Significance of small millets in nutrition and health - A review

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Received: 25-09-2017 Accepted: 12-12-2017

ABSTRACT

Small millets are a group of six crops comprising of finger millet, kodo millet, little millet, foxtail millet, barnyard millet and proso millet. They are considered as nutri-cereals and are source of food, feed and fodder. The crops are grown in a variety of agro-ecological situations including plains, coast and hills as well as in diverse soils and varying rainfall. They are known for resilience and drought enduring capacity and are relatively less prone to major pests and diseases. The richness in calcium, dietary fiber, polyphenol and protein contents in millets make them unique among the cereals. Generally, millets show significant amounts of amino acids like methionine and cystine and also have high fat content than rice and maize. Millets have nutraceutical properties in the form of antioxidants which prevent deterioration of human health such as lowering blood pressure, risk of heart disease, prevention of cancer and cardiovascular diseases, diabetes, decreasing tumor cases etc. The contribution of millets to national food security and their potential health benefits, millet grain is now receiving increasing interest from food scientists, technologists and nutritionists.

Key words: Antioxidants, Gluten-free, Health benefits, Millets, Nutrition, Photochemical.

Small millets are warm-season cereals largely grown in the semi arid tropical regions of Asia and Africa, under rainfed farming systems (Rai et al., 2008). Small millets include finger millet (Eleusine coracana), kodo millet (Paspalum scrobiculatum), proso millet (Panicum miliaceum), foxtail millet (Setaria italica), little millet (Panicum sumatranse) and barnyard millet (Echinochloa frumentacea).

Small millets grains are rich in dietary energy, vitamins, several minerals (especially micronutrients such as iron, calcium and zinc), insoluble dietary fiber and phytochemicals with antioxidant properties (Bouis, 2000) and are considered as “Nutri-cereals”. They are rich in compounds that help against several chronic diseases like ischemic strokes, cardiovascular diseases, cancers, obesity and Type II diabetes (Jones et al., 2000, Jones, 2006).

Millets are important crops of Asia and Africa (especially in India, Nigeria and Niger), with 97% of millet production in developing countries (McDonough et al., 2000). Millets, considered as important food staples in human history. They have been in cultivation in East Asia for the last 10,000 years. India is the world’s largest producer of millet (Lu H. et al., 2009). The total area of small millets in India is around 1.92 m ha, of which finger millet alone occupies 1.19 m ha. Five yearly analysis of data indicate a steady decline in the area of small millets other than finger millet from 5.29 to 0.93 m ha. The production of finger millet fluctuated between 1.61 m t in 1951-55 and 1.94 m t in 2011-15 with high of 2.65 m t during 1976-80 despite huge reduction in area. This was achieved because of doubling of productivity of finger millet from 704 kg/ha to 1631 kg/ha due to wide spread cultivation of high yielding blast tolerant varieties (www.aicrpsm.res.in).

Knowing the importance and to promote cultivation and consumption of small millets, government of India introduced a scheme on “Initiative for Security through Intensive Millet Promotion” (INSIMP) in 2011-12. These crops have been included as an integral part of National Food Security Mission during XIIth plan under coarse cereals and they have also been included in public distribution system at subsidized rates under National Food Security Act (INSIMP Operational Guidelines 2011-12). In India, to promote research on small millets “All India Coordinated Small millets Improvement Project” (AICSMIP) was established under IDRC project in the year 1986 with headquarters at The University of Agricultural Sciences, GKVK, Bengaluru. It has the responsibility to plan, coordinate and execute the research programmes to augment the production and productivity of six small millets. The mandated research in the project is carried out through network of 13 centres located in State Agricultural Universities in the states, ICAR institutes and 21 cooperating centres.

Livestock is a backbone of agrarian economy of arid and semi arid regions of country wherein millet crops have more food feed and fodder values. In addition there has been emergence of alternate industrial uses for these potential value addition in these neglected crops owing to their rich nutritional profile with the advancement in...
Bioactive compounds in small millets: Several constituents of cereals have biological activity in addition to the nutrition that they provide. The grains of small millets are rich in phytochemicals. Phytochemicals include tannins, phenolic acids, coumarins, flavonoids and alky1 resorcinol. Phenols are responsible for the flavor, texture, color, taste and oxidative stability of plant foods (Naczk and Shahidi, 2004). They have nutraceutical properties and are generally located in bran. Millet is more than just an interesting alternative to the more common grains. The grain is also rich in phytochemicals including phytic acid, which is believed to lower cholesterol and phylate, which is associated with reduced cancer risk (Coulibaly et al., 2011). These health benefits have been partly attributed to the wide variety of potential chemo preventive substances called phytochemicals, including antioxidants present in high amounts in foods such as millets (Izadi, et al., 2012).

Chandrasekara and Shahidi (2010) reported in their studies on free – radical quenching activity of finger millet, 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 activity (Devi et al., 2014; Quesad et al., 2011; Kamara et al., 2012).

Millets extract from the seed coat were reported to have shown high antibacterial and antifungal activity compared to whole flour extract due to high polyphenols content in seed coat (Vishwanath et al., 2009; Xu et al., 2011). The primary function of tannins is to protect grains from molds and protect them from deterioration (Waniska, 2000) though they are also responsible for the astringency of the grain. Tannins decrease digestibility of the proteins, carbohydrates and minerals and also possess anti-carcinogenic, gastro-protective, anti-ulcerogenic and cholesterol lowering properties (Prior and Gu, 2005; Dykes and Rooney 2006).

Millets as probiotic and prebiotic: Probiotics are “living microorganisms” which when administered in adequate amounts confer a health benefit on the host (Abd El-Salam et al., 2012). Fermented millet products act as a natural probiotic treatment for diarrhea in young children (Lei et al., 2006). In Africa, millet Koko is prepared in the form of fermented millet porridge and drink (Lei and Jacobsen M. 2004). Prebiotics are non digestible food ingredients that beneficially affect the host by selectively stimulating the growth and activity of one or a limited number of bacteria in the colon (Laminu et al., 2011). Millets whole grain also shows prebiotic activity, which helps to increase the population of bacteria’s that plays a key role to promote digestion. Malting reduces important beneficial biochemical changes in the millet grain.

Nutritional significance of small millets: Nutritional composition of some of the major cereals including coarse cereals and millets (per 100g) is presented as below (Gopalan et al., 2009).

Millets are nutritionally comparable or even superior to major cereals such as wheat and rice, owing to their higher levels of protein with more balanced amino acid profile (good source of methionine, cystine and lysine).

The main constituents of millet kernel are seed coat (tests), embryo and endosperm. Among several varieties of finger millet such as yellow, white, tan, red, brown, only the red colored are cultivated extensively throughout the world. The presence of five layered tests in finger millet makes it unique compared to other millets such as foxtail millet, kodo millet and proso millet. This could be one of the possible reasons for the higher dietary fiber content in the finger millet (FAO 1995).

The nutraceutical importance of finger millet lies in its high content of calcium (344mg/100g), protein (6% to

<table>
<thead>
<tr>
<th>Crop/nutrient</th>
<th>Protein %</th>
<th>Fat %</th>
<th>Fiber (g)</th>
<th>Minerals (g)</th>
<th>Iron (mg)</th>
<th>Calcium (mg)</th>
<th>Phosphorus (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>6.8</td>
<td>0.5</td>
<td>5.2</td>
<td>0.7</td>
<td>1.0</td>
<td>9</td>
<td>143</td>
</tr>
<tr>
<td>wheat</td>
<td>11.8</td>
<td>1.5</td>
<td>12.9</td>
<td>2.7</td>
<td>8.9</td>
<td>14</td>
<td>290</td>
</tr>
<tr>
<td>Finger millet</td>
<td>7.3</td>
<td>1.3</td>
<td>18.6</td>
<td>14.0</td>
<td>3.3</td>
<td>14</td>
<td>283</td>
</tr>
<tr>
<td>Foxtail millet</td>
<td>13.2</td>
<td>4.3</td>
<td>14.0</td>
<td>1.9</td>
<td>3.3</td>
<td>14</td>
<td>283</td>
</tr>
<tr>
<td>Proso millet</td>
<td>12.5</td>
<td>1.1</td>
<td>12.0</td>
<td>2.6</td>
<td>1.5</td>
<td>17</td>
<td>220</td>
</tr>
<tr>
<td>Kodo millet</td>
<td>8.3</td>
<td>1.4</td>
<td>15.0</td>
<td>2.6</td>
<td>1.5</td>
<td>17</td>
<td>220</td>
</tr>
<tr>
<td>Little millet</td>
<td>8.7</td>
<td>5.3</td>
<td>12.0</td>
<td>4.4</td>
<td>5.0</td>
<td>20</td>
<td>280</td>
</tr>
<tr>
<td>Barnyard millet</td>
<td>11.6</td>
<td>5.8</td>
<td>13.5</td>
<td>4.4</td>
<td>5.0</td>
<td>20</td>
<td>280</td>
</tr>
</tbody>
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14%), dietary fiber (18%), carbohydrates (65% to 75%), minerals (2.5% to 3.5%), phytates (0.48%), tannins (0.61%), phenolic compounds (0.3 to 3.00%) and trypsin inhibitory factors, and is recognized for its health beneficial effects, such as anti diabetic, anti-tumorogenic, anti-diarrheal, anti- ulcer, anti-inflammatory, anti-oxidant and anti-microbial properties (Devi et al., 2014; Supriya et al., 1996; Chetan et al., 2007).

Finger millet is milled with the testa which is generally rich in dietary fiber and micronutrients to prepare flour and the whole meal is utilized in the preparation of traditional foods, such as roti (unleavened breads), ambali (thin porridge) and muddle (dumplings) (Devi et al., 2014). On daily consumption of whole grain of finger millet and its products can protect against the risk of cardiovascular diseases, Type II diabetes and gastrointestinal cancers and other health issues (McKeown et al., 2002). The dietary fiber, minerals, phenolics and vitamins concentrated in the outer layer of the seed coat form the part of the food and offer their nutritional and health benefits (Antony et al., 1998).

Barnyard millet is a multipurpose crop which is cultivated for food and fodder. It is a good source of protein (11.6%), which is highly digestible and is an excellent source of dietary fiber (13.5 g/100g) with good amount of soluble and insoluble fractions (Hadimani and Malleshi 1993). The carbohydrate content of barnyard millet is low and slowly digestible, which makes the barnyard millet a nature’s gift for the modern mankind who is engaged in sedentary activities (Veena et al., 2005). Barnyard millet is most effective in reducing blood glucose and lipid levels.

Little millet is rich in cholesteral, when consumed increases good cholesterol in the body, suitable for growing kids and strengthens the body. Its complex carbohydrate digests slowly which is very helpful for diabetic patients (Gayatri 2015). It contains high phosphorous (220 mg/100g) and iron (9.3 mg/100g). It is especially good for people has low body mass. Few recipes which can be prepared using little millet are dosa, idli, pongal, kichadi (Nutritive value of Indian foods NIN 2007).

In Africa and India, proso millet is used as a staple food for thousands of years (Bough et al., 1986). In China, it was the prevalent grain before rice became the dominant staple (Bohle et al., 2003). In Europe, proso millet was one of the main cereals of Slavs. Proso millet is produced in China, Russia, India and countries of Eastern Europe and North America. In Western nations proso millet is of minor economic importance because of the great abundance of wheat, maize and other cereal crops (Delost-Levis et al., 1992). Therefore there the grain of proso millet is mainly used as bird feed. However in recent years, it started to become a more popular crop due to its high quality proteins. Grains are rich in minerals and vitamins and their nutritive parameters are minimally the same over better than common cereals (Seetharam, 1999). The most common protein level varies from 11.5 to 13% with maximum of about 17% (Geervani and Eggum 1989a; Dendy 1995.). Dried conditions cause an increase in protein but the quality of protein decreases (Kalinova and Moudry 2006). The dietary protein of proso millet plays an important role in cholesterol metabolism (Nishizawa and Fudamo 1995). Proso millet is rich in potassium as well as in iron and manganese (Ravindran 1991).

Kodo millet is nutritional grain and a good substitute to rice and wheat. The protein fiber and mineral content are much higher than the major cereals like rice. The kodo millet grain is composed of 8.3% protein. The major protein fraction in kodo millet is gluten (Sudharshana, et al., 1988). Kodo millet is an excellent source of fiber (15%) as opposed to rice (12.9%) and wheat (5.2%). Its flour has a gelatization temperature range of 13°C, which has less resistance to gelatinization (Shinoj et al., 2006) and incorporated in baking of bread and cakes, extrusion of cereal based products, gravy, soup, heat set gel, porridge, instant powders and modified flour and starches for specialty foods. As with other food grains, the nutritive value of kodo millet protein could be improved by supplementation with legume protein.

Apart from being a rich source of nutrients, kodo millet also contains high amounts of polyphenols, antioxidants, tannins, phosphorus and phytic acids. These anti nutrients form complexes with micronutrients such as iron, calcium and zinc and reduce their solubility and bio availability (Balasubramanian, 2013). The antioxidant activity of kodo millet decreases when the whole grain is dehulled and cooked (Chandrasekara et al., 2012).

Foxtail millet grain is rich in protein (12.3%) and iron (2.8mg/100g) as compared to rice (6.8% protein and 1.8mg iron/100g grain) and rich in fat 4.3% which is superior to rice and wheat. The grain is good source of beta – carotene, which is the precursor of Vitamin A (Murugan and Nirmalakumari, 2006). Foxtail millet is mixed with legumes to make porridge and also mixed with soybean to make mixed flour. Foxtail millet has low glycemic index (GI), used for preparation of low GI biscuits and burfi, a sweet product and it is an ideal for people suffering from diabetes (Thathola et al., 2010; Anju and Saritha 2010). Foxtail millet is also fermented to make vinegar, yellow wine, maltose, beer and other related products. It is also used for feeding cage birds and by-product of the foxtail millet is used as animal feed.

**Some potential health benefits of millets**

**Millet for diabetes:** Lower incidences of diabetes have been reported in millet-consuming population. Millet phenolics inhibits like alpha – glucosidase, pancreatic amylase reduce postprandial hyper glycemia by partially inhibiting the enzymatic hydrolysis of complex carbohydrates (Shobana et al., 2009). Inhibitors like aldose reductase prevents the
accretion of sorbitol and reduce the risk of diabetes induced cataract diseases (Chethan et al., 2008a). Finger millet feeding to the diabetic animals for four weeks, controlled the glucose level and improve the anti oxidant status, which hasten the dermal wound healing process (Rajasekaran et al., 2004). Dehulled and heat treated banyard millet has been reported beneficial for Type II diabetes in which low glycemic index for dehulled millet (50.0) and heat treated was recorded (Ugare et al., 2011).

**Millet and aging:** The chemical reaction between amino group of proteins and the aldehyde group of reducing sugars, termed as non enzymatic glycosylation, is a major factor responsible for the complications of the diabetes and aging. Millets are rich in anti oxidants and phenolics like phytates, phenols and tannins which can contribute to the anti oxidant activity important in health, aging and metabolic syndrome (Hegde et al., 2002).

**Millet against cancer and celiac disease:** Millets are known to be rich in phenolic acids, tannins and phytates that act as “anti nutrients”. However these anti nutrients reduce the risk of colon and breast cancer in animals. It is demonstrated that millet phenolics may be effective in the prevention of cancer initiation and progression in vitro (Chandrasekara et al., 2011). The overall growing demand for novel, tasty and “healthy” foods together with the increasing number of people suffering from celiac disease has given birth to a new market consisting of cereal products made from grains other than wheat and rye. In this challenging market, oat, sorghum and millet have gained a special position (Angioloni and Collar 2012). Celiac disease is an immune – mediated enteropathy triggered by the ingestion of gluten in genetically susceptible individuals. However, since millets are gluten free, they have considerable potential in foods and beverages that can be suitable for individuals suffering from celiac disease (Taylor et al., 2006; Taylor and Emmambux 2008). Therefore millet grains and their functions have the potential to be useful in cancer prevention and for producing food products for celiac people.

**Millet for cardiovascular disease:** Obesity, smoking, unhealthy diet and physical inactivity increase the risk of heart attacks and strokes. Most of the world countries face high and increasing rates of cardiovascular disease. It has been demonstrated that rats fed with diet of native and treated starch from barnyard millet had the lowest blood glucose, serum cholesterol and triglycerides compared with rice and other minor millets (Kumari and Thayumanavan 1997). Finger millet and proso millet may prevent cardiovascular disease by reducing plasma tri glycerides in hyper lipidemic rats (Lee et al., 2010).

From the literature reviewed above, it can be observed that nutritive value and potential health benefits of millet grains were found comparable to major cereals such as wheat, rice and maize. Diversification of food production must be encouraged both at national and household levels in tandem with increasing yields. Providing more healthy and traditional whole-grain and multigrain substitutes for refined carbohydrates can be one important aspect of therapeutic dietary modification and promoting utilization of minor-grain foods (Singh and Raghuvanshi 2012).

**CONCLUSION**

Millets are staple food source, which are not only providing major nutrients like protein, carbohydrates, fats etc but also provide ample of vitamins and minerals. In developing countries malnutrition and various health problems like obesity, diabetes, cardiovascular diseases, cancer, celiac disease etc are most prominent because of inadequate supply of nutrition. This is mainly due to the lack of awareness and knowledge among the people in choosing the kind of food, especially the small millets. Millets are easily available and cheap in cost. Millets contains many major and minor nutrients like carbohydrates, protein, fat, dietary fiber, vitamins and minerals as well as antioxidants and phytochemicals. The importance of this study undertakes to concern and to develop specific agenda for these crops which must be recognized as an important food and to introduce the millets as a nutritious food for fulfillment of the nutritional need of the global population and also to find ways to consume the millets effectively and to reduce the problems of malnutrition and other health problems.

The study emphasized on nutraceutical properties of millets and the application of millets as alternative to cereals, potentially healthy to elaborate therapeutic food products like protein and energy rich diet, diet for diabetes and for the gluten free diet. The study also showed that millets are used as “food medicine” as millets are good source of antioxidants such as phenolic acids and glycated flavonoids. Millet foods are also characterized to be a potential probiotic and can enhance the viability of probiotics with potential health benefits.

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American Journal of Food Technology, Volume 37 Issue 1, 2018

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