, steaming and drying process. Parboiling helps to penetrates the water soluble nutrients from outer layer of grain seed coat to inner layer of grain and increases endosperm hardness than un-parboiled grains. Thus, the nutrients present in the outer layer of grains do not get removed during decortications process (kik, 1957; Kakade and Hathan, 2015) [78].

Roasting

Roasting is a most widely used cooking method where hot air cooks the food material evenly from all sides at around 150°C temperature in an open pan. Krantz *et al.* (1983) reported that grinding and roasting enhances grain digestibility and prevent nutrients losses. Gopaldas *et al.* (1982) and Huffingermilletan and Martin (1994) stated that popping reduces certain antinutritional factors and most of the toxin effects for example hemagglutinin, cyanogenic glycosides, gioterogenic, saponins, alkaloids and trypsin inhibitors. Bookwalter *et al.* (1987) stated roasting of millets at 97 ^{0}C inactivates lipase enzyme which helps to minimize fat hydrolysis. Roasting increases net protein utilization and enhances bioavailability of nutrients in roasted millets and legumes mix which is superior to malted, dehulled, baked and boiled mixes (Geervani *et al.*, 1996; Gahlawat and Sehgal, 1994) [20].

Value added products using finger millet

Weaning food

Finger millet malt is being used for the purpose of infant feeding since the ancient times. It is also used for preparation of beverages and milk of lukewarm water. Finger millet is one of the rich sources of calcium and sulphur containing amino acids. Weaning food is prepared using composite malt flour which contains finger millet, bengal gram and green gram. This blend is rich in calcium and protein. The following subsequent steps were used to formulate the weaning foods. The composite flour was soaked in water at room temp. 25 ^{0}C for 48 hours but in summers 38 hours is sufficient for soaking. Then the soaked grains were dried through sun or mechanical drying to stop germination process and the temperature was maintained below 75 ^{0}C with 10-12% moisture content. Higher temperature may causes adverse effects on milling quality of malt millet flour due to parboiling effect or hardening of grain kernels. After drying, the malted grains were roasted at 70-80°C either by heating in pan or by conventional toasting homogeneously, which helps to develop characteristic aroma and desired quality of product. The obtained malt was pulverized in order make it in ready to eat (RTE) form through any size reduction facilities. Then pulverized malt was subjected to sieving which helps to separate fine malt flour and husk. The malted flour was mixed with skim milk powder or whole milk powder, sugar and desired flavouring substances to formulated milk based beverages. The prepared beverage is called as “ragi malt” and it is good source of nutrients and can be used as energy drink & health drinks for all age groups (Varma and Patel, 2013) [25].

Fermented foods

Varma and Patel (2013) [25] stated fermented foods like Idli and Dosa are well-liked foods in several parts of India as breakfast and even as evening meals in southern parts. Ragi is broadly utilized as one of the core ingredient in many of fermented food products which not only improves the taste but also enriches the food with fiber, calcium and protein content due to the reduction in antinutrients content. Fermented foods are also prepared using malted or sprouted finger millet grains depending on the taste and choice. Mugocha *et al.* (2000) [58] optimize the bacterial cultures formulation to produce the composite finger millet and skimmed milk based powder gruel. They inoculated composites powder having 0 to 100% finger millet by volume at various temperatures (30-45 0C). Results showed that using an incubation temperature of 45 0C and a storage temperature of 7 0C thick product of yoghurt like consistency can be obtained regardless of amount of finger millet gruel (0-50%). Mythrayee and Pavithra (2017) [59] studied nutritive profile of the finger millet based composite bread fermented using Baker's yeast and Lactic acid bacilli (LAB). They observed significant improvement in nutrient content of both the types of composite bread in comparison the commercially available white bread product. Bread fermented using Baker's yeast had revealed higher moisture (21.24%) and vitamin B content (1.09% mg) than those fermented using LAB. The improved shelf life features of composite bread was also reported by them which could be the results of lower gluten and moisture content due to the integration of finger millet flour.

Extruded products

Extrusion technology is one of the most widely used novel approaches of transforming ingredients into the value added products. Extrusion cooking is work with the principle of combined efforts of shear force along with high pressure and temperature which is responsible to modify starch properties. Finger millet flour has good extrusion characteristics. Finger millet flour with 16-18% M.C. has capability to extrude in the barrel with temperature ranges from 100-120 ^{0}C well along with excellent expansion index by means of porous, crunchy and smooth surface texture. Pasta and noodles recognized as convenience food products prepared using cold extrusion technology. Various researches had been conducted earlier related to the utilization of finger millet in noodles and pasta formulations. Varma and Patel (2013) [25] has reported different combinations of prepared noodles like wholly made up of finger millet, soy and wheat flour blended in the proportion of 1:4:5 and finger millet flour & wheat flour in the proportion of 1:1. A number of additional combinations of blends can also be explored in the preparation of noodles maintaining food values of ingredients and their accessibility in mind of consumers. Shukla and Srivastava, (2011) [72] reported fortification of 30-50% of finger millets with wheat flour for preparation of noodles has beneficial advantages for diabetic patients due to low glycemic response compared to control. It was reported that pasta prepared with addition of 20% finger millet resulted in improved dietary fiber, minerals and antioxidant profile (Gull *et al.*, 2015; Gull *et al.*, 2018) [15, 269]. Negative impact of finger millet incorporation on cooking and sensory attributes of pasta had also been reported by them. Increased cooking loss as a results of finger millet incorporation was the results of weak protein-starch network in final product (Krishnan and Prabhasankar, 2010; Shukla and Srivastava, 2011) [42, 72]. Sensory score of finger millet pasta degraded due to the the impact of the brick red color of finger millet seed coat (Gull *et al.*, 2016) [28].

Bakery products

The attempts and efforts has been taken to standardize the recipe and also to maintained the quality of certain bakery foods like bread, nankhatai, biscuits and muffins using finger millet as a main ingredient. Seed coat of finger millet is a good source of minerals, dietary fiber and phytochemicals. Seed coat stuff is a by-product of decortications, milling and malting process; which could be further used as composite flour for formulation of biscuits. Varma and Patel (2013) [25] stated addition of finger millet in bakery items improves the fiber as well as micronutrients content. Krishnan *et al.* (2011) [44] has developed finger millet seed coat matter (SCM) based biscuits. Sensory evaluation was conducted for prepared biscuits and they found that 20% of SCM from malted millet, 10% of SCM from hydrothermally and native processed millet may be used in composite flour of biscuit. Saha *et al.* (2011) [67] has formulated biscuits from composite flours having two proportion of 70:30 and 60:40 (w/w) finger millet: wheat flour, which were then examined for biscuit quality and dough features. Results shows that a composite flour of 60:40 (w/w) finger millet: wheat flour was very good mainly related to biscuit quality. Desai *et al.* (2010) [11] has reported the improvement in nutritional quality of cake using malted finger millet with respect to the fiber content and minerals content. Breads are also prepared from millet-based composite flours, finger millet in combination with wheat, proso millet and barnyard millet. Sudha *et al.* (1998) [79] formulated muffins by replacing wheat flour with finger millet flour at a level of 0 to 100% (finger millet), hydrocolloids and emulsifiers. Impact of finger millet, hydrocolloids and emulsifiers on the microscopy of batter, quality characteristics and rheology properties of muffins were also evaluated. Results showed that blend of additives with 60% finger millet flour considerably improved the volume and quality attributes of muffins.

Tables 1: Nutrient profile of millets and other cereals

Crop	Protein (g)	Fat (g)	Fibre (g)	CHO (g)	Energy (kcal)	Ca (mg)	Fe (mg)	Thiamin (mg)	Ribofl-avin(mg)	Niacin (mg)
Rice	7.90	2.7	1.0	76.0	362	33	1.8	0.41	0.04	4.3
Wheat	11.6	2.0	2.0	71.0	348	30	3.5	0.41	0.10	5.1
Sorghum	10.4	3.1	2.0	70.7	329	25	5.4	0.38	0.15	4.3
Pearl Millet	11.8	4.8	2.3	67.0	363	42	11.0	0.38	0.21	2.8
Finger Millet	7.70	1.5	3.6	72.6	336	35	3.9	0.42	0.19	1.1
Foxtail Millet	12.2	4.0	6.7	63.2	351	31	2.8	0.59	0.11	3.2
Proso Millet	12.5	3.5	5.2	63.8	364	8	2.9	0.41	0.28	4.5
Little Millet	9.70	5.2	7.6	60.9	329	17	9.3	0.30	0.09	3.2
Barnyard Millet	11.0	3.9	13.6	55.0	300	22	18.6	0.33	0.10	4.2

Source: Hulse and others (1980); united states national research council/national academy of sciences (1982); USDA/HNIS (1984); Fao (2012).

Table 2: Influence of processing on the nutrients and anti-nutritional content of finger millet

Pretreatments Methods	**Reduction in Antinutritional Factors / Increase in Nutrient Content Proportion**	**Conditions for Treatments**	**References**
Pretreatments Methods	Reduction in Antinutritional Factors / Increase in Nutrient Content Proportion	Conditions for Treatments	References
Boiling	Reduction of polyphenols, trypsin, chymotrypsin and tannins by 30%	105˚C $\pm$1 for 30min	King (1985)
Soaking & Cooking	Reduction of trypsin inhibitors activity (TIA), oxalates, polyphenols, saponins by 33%, tannin by 20% and phytate by 39.47 to 24.17%.	25˚C for 12 h	Hotz and Gibson (2007) [34]; Kakade and Hathan (2015) [78]; Udayasekhara and Deosthale (1988) [65]
Fermentation	Reduction of phytates by 20%, tannins by 52%, trypsin inhibitors by 32%, Increases amount of calcium by 20%, zinc by 26%, phosphorous by 26%, iron by 27%, lysine and tryptophan content by 7.1% and 17.8%, respectively.	25˚C for 24 h	Antony and Chandra (1998) [2]; Dhankhe *et al.* (1987); Singh and Raghuvanshi (2011)
Germination	• Reduction in amylase activity, trypsin inhibitors, phytate by 54%, and tannins by 65% Increase in nutrient composition	25˚C for 48 h	Rao (1994); Mwikya *et al.* (2000); Mamiro and others (2001); Deosthale (2002) [32, 10]
Decortications	Reduction of polyphenols by 74.7%, phytate phosphorus by 39.8%	Milling	Michaelsen et. al. (2008); Kakade and Hathan (2015) [56, 78].
Popping	Reduction of tannin by 54%, phytate by 41% Increases starch digestibility and vitro nitrogen	250˚C at 19% M.C	Malleshi (1997); Pragya *et al.* (2015) [61].

Conclusion

Presence of dietary fiber and polyphenols inside the finger millet can offer various health advantages including anti-diabetic, hypocholesterolaemic, Prevention from diet associated chronic diseases, antioxidant and antimicrobial effects. Processing technologies can be applied to improve micronutrients bioavailability and also for enhancing the diets quality of finger millet. Consumption of Finger millet can be amplified through its proper processing and value addition from rural to urban area**.** Finger millet may be applicable formulations of different value-added food products possibly attributed to its well-balanced protein profile and gluten free nature. This study along with raising the profitability of its cultivators also speeds up the income and employment opportunities in rural area.

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