

Review

Finger millet for food and nutritional security

Pragya Singh^{1*} and Rita Singh Raghuvanshi²

¹Applied Human Nutrition, INFST, College of Agriculture, Hawassa University, Ethiopia.

²Department of Foods and Nutrition, College of Home Science, GBPUA&T, Pantnagar, Uttaranchal, India.

Accepted 31 December, 2011

Finger millet is amongst the major crops of Uttaranchal. Over the years there has been rapid decline both in production and consumption of millets. Chemical composition of finger millet revealed that total carbohydrate content of finger millet has been reported to be in the range of 72 to 79.5%. Finger millet has nearly 7% protein but large variations in protein content from 5.6 to 12.70% have been reported by various studies. 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 to 4.13% in finger millet. Calcium content of 36 genotypes of finger millet ranged from 162 to 487 mg %. Singh and Srivastava (2006) reported the iron content of 16 finger millet varieties ranged from 3.61 mg/100g to 5.42 mg%. Finger millet is the richest source of calcium and iron. Calcium deficiency leading to bone and teeth disorder, iron deficiency leading to anemia can be overcome by introducing finger millet in our daily diet. Maximum utilization of the nutrient potential of the millet is limited by the presence of phytates, phenols, tannins and enzyme inhibitors but their effect can be reduced by using processing techniques like popping, roasting, malting and fermentation. The use of these techniques not only decreases the content of antinutrients but increases the bioavailability of certain minerals like calcium and iron. Composite flours made by using finger millet can be used for preparation of various nutrient dense recipes which can be effectively used for supplementary feeding programs.

Key words: Bioavailability, malting, chemical composition, composite flour, antinutrients.

INTRODUCTION

Nutritional well being is a sustainable force for health and development and maximization of human genetic potential. The nutritional status of a community has therefore been recognized as an important indicator of national development. In other words, malnutrition is an impediment in national development and hence assumes the status of national problem. For solving the problem of deep-rooted food insecurity and malnutrition, dietary quality should be taken into consideration. Diversification of food production must be encouraged both at national and household level in tandem with increasing yields. Growing of traditional food crops suitable for the area is one of the possible potential successful approaches for improving household food security.

Millets also referred to as coarse cereals are a variety of small edible grasses belonging to the grass family

(*Gramineae/Paniceae*). These are distributed in about 10 genera and 20 species in all (Lupien, 1990). Millet is a collective term referring to a number of small seeded annual grasses that are cultivated as grain crops, primarily on marginal lands in dry areas in temperate, subtropical and tropical regions (Baker, 1996). The millets include five genera of the *Panaceae* family (*Panicum*, *Setaria*, *Echinochloa*, *Pennesetum* and *Eleusine*). The most important cultivated species are: Proso millet (*Panicum miliaceum*), Foxtail millet (*Setaria italica*), Japanese barnyard millet (*Echinochloa frumentacea*), Finger millet (*Eleusine coracana*) and Koda millet (*Paspalum scrobiculatum*).

FINGER MILLET

Finger millet, *E. coracana* L. is also known as ragi and mandua (India); kaddo (Nepal); fingerhirse (Germany); petit mil, eleusine cultivee, coracan, koracan (France);

*Corresponding author. E-mail: pragyasinh85@yahoo.co.in.

bulo (Uganda); *kambale*, *lupoko*, *mawele*, *amale*, *bule* (Zambia); *poho*, *rapoko*, *zviyo*, *njera*, *mazhovole* (Zimbabwe); finger millet, African millet, koracan (England); *dagussa*, *tokuso*, *barankiya* (Ethopia); *wimbi*, *mugimbi* (Kenya). It is an important staple food in parts of eastern and central Africa and India.

Chemical composition and nutritive value of finger millet

Nutritionally, finger millet is good source of nutrients especially of calcium, other minerals and fibre. Total carbohydrate content of finger millet has been reported to be in the range of 72 to 79.5% (Pore and Magar, 1979; Hulse et al., 1980; Joshi and Katoch, 1990; Bhatt et al., 2003). The carbohydrates include starch as the main constituent being 59.4 to 70.2% (Pore and Magar, 1979; Wankhede et al., 1979; Antony et al., 1996; Nirmala et al., 2000; Mittal, 2002). Finger millet starch granules exhibit polygonal rhombic shape (Jideani et al., 1996). About 80 to 85% of the finger millet starch is amylopectin and remaining 15 to 20% is amylose (Wankhede et al., 1979; Jideani et al., 1996). Bhatt et al. (2003) reported that non-starch polysaccharide account for 20 to 30% of the total carbohydrates in finger millets. Pore and Magar (1979) reported reducing sugar in the range of 1.2 to 1.8% whereas Nirmala et al. (2000) reported value of 1.5% reducing sugar and 0.03% non-reducing sugar in finger millet.

Mittal (2002) reported the *in vitro* starch digestibility (IVSD) of native finger millet as 71.67%. Roopa et al. (1998) calculated digestibility indices of finger millet based preparation by *in vitro* starch hydrolysis. Authors reported that the starch digested *in vitro* was 17 to 27%.

Ramulu and Rao (1997) reported total dietary fibre (TDF), insoluble dietary fibre (IDF), and soluble dietary fibre (SDF) content in finger millet to be 12, 11 and 2%, respectively. Kamath and Belavady (1980) found 18.6% dietary fibre and 3.6% crude fibre in finger millet. Joshi and Katoch (1990) reported 3.7% crude fibre in finger millet.

Millets have hypoglycemic effect, which is attributed to high fibre content. High fibre diets containing complex carbohydrates are slowly digested and absorbed thus bring reduction in postprandial glucose (Geetha and Parvathy, 1990).

The second major component of millet is protein. Finger millet has nearly 7% protein but large variations in protein content from 5.6 to 12.70% have been reported (Joshi and Katoch, 1990; Ravindran, 1991; Rao, 1994; Marimurthu and Rajagopalan, 1995; Antony et al., 1996; Vadivoo et al., 1998; Mushtari Begum, 1998; Gautam, 2000; Sharma, 2001; Bhatt et al., 2003). Singh and Srivastava (2006) analysed 16 finger millet varieties and found out that it ranged from 4.88 to 15.58% with a mean value of 9.728%. Vadivoo et al. (1998) analysed 36

genotypes of finger millet and reported their protein content in the range of 6.7/100 to 12.3/100 g with the mean of 9.7/100 g. They reported that the protein content of brown seeded types was higher than white seeded type. Similar findings were reported by Samantaray and Samantaray (1997). Prolamin is the major fraction on finger millet protein, being 24.6 to 36.2% of total protein (Lupien, 1990). Antony and Chandra (1998) reported 99.1 mg soluble proteins per 100 g in finger millet.

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). Also, finger millet amino acid profile gives a good ratio of essential to total amino acids. When compared to FAO amino acid scoring pattern for children 2 to 5 years old (FAO, 1991), lysine was limiting while all other amino acids scored higher than that of 1. Tryptophan is usually the second most deficient amino acid in cereals. However, is not deficient in finger millet. Threonine too was not deficient, in contrast to rice, wheat and sorghum (FAO, 1968). Among millets, finger millet is relatively better balanced in essential amino acids because it contains more lysine, threonine and valine (Ravindran, 1992). Lysine content and the methionine content of the protein are inversely correlated with the protein content of the finger millet grain. The albumin and globulin fractions contain a good compliment of essential amino acids and the prolamin fraction contains higher proportion of glutamic acid, proline, valine, isoleucine, leucine and phenylalanine but low, arginine and glycine (Lupien, 1990). The isoleucine content of finger millet is high. The ratio between leucine and isoleucine is about 2 almost equal to that of rice and wheat (Indira and Naik, 1971). Antony et al. (1996) reported that finger millet had sulphur containing amino acids equal to that of milk. Rao (1994) reported PER of 1.40%, protein digestibility of 76% and net protein utilization of 35 for a diet containing 100% finger millet. *In vitro* protein digestibility ranged from 55.4 to 88.1% in 32 varieties of finger millet (Ramachandra et al., 1977). Antony and Chandra (1998, 1999) reported *in vitro* protein digestibility in the range of 50 to 65%. The authors observed a negative correlation of *in vitro* protein digestibility with phytates, phenols, tannins and antitryptic activity. Mittal (2002) reported IVPD of native finger millet flour as 62.94%.

The crude fat content in finger millet has been reported in range of 1.3 to 1.8% (Bhatt et al., 2003; Singh et al., 2003; Malleshi and Desikachar, 1986; Lupien, 1990) but Antony et al. (1996) have reported a higher percentage (2.1%) of crude fat. The fat content in brown and white varieties of finger millet ranged from 1.2 to 1.4% (Seetharam, 2001). Sridhar and Lakshminarayana (1994) reported total lipid content in finger millet to be 5.2% (free lipids 2.2%; bound lipids 2.4%; structural lipids 0.6%). The non polar lipid fraction was 80%, glycolipids 6% and

phospholipids 14% in finger millet fat. Finger millet though low in fat content, is high in polyunsaturated fatty acids (Antony et al., 1996). The major fatty acid in finger millet was oleic acid followed by palmitic acid and linoleic acid. It had little amount linolenic acid also. The fatty acid profile showed that saturated fatty acids account for 25.6% while unsaturated fatty acids accounts for 74.4% of total fatty acids (Sridhar and Lakshminarayana, 1994).

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) 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). Singh and Srivastava (2006) 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%. Finger millet is rich in calcium. Calcium content of 36 genotypes of finger millet ranged from 162 to 487 mg% with mean value of 320.8 mg% (Vadivoo et al., 1998). The average calcium content (329 mg%) in white varieties was considerably higher than the brown (296 mg%) varieties (Seetharam, 2001). Bhatt et al. (2003) reported the calcium content of finger millet as 344 mg%. The iron content of finger millet ranged from 3.3 to 14.8 mg% (Babu et al., 1987). Singh and Srivastava (2006) reported the iron content of 16 finger millet varieties ranged from 3.61 mg/100g to 5.42 mg% with a mean value of 4.40 mg/100g. According to Vijayakumari et al. (2003) finger millet is the richest source of calcium and iron. Calcium deficiency leading to bone and teeth disorder, iron deficiency leading to anemia can be overcome by introducing finger millet in our daily diet. Singh and Srivastava (2006) observed that the zinc content of the sixteen varieties of finger millet ranged from 0.92 to 2.55 mg% with a mean value of 1.34 mg%. The phosphorous content ranged from 130 to 295 mg% with a mean value of 180.43 mg% (Singh and Srivastava, 2006).

Millets in general are rich sources of vitamin B but available data are very meager on vitamin content of millets. Gopalan et al. (1999) have reported 45 µg carotene per 100 g of finger millet while Bhaskaracharya (2001) reported that finger millet is very poor source of β-carotene (0 to 1 µg/100g). Vitamin A content of finger millet has been reported to be 6 retinol equivalent (nap.edu, 1996).

Nutritional inhibitors and toxic factors

Maximum utilization of the nutrient potential of the millet is limited by the presence of phytates, phenols, tannins and enzyme inhibitors. Tannins bind to both exogenous

and endogenous proteins including enzymes of the digestive tract affecting utilization of proteins (Asquith and Butler, 1986). Among millets finger millets have been reported to contain high amounts of tannins ranging from 0.04 to 3.74% of catechin equivalents (Rao, 1994; Antony and Chandra, 1998; Antony and Chandra, 1999). Rao and Prabhavati (1982) have reported 360 mg/100g tannins in brown finger millet. They also found that 50% of the iron present in the diet might be bound to tannins. *In vitro* protein digestibility has been found to be negatively associated with tannin content of finger millet varieties (Ramachandra et al., 1977). Soaking, roasting, boiling, germination and fermentation have been found to reduce tannin content (Rao and Prabhavathi, 1982). Malting decreased the tannin content by 54% in brown finger millet (Rao, 1994).

Phytic acid, myo-inositol 1,2,3,4,5,6-hexakis (dihydrogenphosphate), is the main phosphorus store in mature seeds. Phytic acid has a strong binding capacity. It readily forms complexes with multivalent cations and proteins (Haug and Lantzsch, 1983). Phytate content in finger millet as observed by various authors has been found to be in range 0.679 to 0.693 g/100mg (Antony and Chandra, 1999). Finger millet has been found to contain 41% phytic phosphorus as percentage of total phosphorus (Deosthale, 2002). Rao (1994) reported phytate content to be 149 to 150 mg/100g in finger millet grains. The dietary phytic acid binds not only with the seed derived minerals but also with other endogenous minerals encountered in the digestive tract (Raboy, 2000). Agte and Joshi (1997) reported that for cereal based vegetarian meals, processing such as soaking cereal flour prior to heating can activate phytases and therefore favour zinc availability. Malting of the grain significantly reduced the phytin phosphorus content of finger millet (Rao and Deosthale, 1988; Malleshi and Desikachar, 1986; Deosthale, 2002). Rao (1994) reported that malting decreased the phytin phosphorus content by 58 to 65% in brown and white finger millet varieties, respectively. Mammiro et al. (2001) found that there was marked reduction in phytic acid content in finger millet during processing. Phytic acid decreased by 49.2 and 66.5% after germination and fermentation, respectively. Phytic acid decreased in finger millet by 84.7% when combinations of processing methods were used. The partial retention of phytates is beneficial for their contribution to health benefits such as antidiabetic, antioxidant and anticancer effects, which have been recently recognized (Graf et al., 1987; Thompson, 1993).

PROCESSING OF MILLETS

Methods of food processing have been developed over the centuries and are adopted to make the final product more attractive in flavour, appearance, taste, consistency etc. Besides these aspects of consumer preferences,

several of the methods aim at making the food safe and wholesome and increase its shelf life. The common household practices of processing these foods include milling, germinating or sprouting, malting, fermentation and cooking. Each of these processes qualitatively modifies the nutritive value of the food.

Grinding/milling

Small millets containing large portion of husk and bran require dehusking and debranning prior to consumption (Hulse et al., 1980). In the process of milling of food grains, the main objective is to remove the coarse fibrous bran or the seed coat. However, in all these processes the nutrient rich parts of the grain, namely the germ and the aleurone layers, are also displaced resulting in a product poorer in nutrient content (Deosthale, 2002). Millets were earlier decorticated at household level by hand pounding, but are currently milled in rice milling machinery. The millets are mostly powdered in plate mills and the whole meal is used for traditional food preparations (Desikachar, 1975). Dry, moistened or wet grain is normally pounded with wooden or stone mortar. Moistening the grain by adding about 10% water facilitates removal of fibrous husk (Lupien, 1990). Hadimani and Malleshi (1993) reported the use of moist conditioning, grinding and sieving to obtain finger millet flour. In wet milling, millet is soaked in water overnight (and sometimes longer) and then ground to paste by hand often between two stones (Lupien, 1990). Milled grains hydrate quickly and cook to soft texture in a short time. During milling, some starch granules (usually 5 to 10%) are physically damaged by grinding action of roller mills.

Intact starch granules are relatively resistant to α and β -amylases, whereas damaged granules are susceptible to enzyme attack. With increased starch damage, the water binding capacity of flour increases but excessive starch damage causes a decreased bread quality (Deosthale, 2002). The nutrient content of food grain is relatively poor after milling but the bioavailability of certain nutrients improves considerably. Removal of complex polysaccharides of fibrous bran, tannins and phytates during milling improves the bioavailability of iron (Rao and Prabhavathi, 1978). Dehulling removes most of the phenols from finger millet grain with concomitant increase in *in-vitro* protein digestibility (Ramachandra et al., 1977).

Fermentation

Fermentation can be spontaneously initiated without the addition of microorganisms or controlled by the use of specific cultures of starters from previous batch of fermented products (Frazier and Westhoff, 1986).

Changes that take place during fermentation include increase in amino nitrogen, the breakdown of proteins and destruction of any inhibitors that may be present (Davidek et al., 1990). Traditionally, finger millet is consumed in the form of thick porridge (mudde or dumpling), thin porridge (ambali), fried and baked pancake (*roti*, dosa) and beverages (*chang/ jnard*). Most of these involve fermentation step (Madhavi and Vaidehi, 1990; Hadimani and Malleshi, 1993; Gomez, 1993). Fermentation of finger millet using different cultures has been shown by Antony et al. (1996), Antony and Chandra (1999), and Mbithi et al. (2000). Lactic acid fermentation has been found to affect the amount of amino acids in cereals and legumes. Hamad and Fields (1979) observed that fermentation increased the lysine content in millets. Fermenting finger millet with *Lactobacillus salivarius* caused an increase in tryptophan and lysine by 17.8 and 7.1%, respectively. Also, the leucine to lysine ration, which is an indicator of pellagrigenic character of protein, decreased significantly during fermentation (Mbithi et al., 2000).

Enhancement of biological value (BV), net protein utilization (NPU), thiamin, riboflavin and niacin contents has been shown in fermented finger millet (Aliya and Geervani, 1981; Rajyalakshmi and Geervani, 1990). Basappa et al. (1997) observed significant higher concentrations of riboflavin (0.62 mg/100g), pantothenic acid (1.6 mg/100g), and niacin (4.2 mg/100g) in the fermented finger millet than in raw grains. They also observed that cyanocobalamin was synthesized during finger millet fermentation. Antony and Chandra (1998) reported that fermentation of finger millet flour using endogenous grain microflora showed a significant reduction of phytates by 20% and tannins by 52% and trypsin inhibitor activity by 32% at the end of 24 h. There was a simultaneous increase in mineral availability (calcium-20, phosphorous-26, iron-27 and zinc-26%).

Roasting

Roasting and grinding processes render the grain digestible, without the loss of nutritious components (Krantz et al., 1983). The puffing and roasting are almost similar processes, but the volume expansion in puffing is higher (Srivastava et al., 1994). Roasting of cereals, pulses and oilseeds is a simpler and more commonly used household and village level technology which is reported to remove most antinutritional or toxic effects such as trypsin inhibitor, hemagglutinin, giotrogenic agents, cyanogenic glycosides, alkaloids and saponins and increase storage life (Gopaldas et al., 1982; Huffman and Martin, 1994).

Bookwalter et al. (1987) reported inactivation of lipase in millet flours when roasted at 97°C. Inactivation of lipase led to minimization of fat hydrolysis. Geervani et al. (1996) reported significantly higher NPU from roasted

millet and legumes mix as compared to dehulled, boiled, malted and baked mixes. Weaning foods prepared by roasting of barnyard and finger millet increased iron bioavailability (Gahlawat and Sehgal, 1994).

Popping

Popping or puffing is a simple processing technique of cereals to prepare ready to eat products. Popped grain is crunchy, porous and a precooked product. Popping invariably improves taste and flavour (Malleshi, 1996). Malleshi and Desikachar (1981) observed that to obtain fully expanded millets, the grain moisture content should be 19% and popping temperature of about 250°C. It is difficult to debran popped grains hence popped grains have slightly higher fibre content. Popping of millets produces a porous product of low bulk density and pleasing texture with a distinct appealing flavour (Lewis et al., 1992).

Popped grains especially of finger millet possess a pleasant aroma and acceptable taste. Popped grains besides useful as a convenient food, could be used as a component of nutritious foods in the nutrition intervention programmes (Malleshi, 1997). Popping / puffing increases the *in vitro* nitrogen and starch digestion. Protein digestibility is influenced by heating, which renders the protein more susceptible to hydrolysis because of structural changes (Lewis et al., 1992). Increase in starch digestibility has been attributed to high degree of starch gelatinization and release of starch granules from protein matrix, rendering them more susceptible to enzymatic digestion (Murlikrishna et al., 1986).

Malting

Malting of finger millet is a common technique in India and malted finger millet is considered superior to malted sorghum and malted maize. Studies have shown that finger millet develops higher amylase activity than sorghum and other millets (Malleshi and Desikachar, 1986; Senappa, 1988). Malleshi and Desikachar (1986) reported that finger millet malt has highly agreeable flavour with adequate starch hydrolyzing enzymes. The maximum activity of amylase develops after 4 to 5 days of germination.

Shukla et al. (1986) reported that total carbohydrate and soluble sugars ranged from 73.7 to 83.1% and 2.9 to 9.9 mg/100g, respectively in malted flour of finger millet. The total and reducing sugar content increased from 1.5 to 16.0 and 1.44 to 8.36%, respectively and there was marginal decrease in dietary fibre. Shukla et al. (1986) reported 4.6 to 5.7% protein in malted finger millet. Rao (1994) reported 8.2 and 11.3% protein content in brown and white varieties of malted finger millet, respectively.

There was decrease in protein content after malting (Hemalanini et al., 1980; Shukla et al., 1986; Rao, 1994). Malleshi and Desikachar (1986) reported changes in lysine, tryptophan, threonine and methionine during sprouting of millets. After malting, lysine and tryptophan increased from 3.5 to 4.0/100 and 1.3 to 1.5/100 g protein, respectively. Mibithi et al. (2000) have also reported that the sulfur containing amino acids (methionine and cysteine) and lysine increased in finger millet during sprouting. Rao (1994) found that malting increased PER of brown and white varieties but the increase was significant for white varieties only. Contrary to this Malleshi and Desikachar (1986) reported a significant improvement in protein efficiency ratio from 0.9 to 1.06 in brown finger millet varieties upon 48 h of sprouting. Losses in minerals have been reported due to malting and germination. Rao (1994) reported that total iron decreased in brown finger millet from 4.4 to 1.8 mg/100g and in white finger millet from 12.0 to 2.8 mg/100g. Similarly, Hemalanini et al. (1980) have reported that malted finger millet flour resulted in 32, 26 and 33% losses in calcium, phosphorous and iron, respectively. Such losses have been observed, due to removal of seed coat of finger millet grain. Sprouted finger millet contained 323.85 mg calcium, 230 mg phosphorous and 5 mg iron. Ionisable iron (27.1 and 55%) and soluble zinc (81 and 25%) contents increased significantly after malting, in brown and white finger millet (Rao, 1994). Deosthale (2002) reported ionisable iron content to be 88.3% at pH 7.5 in malted finger millet as compared to 7.4% in raw finger millet. Mamiro et al. (2001) reported that germination of finger millet for 48 h has significantly increased the *in vitro* extractability of calcium, iron and zinc. Rao (1994) found that malting decreased the tannin by 54% in brown finger millet and phytin phosphorous by 58 and 65% in brown and white finger millet, respectively. On malting, loss of phytate in finger millet was observed from 41 to 33% (Deosthale, 2002 and Mamiro et al., 2001). During sprouting of finger millet, growth of lactic acid bacteria, a desirable microflora has been reported. The associated changes are beneficial in the development of traditional foods (Varadaraj and Horigane, 1998).

COMPOSITE FLOURS OF MILLETS

Composite flour technology is initially referred to process of mixing wheat flour with cereal and legume flour for making bread and biscuits. However, the term can also be used with regard to mixing of non-wheat flours, roots and tubers or other raw materials (Dendy, 1992). Composite flour technology makes it possible to blend, mix or fortify one food material with others so that the resulting fortified mix has not only better nutritional quality but also the necessary attributes for consumer acceptance (Lupien, 1990).

Vaidehi (1997) prepared composite flour by adding 5 to 10% defatted soy flour with *ragi* flour. Khetrapaul et al. (2003) prepared chapattis by fortifying wheat flour with soy flour and pearl millet flour and found out a significant increase in protein content of developed *chapati* by 28.61% and crude fibre content by 26.73% when compared with control *chapatis*. Mittal (2002) prepared various convenience mixes using finger millet and developed various food products viz *mathri*, *sevain*, *kachari*, *kachauri*, *laddu*, *cheela*, biscuits and *halwa* and found them to be nutritionally superior than their respective controls. Singh and Srivastava (2007) developed iron rich biscuits using finger millet which can be effectively used for supplementary feeding programs.

CONCLUSION

Cereals and millets constitute a major component of diet consumed in developing countries like India. Finger millet is an important staple food in parts of eastern and central Africa and India. It is non acid forming food and easy to digest. It is considered to be one of the least allergic and most digestible grains available and is a warming grain so it helps to heat the body in cold or rainy season. However, the use of finger millet is limited due to coarse nature of the grain. It has high fibre content and outer cover of the grain is thick, which makes its processing difficult and gives a poor sensory quality. Lack of adequate marketing avenues of these crops has also led to their rapid decline both in production and consumption.

Also, an increasing taste for mill-polished rice is out competing these mountain crops. It is remarkable that despite the grain being an ancient food, research on millet and its food value is in its infancy and its potential vastly untrapped. Finger millet grain is highly nutritious, being richer in protein, fat and minerals especially calcium and iron compared to rice. Composite flour technology holds excellent promise for developing countries. Although actual consumer trials have been rare, products made with composite flours have been well accepted in Colombia, Kenya, Nigeria, Senegal, Sri Lanka and Sudan. The products made from composite flours are nutritionally superior to their respective controls and can be successfully used for supplementary feeding programmes. Efforts should be made to educate people about nutritive value and health benefits of finger millet and its food products.

REFERENCES

- Agte V, Joshi SR (1997). Effect of traditional food processing on phytate degradation in wheat and millets. *J. Agric. Food. Chem.*, 45 (5): 1659-1661.
- Aliya SQ, Geervani P (1981). An assessment of the protein quality and vitamin B content of commonly used fermented products of legumes and millets. *J. Sci. Food. Agric.* 32: 837-842.
- Antony U, Chandra TS (1998). Antinutrient reduction and enhancement in protein, starch and mineral availability in fermented flour of finger millet (*Eleusine coracana*). *J. Agric. Food Chem.*, 46 (7): 2578-2582.
- Antony U, Chandra TS (1999). Enzymatic treatment and use of starters for the nutrient enhancement in fermented flour of red and white varieties of finger millet (*Eleusine coracana*). *J. Agric. Food Chem.*, 47 (5): 2016-2019.
- Antony U, Sriprya G, Chandra TS (1996). Effect of fermentation on the primary nutrients in finger millet (*Eleusine coracana*). *J. Agric. Food Chem.*, 44: 2616-2618.
- Asquith TN, Butler LC (1986). Interaction of condensed tannins with selected proteins. *Phytochemistry*. 25: 1591-1593.
- Babu B V, Ramana T, Radhakrishna TM (1987). Chemical composition and protein in hybrid varieties of finger millet. *Indian J. Agric. Sci.*, 57 (7): 520-522.
- Baker RD (1996). Millet production. Guide A-414. At: <http://www.google.com>. p. 6.
- Basappa SC, Somashekar D, Agarwal R, Suma K, Bharthi K (1997). Nutritional composition of fermented ragi (chhang) by phab and defined starter cultures as compared to unfermented ragi (*Eleusine coracana* G.). *Int. J. Food Sci. Nutr.*, 48 (5): 313-319.
- Bhaskarachary K (2001). Food based strategy for combating vitamin A deficiency. *Nutrition News*. 21 (2): 1-4.
- Bhatt A, Singh V, Shrotria PK, Baskheti DC (2003). Coarse Grains of Uttaranchal: Ensuring sustainable Food and Nutritional Security. *Indian Farmer's Digest*. pp. 34-38.
- Bookwalter GN, Lyle SA, Warner K (1987). Millet processing for improved stability and nutritional quality without functionality changes. *J. Food Sci.*, 52 (2): 399-402.
- Davidek J, Velisek J, Pokorny J (1990). Chemical changes during food processing. New York, Tokyo, Elsevier Amsterdam-Oxford. p.448
- Dendy DAV (1992). Composite flour past, present and the future: a review with special emphasis on the place of composite flour in the semi-arid zones. In: Gomez M I, House L R, Rooney L W, Dendy D A V eds. Utilization of sorghum and millets. Oxford, C.A.B. International. pp. 67-73.
- Deosthale YG (2002). The nutritive value of foods and the significance of some household processes. <http://www.unu.edu>. p. 6
- Desikachar HSR (1975). Processing of maize, sorghum and millets for food uses. *J. Sci. Ind. Res.*, 34: 231.
- FAO (1968). Cereal and Grain Products. In: Food composition table for use in Africa. U.S. department of health, education and welfare, Bethesda MD 2001 and FAO, Rome, Italy. pp. 12-24.
- FAO (1991). Amino Acid Scoring Pattern. In: Protein quality evaluation, FAO/WHO Food and Nutrition Paper, Italy. pp. 12-24.
- Frazier WC, Westhoff DC (1986). Food Microbiology. New Delhi, Tata McGraw Hill Publishing Company Limited. 382 p.
- Gahlawat P, Sehgal S (1994). Protein and starch digestibility and iron availability in developed weaning foods as affected by roasting. *J. Hum. Nutr. Dietet.*, 7(2): 121-126.
- Gautam R (2000). Bole-bisrae motae anaaj, kethi (10): 14-17.
- Geetha C, Parvathi P (1990). Hypoglycemic effect of millet incorporated breakfast items on selected non-insulin dependent diabetic patients. *Indian J. Nutr. Dietetics*, 27: 316-320
- Geervani P, Vimala V, Uma Pradeep K, Rama Devi M (1996). Effect of processing on protein digestibility biological value, and net protein utilization of millet and legume based infant mixes and biscuits. *Plant Foods Hum. Nutr.*, 49: 221-227.
- Gomez M I (1993). Preliminary studies on grain quality evaluation for finger millet as a food and beverage use in the southern African region. In: Advances in small millets. Riley KW., Gupta SC, Setharam A, Mushong, JN New Delhi, India, Oxford and IBH Publishing. pp. 289-296.
- Gopalan C, Ramshashtri B V, Balasubramanian SC (1999). Revised and updated by Narasinga Rao BS, Deosthale YG, Pant KC, Nutritive value of Indian foods. Hyderabad, NIN, p.156
- Gopaldas T, Inamdar F, Patel J (1982). Malted versus roasted, young child mixes: viscosity, storage and acceptability trials. *Indian J. Nutr. Dietet.*, 19: 327-336.
- Graf E, Empson KL, Faton JW (1987). Phytic acid. A natural antioxidant. *J. Biol. Chem.*, 262 (24): 11647-11650.
- Hadimani NA, Malleshi NG (1993). Studies on milling physico-chemical properties, nutrient composition and dietary fibre content of small millets. *J. Food Sci. Technol.*, 30 (1): 17-20.

- Hamad AM, Fields ML (1979). Evaluation of protein quality and available lysine of germinated and fermented cereals. *J. Food Sci.*, 44: 456-458.
- Haug W, Lantzsich H J (1983). Sensitive method for the rapid determination of the phytate in cereals and cereal products. *J. Sci., Food Agric.*, 34: 1423-1426.
- Hemanalini G, Umapathy KP, Rao JR, Saraswathi G. (1980). Nutritional evaluation of sprouted ragi. *Nutr. Rep. Int.*, 22(2): 271-277.
- Huffman S L, Martin L H (1994). First feedings: Optimal feeding of infant and toddlers. *Nutr. Res.*, 14: 127-159.
- Hulse JH, Laing EM, Pearson OE (1980). Sorghum and the millets: their composition and nutritive value. London, Academic Press. p. 997
- Indira R, Naik MS (1971). Nutrient composition and protein quality of some minor millets. *Indian. J. Agric. Sci.*, 41 (10): 795-797.
- Jideani I A, Takeda Y, Hizurri S (1996). Structure and physico-chemical properties of starches from acha (*Digitaria exilis*) iburu (*D. iburu*) and tomba (*Eleusine coracana*). *Cereal Chem.*, 73 (6) 677-685.
- Joshi HC, Katoch KK (1990). Nutritive value of millets: A comparison with cereals and pseudocereals. *Himalayan Res. Dev.*, 9: 26-28.
- Kamath MV, Belavady B (1980). Unavailable carbohydrates of commonly consumed Indian foods. *J. Sci. Food Agric.*, 31: 194-202.
- Krantz ME, Panaari S, Colgate S (1983). "Sarbotan pitho". a home prepared weaning food for Nepal. Hoviprep monograph series no. 1. UNICEF/ US agency for international development. International Food and Nutrition Programme. p. 59
- Lewis KD, Lorenz K, Tribelhorn R (1992). Puffing quality of experimental varieties of proso millets (*Panicum miliaceum*). *Cereal Chem.* 69 (4): 359-365.
- Lupien JR (1990). Sorghum and millets in human nutrition. FAO, ICRISAT. At ao.org. p.86
- Madhavi M, Vaidehi M P (1990). Fermented beverages from minor millets, their acceptability and chemical composition. *Beverage Food World.* 12: 30-32.
- Malleshi NG, Desikachar HSR (1986). Influence of malting conditions on quality of finger millet. *J. Inst. Brew.*, 92: 81.
- Malleshi NG, Desikachar HSR (1986). Nutritive value of malted millet flours. *Plant Foods Hum Nutr.*, 36: 191-196.
- Malleshi NG (1996). Processing of small millets for food and industrial uses. In: Proceedings of first international small millet workshop, Bangalore, October 29-November 2, 1986. Small millets in Global Agriculture. Seetheram, A; Railey KW, Harinarayana G (eds). New Delhi, Oxford and IBH. pp. 321-329.
- Malleshi NG (1997). Small millets-potential and prospects for preparation of value added food products. National seminar on small millets, extended summaries. ICAR and Tamil Nadu Agricultural University. 23-24 April. p. 109-111.
- Malleshi NG, Desikachar HSR (1981). Varietal differences in puffing quality of ragi (*Eleusine coracana*). *J. Food Sci. Technol.*, 18: 30.
- Mamiro PRS, Vancamp J, Mwiky SM, Huyghraert A (2001). In vitro extractability of calcium, iron and zinc in finger millet and kidney beans during processing. *J. Food Sci.*, 66 (9): 1271-1275.
- Marimurthu R, Rajagopalan R (1995). Protein stability in ragi. *Madras J.*, 82 (11): 616-617.
- Mbithi-Mwikya S, Ooghe W, Van Camp J, Nagundi D, Huyghebaert A (2000). Amino acid profile after sprouting, Autoclaving and lactic acid fermentation of finger millet (*Eleusine coracana*) and kidney beans (*Phaseolus vulgaris* L.) *J. Agric. Food Chem.*, 48 (8): 3081-3085.
- Mittal M (2002). Development of finger millet and barnyard millet based convenience mixes for food products and their evaluation for nutritional quality, storage stability and acceptability. Thesis. Ph.D. G.B. Pant Univ. of Agric and Technol. Pantnagar. p. 260
- Murlikrishna G, Malleshi NG, Desikachar HSR, Tharanathan RN (1986). Effect of popping on the properties of some millet starches. *Starch*, 38(2): 48-51.
- Mushtari BJ (1998). Nutritive value of Ragi (*Eleusine coracana* Gaertn) before and after malting. *Beverage Food World*, 25 (5): 38-42.
- Nap E (1996). Finger millet. In: *Lost Crops of Africa: Volume I: Grains.* National Academy Press. pp. 39-58.
- Nirmala M, Subba Rao MVST, Muralikrishna G (2000). Carbohydrates and their degrading enzymes from native and malted finger millet (ragi, *Eleusine coracana* Indaf-15) *Food Chem.*, 69: 175-180.
- Pore MS, Magar NG (1979). Nutrient composition of hybrid varieties of finger millet. *Ind. J. Agric. Sci.*, 49 (7): 526-531.
- Raboy V (2000). Low phytic acid grains. *Food Nutr. Bull.*, 21(4): 423-427.
- Rajyalakshmi P, Geervani P (1990). Studies on tribal foods of south India: effect of processing methods on the vitamin and in vitro protein digestibility of cereals/ millets and legumes. *J. Food Sci. Technol.* 27: 260-263.
- Ramulu P, Udayaekhara Rao P (1997). Effect of processing on dietary fibre content of cereals and pulses. *Plant Foods Hum. Nutr.*, 50: 249-257.
- Rao U, Deosthale YG (1988). IN vitro availability of iron and zinc in white and coloured ragi (*Eleusine coracana*): A role of tannin and phytate. *Plant Foods Hum. Nutr.* 38: 35-41.
- Rao BSN, Prabhavati T (1982). Tannin content of foods consumed in India and its influence on ionisable iron. *J. Sci. Food Agric.*, 33: 89-96.
- Rao BSN, Prabhavati T (1978). An in vitro method for predicting the bioavailability of iron from foods. *Am. J. Clin. Nutr.*, 31: 169-175.
- Rao KB, Mithyantha MS, Devi LS, Perur NG (1973). Nutrient content of some new ragi varieties. *Mysor J. Agric. Sci.*, 7: 562-565.
- Rao PU (1994). Evaluation of protein quality of brown and white ragi (*Eleusine coracana*) before and after malting. *Food Chem.*, 51: 433-436.
- Ravindran G (1991). Studies on millets: proximate composition, mineral composition, phytate, and oxalate contents. *Food Chem.*, 39 (1): 99-107.
- Ravindran G (1992). Seed proteins of millets: amino acid composition, proteinase inhibitors and in vitro digestibility. *Food Chem.*, 44 (1): 13-17.
- Roopa MR, Urooj A, Puttaraj S (1998). Rate of invitro starch hydrolysis and digestibility index of ragi-based preparations. *J. Food Sci. Technol.*, 35 (2): 138-142
- Samantaray GT, Samantaray BK (1997). X-ray Diffraction Study of Ragi (*Eleusine coracana*) Starch. *J. Food. Sci. Technol.*, 34(4): 343-344.
- Seetharam A (2001). Annual Report 2000-01 All India Coordinated Small Millets Improvement Project, Bangalore. pp 1-28.
- Senappa M (1988). Sorghum and millets in east Africa with reference to their use in weaning foods In: Proceedings of workshop, Nairobi, Kenya, 12-16 October, 1987, Improving young child feeding in eastern and southern Africa: household level food technology. Alnwick D, Moses S, Schmidt O G eds. Ottawa, International Development Research Centre. pp. 39-54.
- Sharma K (2001). Bhaut kuch haat ke khayeeega kal. *Avishkar* October. 448-455.
- Shukla SS, Gupta OP, Suarkar NJ, Tomar AK, Sharma YK (1986). Malting quality of ragi varieties-nutrient and mineral composition of their malts. *Indian J. Nutr. Diet.*, 28 (8): 223-227.
- Singh P, Srivastava S (2007). Development and quality evaluation of Iron Rich Biscuit Mixes Using Finger Millet. *J. Community Mobilization Sustainable Dev.*, 2(1): 89-94.
- Singh P, Srivastava S (2006). Nutritional composition of sixteen new varieties of finger millet. *J. Community Mobilization Sustainable Dev.*, 1(2): 81-84.
- Sridhar R, Lakshminarayana G (1994). Content of total lipids and lipid classes and composition of fatty acids in small millets: foxtail (*Setaria italica*), proso (*Panicum miliaceum*), and finger (*Eleusine coracana*). *Cereal Chem.*, 71 (4): 355-358.
- Srivastava PP, Das H, Prasad S (1994). Effect of roasting process variables on hardness of Bengal gram, maize and soybean. *J. Food Sci. Technol.*, 31 (1): 62-65.
- Thompson LU (1993). Potential health benefits and problems associated with anti-nutrients. *Food Res. Int.*, 26: 131-149.
- Vadivoo AS, Joseph R, Garesan NM (1998). Genetic variability and calcium contents in finger millet (*Eleusine coracana* L.Gaertn) in relation to grain colour. *Plant Foods Hum. Nutr.*, 52 (4): 353-364.
- Vaidehi MP (1997). Traditional foods from ragi-composition flours and convenient foods for better nutrition and health. In: National seminar on small millets, extended summaries by ICAR and Tamil Nadu Ag. Univ. April 23rd-24th, pp. 126-127.
- Varadaraj MC, Horigane A (1998). Biochemical characteristics and microbial profile during sprouting process in grains of *Eleusine*

coracana L. (finger millet). J. Agric Food Chem., 46: 1719-1726.

Vijayakumari J, Mushtari Begum J, Begum S, Gokavi S (2003) Sensory attributes of ethnic foods from finger millet (*Eleusine coracana*). Recent Trends in Millet Processing and utilization. In: Proceeding of National Seminar on Processing and Utilization of Millet for Nutrition Security held on October 7-8,2003 organized under RNPSI (NATP) at CSHAV, Hisar. pp. 7-12.

Wankhede DB, Shehnaj A, Raghavendra Rao MR (1979) Carbohydrates composition of finger millet (*Setaria italica*). Plant Foods Hum. Nut., 28: 293-303.