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Processing and value addition: A finger millet review

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Abstract
Finger millet (*Eleusine coracana* L.) is commonly known as Ragi or Mandua. It is one of the important millet grown in various parts of India. It has excellent nutritional value (as it contains 6% to 8% protein, 1% to 1.7% fat, 65% to 75% starch, 2% to 2.25% minerals and 18% to 20% dietary fiber and it provides highest level of 344mg/100mg of calcium and 0.3 to 3% of phenolic compounds). Processing technologies of finger millet grains such as milling, roasting, popping and malting gives different types of food preparations to make the final food product more attractive in appearance, taste, flavor and overall acceptability. This review gives the nutritional and health benefits of finger millet and its utilization in value added food products.

Keywords: Finger millet, nutritional significance, processing technologies, value addition and health benefit

Introduction
Millets are minor cereals of the grass family (Poaceae) which is alternative food source of increasing world population. There are some challenges faced by human being and also animals as water scarcity, rising food prices and other socio-economic impacts. Thus millet is called as a poorest people food in arid and sub-arid regions (Saleh *et al.,* 2013) [58]. They are small seeded, annual cereal grasses, many of which are adapted to tropical and arid climates and are characterized by their ability to survive in less fertile soil (Hulse *et al*., 1980) [22].
Millet presently comprises approximately 11.4% of the total area employed for cereals and 4.1% of the total cereals output (FAOSTAT, 2007) [15]. Cereals form a major portion of human diet and are an important source of starch and other dietary carbohydrates (dietary fibre), which play an important role in the energy requirement and nutrient intake of human (Chandra *et al.,* 2018) [7]. Millet is most important cereal after rice, sorghum and wheat and is a staple food for thousands of years in many parts of Africa and India. It can be grown on poor sandy soil in low rainfall areas (Purseglove, 1972) [44].
India is the leading producer of small millets *viz*, finger millet, kodo millet, foxtail millet, proso millet and little millet. Annual planting area around them is 2.5 million hectares and area under finger millet comprising about 40-50% of crop's global area. The production of finger millet in Karnataka is accounting to 58% of the total production (Mushtari *et al.,* 2016) [36]. 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].
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) [8]. With the changes in scenario of utilization pattern of processed products and awareness of the consumers about the health benefits, finger millet has gained importance because of its functional components, such as slowly digestible starch and resistant starch (Wadikar *et al.*, 2007) [72], exceptionally rich in calcium (344mg/ 100mg) compared to all other cereals and an excellent plant source of natural iron (3.9mg/100mg) (Gopalan *et al.*,2004) [19]. 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) [8].
Finger millet has excellent nutritional value and is even superior to other common cereals. It is a richest source of calcium (344mg) and magnesium (408mg) than other millets. Emerging bakery products prepared from this millet are pasta, noodles, vermicelli, and bread. Being

gluten free, it is suitable for individuals suffering from celiac disease. Commonly used processing techniques for this millet are milling, malting, popping, and decortications (Gull *et al*., 2015) [17]. With the regard to protein (6-8%) and fat (1-2%) it is comparable to rice and with respect to mineral and micronutrient contents it is superior to rice and wheat. Nutritionally; it has high content of calcium (344mg/100g), dietary fiber (15-20%) and phenolic compounds (0.3-3%) (Gull *et al*., 2014) [16].

The nutritive potential of millets in terms of carbohydrate, protein, and energy values can be compared to that of popular cereals such as rice, wheat, or barley. Millets contain the highest percentage of healthy dietary fibers among the cereals (Malleshi *et al.*, 1996) [37] and a higher mineral content than rice or wheat. Being indigenous minor millet this is used in the preparation of geriatric, infant food and health foods both in natural and malted forms. The grains of this millet are converted into flours for preparation of products like porridge, puddings, pancakes, biscuits, roti, bread and other snacks (Hulse *et al.*, 1980) [22]. When malted it is also used as a nourishing food for infants and is regarded as wholesome food for diabetic's patients.

Nutritional Significance of finger millet

Finger millet is good source of nutrients especially of calcium, minerals and fiber. Finger millet is having excellent nutritional value. It contains 6% to 8% protein, 1% to 1.7% fat, starch 65% to 75%, minerals 2% to 2.25% and dietary fiber 18% to 20%. Its proximate composition is superior to wheat, maize, sorghum and rice with regard to dietary fiber, calcium and few micronutrients. The seed coat of this millet is rich source of phenolic compounds, minerals and dietary fiber (Shobana *et al.*, 2009) [55].

Protein

Protein content of this millet ranges between 6% to 8%, although low protein content of 5% and high protein content of 12% have been reported in different varieties (Hulse *et al.*, 1980) [22]. Prolamins content is about 35-50%, albumins and globulins constitute 8% to 15% of total proteins. Its Amino acid composition is good as it contains (2.5%) lysine, (13%) tryptophan, (2.9%) methionine, (3.1%) threonine, (4%) leucine and isoleucine (Gull *et al.*, 2016) [18].

Carbohydrate

In ragi, the carbohydrates include starch as the main constituent being 59.4-70.2% (Antony *et al*., 1996 and Mittal, 2002). Finger millet starch granules exhibit polygonal rhombic shape (Jideani, 1996) [27]. About 80-85% of the finger millet starch is amylopectin and remaining 15-20% is amylase (Wankhede *et al*., 1979) [73]. (Bhatt *et al*., 2003) [6] reported that non starch polysaccharide account for 20-30% of the total carbohydrates in finger millets.

Total carbohydrate content of finger millet has been reported to be in the range of 72-79.5% (Bhatta *et al*., 2003) [6]. (Pore and Magar, 1979) reported reducing sugar in the range of 1.2-1.8% whereas (Nirmala *et al.*, 2000) [43] reported value of 1.5% reducing sugar and 0.03% non-reducing sugar in finger millet. (Ramulu and Rao, 1997) [49] reported total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF) content in finger millet to be 12.0%, 11.0%, and 2.0%, respectively. (Kamath and Belavady, 1980) [28] found 18.6% dietary fiber and 3.6% crude fiber in finger millet. (Joshi and Katoch, 1990) [26] reported 3.7% crude fiber in finger millet.

Minerals

The mineral composition of millet grains is highly variable. The genetic factors and environmental conditions prevailing in growing region affect the mineral content of these food grains. Total ash content is higher in finger millet than in commonly consumed cereal grains. The ash content has been found to be nearly 1.7 (Rao, 1994) to 4.13% (Rao *et al.*, 1973) [51] in finger millet. Most of the studies have shown it in the range of 2.1 to 2.7% (Samantaray and Samantaray, 1997; Bhatt *et al*., 2003; Mushtari, 1998; Malleshi and Desikachar, 1986; Lupien, 1990) [6, 53, 6, 39, 33]. (Singh and Srivastava, 2006) [56] showed that the total ash content of the sixteen varieties of finger millet ranged from 1.47 to 2.58% with a mean value of 2.11%. (Kurien *et al*., 1959) [29] reported that nearly 49% of total calcium content of finger millet is present in the husk. (Sripriya *et al*., 1997) [56] reported that germination and fermentation of finger millet decreased the phytate content by 60% and improved bioavailability of minerals. (Platel *et al*., 2010) [4] also reported increased bioaccessibility of minerals (iron, manganese) on malting of finger millet. Decortication of finger millet decreased the total mineral contents but increased the bioaccessibility of calcium, iron, and zinc, whereas popping of finger millet decreased the bioaccessibility of calcium but increased the bioaccessibility of iron and zinc. Malting of finger millet increased the bioaccessibility of calcium, iron, and zinc (Rateesh, Usha, and Malleshi, 2012) [48].

Dietary fiber

Total dietary fiber content of finger millet grain is 22.0% and is relatively higher than most of other cereal grains, e.g. 12.6 wheat, 4.6 rice, 13.4 maize, and 12.8% sorghum, respectively. Dietary fibers are categorized as water soluble or insoluble. (Chethan and Malleshi, 2007) [9] reported that finger millet grain contained 15.7% insoluble dietary fiber and 1.4% soluble dietary fiber, while (Shobana and Malleshi, 2007) [59] reported 22.0% total dietary fiber, 19.7% insoluble dietary fiber, and 2.5% soluble dietary fiber in finger millet.

Processing of Finger Millet

Similar to other cereal grains finger millet is also required to undergo certain basic steps of primary processing operations, such as cleaning, grading and separation where in removal of unwanted materials like, stones, soil particles, stalks, chaffs, grains of other crops etc. These operations are also important for adding value to the produce from the point of view of getting better returns from their sale.

Milling

Generally, finger millet is pulverized to flour for preparation of food products. First, it is cleaned to remove foreign materials such as stones, chaffs, stalks, etc., then passed through abrasive or friction mills to separate out glumes (non-edible cellulosic tissue), and then pulverized. Normally, it is pulverized in stone mill or iron disk or emery-coated disk mills. Sometimes, pearling or decortications is used to dehusk the finger millet grain; it results in pulverization of both the seed coat and endosperm. Hence, finger millet is invariably pulverized along with the seed to prepare wholemeal. Centrifugal sheller can also be used to dehull/decorticate the small millets (Gull *et al*., 2015) [17].

Roasting

Traditional roasting of grains is used primarily to enhance flavor, but other benefits include reduction of antinutritional

factors (D' Appolonia, 1978; Khan *et al*., 1988; Gahlawat and Sehgal, 1992) [13, 30, 20] and extension of storage life (Huffman and Martin, 1994) [21]. Roasting and grinding processes render the grain digestible, without the loss of nutritious components (Krantz *et al*., 1983) [31]. The puffing and roasting are almost similar processes, but the volume expansion in puffing is higher (Srivastava *et al*, 1994) [60]. Finger millet subjected to roasting at different temperatures for a different time was milled into flour and porridge was prepared. It was found that porridge viscosity decreased with increasing roasting time and temperature. Viscosity decreased by 50-60% in roasted finger millet; however, roasting did not affect the proximate composition (Auko, 2009) [2].

Popping

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. (Wadikar *et al.*, 2007) [72] 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 °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%. 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*.,1986) [61].

Malting

Malting of finger millet is commonly practiced for specialty foods. During this process bioavailability of proteins, carbohydrates and minerals are enhanced. Some B- group vitamins are synthesized and concentration of anti-nutritional factors is also reduced. Malting involves soaking of viable seeds in water to hydrate and to facilitate sprouting. These sprouts are then kiln dried. Finally the rootlets are separated from the grain manually by rubbing with hand. All these operations influence the quality of malt. Seed germination is most important step because during this process the hydrolytic enzymes are developed these cause endosperm modification and increases nutritional properties. Malting of finger millet has been successfully utilized for developing various health foods such as infant food, weaning food, milk based beverages and confectionary products (Malleshi, 2007) [59]

Value added food products using finger millet

Finger millet can be used in a variety of ways and is a great substitute for other grains such as rice and other starchy grains. Some of the examples of value added products and possibilities of utilizing this minor millet as one of the basic ingredients are discussed below. These products are either in practice or have been demonstrated for enhancing consumption of this particular millet.

Chapatti (Roti)

Wheat and finger millet in the ratio of 7:3 (wheat: finger millet) is suitable for making chapatti (roti). In this proposed blend, though the gluten content is reduced the making of flattering chapatti is not affected. Moreover, the color of the chapatti turns to slightly dark. Fortification of finger millet in chapattis not only improves the taste but also controls glucose levels in diabetic patients very efficiently. Slower digestion rate and bulkiness of the fibres makes us feel fuller on, fewer calories and therefore may help to prevent from eating excess calories. In addition Finger millet fiber content is helpful to the individuals having the problem of constipation (Gull *et al*., 2014) [16].

Papad

Papad is a traditional product in south India. Finger millet flour (15-20%) added in other essential ingredients such as black gram, rice and spices. (Begum, 2007) [5], reported that addition of finger millet flour (upto 60%) is possible and practiced in Karnataka. During papad preparation finger millet flour is first cooked in water up to gelatinized. A thin sheet is prepared by rolling and cutting the dough into desired shapes and sizes followed by drying of these papad pieces to desired moisture content of 7. Since the pericarp of finger millet grain is not separated out from the starch so that it gives a little dark colour to the papad. The dark colour of papad turns to lighter after frying (Verma and Patel, 2012) [67].

Bakery Products

Incorporation of finger millet flour in the preparation of bakery products like biscuit, nankhatai, muffins and bread has been attempted and efforts are being made to standardize the recipe and product quality. The use of millets in bakery products will not only superior in terms of fiber content, micronutrients but also create a good potential for millets to enter in the bakery world for series of value added products. In a recent study, attempts have been made to improve the nutritional quality of cakes with respect to the minerals and fiber content by supplementing with malted finger millet flour (Desai *et al*., 2010) [14]. In recent years, finger millet has received attention and efforts are under way to provide it to the consumer's inconvenient forms (Singh *et al*., 2012) [62].

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, fiber, crude fat, vitamins B, C and their availability, minerals (Sangita and Srivastav, 2000) [63], 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) [41].

Fermented foods

(Varma and Patel, 2012) [67] 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) [42] 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 °C). Results showed that using an incubation temperature of 45 °C and a storage temperature

of 7 °C thick product of yoghurt like consistency can be obtained regardless of amount of finger millet gruel (0-50%).

Noodles

The changing food habits of children and teen aged groups have created a good market of noodles in India and abroad. The demand for millet noodles particularly the noodles made out of finger millet is growing due to awareness of its nutritional properties. Noodles are 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. In case of exclusive millet-based noodles, pretreatment to the millet flour is given to facilitate extrusion and smooth texture which should retain while drying and cooking. Generally, in the preparation of noodles, wheat flour is invariably used as an important member of blend because the presence of wheat gluten has an added advantage which not only helps in easy extrusion but also gives a smooth and fissure free texture to the noodles. Several other combinations of blends can be explored in the preparation of noodles keeping food values of ingredients and their availability in mind (Thapliyal and Singh, 2015) [68]

Health benefits of Finger millet

The interest in finger millet due to its health benefits namely, hypoglycemic characteristics (Lakshmi and Sumathi, 2002) [34] and also antimicrobial and antioxidant activities of its polyphenols have been growing (Chetan and Malleshi, 2007) [59]. (Chandrasekara and Shahidi, 2010) [10] reported in their studies on free-radical quenching activity of finger millet (Eleusine coracana), that non processed brown finger millet had the highest radical quenching activity than the processed one and postulated that tannins and phytic acid were responsible for the activity (Devi *et al*., 2014; Quesada *et al*., 2011; Kamara *et al*.,2012) [12, 47, 32]. Several studies are available on the antioxidant properties (Chandrasekara and Shahidi, 2011; Hegde and Chandra, 2005; Sripriya *et al*., 1996; Subba Rao and Muralikrishna, 2002; Varsha *et al*., 2009; Veenashri and Muralikrishna, 2009) [24, 64, 65, 70] and antimicrobial properties of finger millet (Antony *et al*., 1998; Chethan and Malleshi, 2007; Varsha *et al*., 2009) [4, 9, 69]. Production of statins (antihypercholesterolemic metabolites) from finger millet was attempted by (Venkateswaran and Vijayalakshmi, 2010) [71]. The other health beneficial aspects of finger millet feeding, namely, the glucose lowering, cholesterol lowering, nephro protective properties, antioxidant properties, wound healing properties, and anti cataractogenesis properties of finger millet were reported by several authors (Hegde *et al*.,2005; Hegde, Rajasekaran *et al*.,2005; Rajasekaran *et al*.,2004; Shobana *et al*., 2010) [25, 24, 50, 54]. Improvement on the status of hemoglobin in children on feeding finger millet-based food was reported by (Tatala *et al*., 2007) [66].

Conclusion

Health benefits and nutritive value of millet grains were found comparable to major cereals. Several processing technologies were found to improve nutritional characteristics of millets. Utilization of millet grains as food is still limited to populations in rural areas. This is due to the lack of innovative millet processing technologies. Finger millet is an important staple food in parts of eastern and central Africa and India. Its nutritional and functional properties have been reviewed and found best among all cereals grains. Vitamins, minerals, fatty acids and antioxidant properties of this make its strong contribution to human nutrition. Processing and value addition technologies have made it possible to process and prepare value added products acceptable to both rural and urban consumers. This review provides a scientific rationale use of finger millet as a health- promoting food.

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