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Review Article

Nutraceutical and Food Processing Properties of Millets: A Review

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Abstract

Millet grains have substantial benefits as a draught resistant crop, yield good productivity in the areas with water scarcity, possesses remarkable edible & nutritive values, and ease of processing & food manufacturing. Agriculture & Food security policymakers of developing countries should give due attention in promoting the research work & projects for studying the processing, food manufacturing, improvement in nutritive values and potential health benefits of the millet grains to promote their utilization as food in respective countries. Most of the developing countries have already started working in the field of improvement of edible potential of millet grains. Millet oil could be a good source of linoleic acid and tocopherols. Millet is an alkaline forming grain that is gluten-free. Millets are also rich sources of phytochemicals and micronutrients, play many roles in the body immune system. 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. Other health benefits are increasing the time span of gastric emptying, provides roughage to gastro intestine. Millet is an alkaline forming food. Alkaline based diet is often recommended to achieve optimal health. In developing country, cereal-based foods have low bioavailability of minerals like iron, zinc initiate critical problem for infants and young children. Food processing techniques are used to enhance nutritional quality, improve the digestibility and bioavailability of food nutrients with reducing anti-nutrients. This study undertakes to concern and developing specific agenda for these crops which must be recognized as an important food and introduce the millets as a nutritious food, fulfillment of the nutritional need of global population and combat malnutrition.

Keywords: Phytochemicals; Anti-nutrients; Probiotic & prebiotic; Gluten-free

Introduction

Nutritional quality of food is the most important parameter for maintaining human health and complete physical well being. Since nutritional well being is the driving force for development and maximization of human genetic potential [1]. Dietary quality of food should be taken into consideration for maintaining overall maximization of human health and fitness to solving the problem of deep rooted malnutrition. Diversification of food production must be encouraged both at national and household level in tandem with increasing yields and household techniques [2]. Some of the agricultural foods are not using as human main food because of unawareness of people. Millets are one of them. Millets are being used as animal and bird feed. Millet has many nutritious and medical functions reported by Yang, et al. [3]. These are underutilized and neglected crop because of little knowledge to people and some critical problems like lower cooking quality, taste and low bioavailability of millets. These problems can be solved and make them valuable as food for poor families to combat malnutrition and important source of income.

Millet is a very important crop with following characteristics: millet is known to be a drought-resistant crop, resistance to pests and diseases, short growing season as compared to other major cereals [4]. Due to above mentioned advantageous characteristics; millet grains are receiving specific attention in the developing countries (like India, China & some countries from Africa Continent) in terms of utilization as food. Some developed countries are also giving due attention to millet grains in terms of its good potential in the manufacturing of bioethanol and biofilms [5]. Millets are important food crop in developing countries. Millets contain major and minor nutrients in remarkable amount. This study emphasized on millet recognized as high-energy nutritious food to help in reducing malnutrition, nourishing the common population and to help in preventing and curing the diseases like obesity, diabetes, CVD, etc. Millet is gluten-free food. Millet can be a substitute for celiac patients.

FAO, (2012) reported that traditional food processing (such as decortications, milling, germination, fermentation, malting roasting etc.) are commonly used for preparation of food products of millets to improve their edible, nutritional, and sensory properties [6]. But negative changes of millets are not avoidable because industrial method of processing are not well develop compare to other cereal. Mal, et al. suggested that millets can be source of value-added healthy food-products with different varieties for traditional and nontraditional millet users [7].

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Country	Production (Tonnes)	Footnote
India	10,910,000	
Nigeria	5,000,000	F
Niger	2,955,000	*
China	1,620,000	F
Mali	1,152,331	
Burkina Faso	1,109,000	*
Sudan	1,090,000	
Ethiopia	807,056	
Chad	582,000	*
Senegal	572,155	
World	29,870,058	A

Table 1: Top 10 Millet Producers – 2013.
No symbol: Official figure; *: Unofficial figure; F: FAO estimate; A: May includes official; semiofficial or estimated data

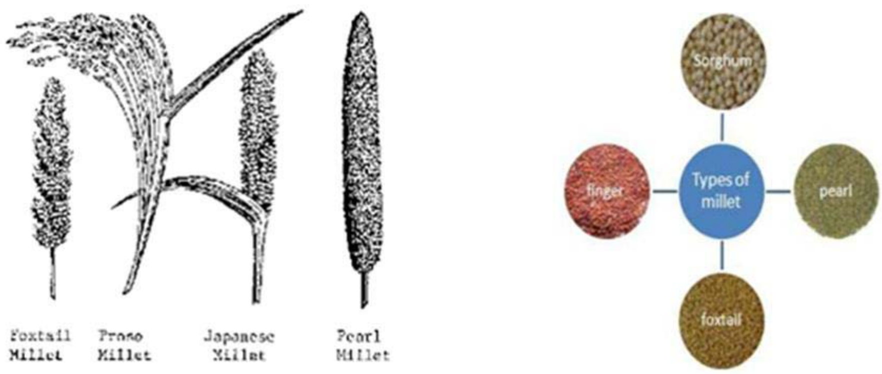

Figure 1: Types of Millets.

Production of Millets

Millets are important crops of Asia and Africa (especially in India, Nigeria and Niger), with 97% of millet production in developing countries [8]. Lu et al. reported that Millets, considered as important food staples in human history [9]. They have been in cultivation in East Asia for the last 10,000 years. India is the world's largest producer of millet. In the 1970s, India was used as a food staple among all millet crops. By the 2000s, the annual millet production had increased in India, yet per capita consumption of millet had dropped about 50 to 75%. As of 2005, most millet produced in India is being used for alternative implications such as alcohol production and livestock fodder [10]. Indian organizations are finding ways to enhance millet use as food to increase more production and found that some consumers prefer the taste of other grains (Table 1) [11].

Consumption of Millets in India

National Nutrition Monitoring Bureau [12] has reported that the consumption of millets was higher in the states of Gujarat (pearl millet, maize), Karnataka (finger millet), Maharastra (sorghum) but negligible in the states of Kerala, Orissa, West Bengal and Tamil Nadu where rice is the most consumed cereal. Cereals are being consumed as main staple by Indians that constitute 70-80% of the total energy intake [13]. Recent study by NNMB on dietary profile of urban Indians (from the Chennai Urban Rural Epidemiology Study (CURES)) revealed that only 2% of the total calories (6.7 g/d) were contributed by the millets [1].

Millets Varieties

Millets are different from one another by appearance, plant, grain type, maturity, morphological features etc. Millets are classified into two types, Major Millets and Minor Millets. Major millets are Pearl millet (Pennisetumglaucum), most widely used for human consumption [14], Foxtail millet (Setaria italic) [3], Proso millet or white millet (Panicummiliaceum) and Finger millet (Eleusinecoracana). Minor millets include Barnyard millet (Echinochloa spp.), Kodo millet (Paspalumscrobiculatum), Little millet (Panicumsumatrense), Guinea millet (Brachiariadeflexa), Browntop millet (Urochloa ramose), Teff (Eragrostistef), Fonio (Digitariaexilis), Sorghum (Sorghum spp.) and Job's tears (Coixlacrima-jobi) reported by Adekunle (Figure 1) [15].

Millets and its potential

Millets are tiny in size, round in shape and minor cereals of the small seeded-grass family ***(Poaceae)***. It is characterized by their remarkable ability to survive in less fertile soil, drought-resistant, resistance to pests and diseases, short growing season [4] and cultivated round the year and all over the world. The word millet is derived from the beginning of human civilization, millets are

	Protein (g)	Carbohydrates (g)	Fat (g)	Minerals (g)	Fiber (g)	Calcium (mg)	Phosphorous (mg)	Iron (mg)	Energy (Kcal)	Thiamin (mg)	Niacin (mg)
Finger	7.3	72	1.3	2.7	3.6	344	283	3.9	336	0.42	1.1
Sorghum	10.4	70.7	3.1	1.2	2.0	25	222	5.4	329	0.38	4.3
Pearl	11.8	67.0	4.8	2.2	2.3	42	-	11.0	363	0.38	2.8
Foxtail	12.3	60.2	4.3	4.0	6.7	31	290	2.8	351	0.59	3.2
Little	7.7	67.0	4.7	1.7	7.6	17	220	9.3	329	0.3	3.2
Kodo	8.3	65.9	1.4	2.6	5.2	35	188	1.7	353	0.15	2.0
Proso	12.5	70.4	1.1	1.9	5.2	8	206	2.9	354	0.41	4.5
Barnyard	6.2	65.5	4.8	3.7	13.6	22	280	18.6	300	0.33	4.2
Paddy Rice	6.8	78.2	0.5	0.6	1.0	33	160	1.8	362	0.41	4.3
Wheat	11.8	71.2	1.5	1.5	2.0	30	306	3.5	348	0.41	5.1

Table 2: Nutritional Benefits of Different Millets.

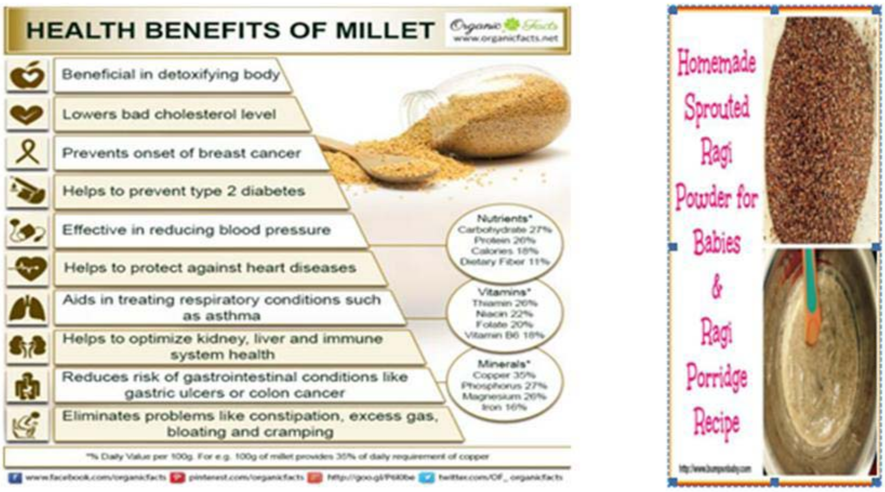

Figure 2: Health Benefits of Millets.

considered as first domesticated cereal [16]. Bhattacharjee, et al., [17] reported that India is the largest producer of pearl millet. Millets have uniqueness because of its richness in protein, calcium, dietary fibre and polyphenols [4]. Obilana & Manyasa [18] founded that millets contain significant amount of sulphur containing essential amino acids like methionine and cysteine.

Nutrient dense millets

Millets contain 60-70% carbohydrates, 7-11% proteins, 1.5-5% fat, and 2-7% crude fibre and are also rich in vitamins and minerals. They are excellent source of vitamin B, magnesium, and antioxidants. Millet is also a good source of other dietary minerals like manganese, phosphorus and iron. Millet proteins are good source of essential amino acids except lysine and threonine but are relatively high in sulphur containing amino acids methionine and cysteine [19]. Apart from this, some essential fatty acids like linoleic, oleic and palmitic acids found in free form and monogalactosul, diacylglycerols, digalactosyl diacylglycerols, phosphatidylethanolamine, phosphatdyl serine and phosphatidyl choline in the bound form present in millets [20]. Other fatty acids i.e. arachidic acid, behenic acid, erucic acid are found in trace amounts. Millet oil could be a good source of linoleic acid and tocopherols [21]. Millet is an alkaline forming grain that is gluten-free [22]. Vitamin B such as Niacin, folacin, riboflavin, and thiamine and phosphorus are present in millets that play a key role in energy synthesis in the body (Table 2).

Millets as a Healthy Food

Millets serve as a major food component specifically among the non affluent segments in their respective societies. Various traditional foods and beverages such as roti, bread (fermented or unfermented), porridge, snack and fast foods, baby foods, millet wine, millet nutrition powder etc are made up of millets [23].

Millets and Phytochemicals

Millets are also rich sources of phytochemicals and micronutrients. Phytochemicals such as phenolics (bound phenolic acid-ferulic acid, free phenolic acid-protocatechuic acid), lignans, β-glucan, inulin, resistant starch, phytates, sterols [24], tocopherol, dietary fiber [4] and carotenoids are present in millets. The main polyphenols are phenolic acids and tannins, while flavonoids are present in small quantities; they act as antioxidant and play many roles in the body immune system [25].

Millets as Probiotic and Prebiotic

Probiotics aid the existing flora or help repopulate the colon when bacteria levels are reduced by antibiotics, chemotherapy or disease. Probiotics are "living microorganisms" which when administered in adequate amounts confer a health benefit on the host [26]. Fermented millet products act as a natural probiotic treatment for diarrhea in young children [27]. In Africa, millet *koko* is prepared in the form of fermented millet porridge and drink [28] and lactic acid-fermented porridge [29].

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 [30]. Millet's whole grain also shows prebiotic activity, which helps to increase the population of friendly bacteria that plays a key role to promote digestion. Malting induces important beneficial biochemical changes in the millet grain.

Millets as Nutraceutical

The concepts of food consumption are changing from previous to present time. Previous emphasis has been on survival, hunger satisfaction, health maintenance and absence of adverse effects on health and current emphasis is on encouraging the use of nutraceutical foods which promise to promote better health and well being thus helping to reduce the risk of chronic diseases such as obesity, diabetes, CVD and cancer. Millets have nutraceutical properties in the form of antioxidants which prevent deterioration of human health [31].

Health Benefits of Millets

Millets have many nutraceutical properties that are helpful to prevent many health problems such as lowering blood pressure, risk of heart disease, prevention of cancer and cardiovascular diseases, decreasing tumour cases etc. Other health benefits are increasing the time span of gastric emptying, provides roughage to gastro intestine [32]. Millet is an alkaline forming food. Alkaline based diet is often recommended to achieve optimal health, meaning when it combines with digestive enzymes. The soothing alkaline nature of millet helps to maintain a healthy pH balance in the body, crucial to prevent illnesses (Figure 2).

Millets and diabetes

Lower incidences of diabetes have been reported in millet-consuming population. Millet phenolics inhibits like alpha-glucosidase, pancreatic amylase reduce postprandial hyperglycemia by partially inhibiting the enzymatic hydrolysis of complex carbohydrates [33]. Inhibitors like aldose reductase prevents the accumulation of sorbitol and reduce the risk of diabetes induced cataract diseases [34]. Finger millet feeding controls blood glucose level improves antioxidant status [35] and hastens the dermal wound healing process in diabetic rats [36].

Millets and cardiovascular disease

Millets are good sources of magnesium that is known to be capable of reducing the effects of migraine and heart attack. Millets are rich in phyto-chemicals containing phytic acid which is known for lowering cholesterol [37]. Finger millet may prevent cardiovascular disease by reducing plasma triglycerides in hyperlipidemic rats [38].

Millets and celiac disease

Celiac disease is an immune-mediated enteropathy triggered by the ingestion of gluten in genetically susceptible individuals. Millets are gluten-free, therefore an excellent option for people suffering from celiac diseases and gluten-sensitive patients often irritated by the gluten content of wheat and other more common cereal grains [39].

Millets and cancer

Millets are known to be rich in phenolic acids, tannins, and phytate that act as "antinutrients" However; these antinutrients reduce the risk for colon and breast cancer in animals. Chandrasekara et al. have demonstrated that millet phenolics may be effective in the prevention of cancer initiation and progression *in vitro* [40].

Millets and anti-inflammatory activity

Ferulic acid is very strong antioxidant, free radical scavenging and anti-inflammatory activity. Antioxidants significantly prevent tissue damage and stimulate the wound healing process. Rajasekaran *et al.* [36] have reported good antioxidant effects of finger millet on the dermal wound healing process in diabetes induced rats with oxidative stress-mediated modulation of inflammation.

Millets and aging

The chemical reaction between the amino group of proteins and the aldehyde group of reducing sugars, termed as nonenzymatic glycosylation, is a major factor responsible for the complications of diabetes and aging. Millets are rich in antioxidants and phenolics; like phytates, phenols and tannins which can contribute to antioxidant activity important in health, aging, and metabolic syndrome [41].

Millets and antimicrobial activity

Millets fraction and extract have been found to have antimicrobial activity. Seed protein extracts of pearl millet, sorghum, Japanese barnyard millet, foxtail millet, samai millet and pearl millet were evaluated *in vitro* for its ability to inhibit the growth of *Rhizoctonia solani, Macrophomina phaseolina,* and *Fusarium oxysporum.* Protein extracts of pearl millet are highly effective in inhibiting the growth of all 3 examined phytopathogenic fungi [42].

Anti-Nutrients Present in Millets

In developing country, cereal-based foods have low bioavailability of minerals like iron, zinc initiate critical problem for infants and young children. These anti-nutritional factors which acting on iron and zinc bioavailability are certain phenolic compounds, phytates, and fibres [43]. The proportions of these anti-nutrients in diet can be reduced by some household food processing techniques like decortication, germination, malting, fermentation etc [44], which may also change mineral content and bioavailability.

Food Processing Techniques

Food processing techniques are used to enhance nutritional quality, improve the digestibility and bioavailability of food nutrients with reducing anti-nutrients. Some food techniques are decortications, milling, soaking, cooking, germination, fermentation, malting, popping etc.

Soaking

Soaking of grains is popular and household food processing technique. It is used for reducing antinutritional compounds like phytic acid and phytase activity to improve bioavailability of minerals [45]. Pawar, et al. [46] founded that combination of different processing like dehulling, soaking and cooking decreased in significant amount of antinutrients like polyphenols, phytate and increase the protein digestibility *in vitro* and improve the bioavailability of minerals such as iron and zinc.

Germination

Shahidi & Chandrasekara reported that germination of millets (Pennisetumtyphoides) decreased the levels of tannins (1.6% to 0.83%).Germination improved the *in vitro* protein (14% to 26%) and starch (86% to 112%) digestibility in pearl millet [16]. It also led to the reduction of anti-nutrients such as phytic acid, tannins, and polyphenols, which form complexes with protein [47]. Krishnan, et al., founded that the *in vitro* extractability and bio-accessibility of minerals such as calcium, iron and zinc were increased and anti-nutritional factor such as phytic acid were decreased in pearl and finger millets by germination [48]. Pearl millet has higher beta-amylase activity and higher free alpha-amino nitrogen in comparison to sorghum after malting [49]. Germination and probiotic fermentation significantly improved the contents of thiamine, niacin, total lysine, protein fractions, sugars, soluble dietary fiber [50].

Fermentation

Fermentation is widely used in food preservation, provides many varieties of food products with different flavors and texture, and improves the nutritional properties of raw food significantly [51]. Fermentation decreases the levels of antinutrients and improves the protein availability, digestibility *in vitro* and appreciable change in chemical composition of food material [47]. Ahmed, et al., [52] reported that fermentation of pearl millet improve nutrient value like moisture, ash, fibre, protein and fat and significantly reduced the mineral contents such as sodium, potassium, iron, zinc etc. and enhanced flavonoids after 16 hours of fermentation [53].

Popping or Puffing

Popping is one of the processing techniques which uses sand as heat transfer media with HTST (high-temperature short time) method resulting starch gelatinization and the endosperm bursts open giving highly desirable flavor and aroma. It is used as ready-to-eat food [54] at commercial scale thus promoting utilization of millet grains [39].

Conclusion

Millets are staple food source that is not only providing major nutrients like protein, carbohydrate, fat etc. but also provide ample of vitamins and minerals. In developing country, occurrence of malnutrition and various health problems like obesity, diabetes, cardiovascular disease, skin problems, cancer, celiac disease etc. are most prominent because of inadequate supply of nutrition. This is mainly due to the little utilized agricultural crops as food and unawareness of people and lack of knowledge to people. Millets are easily available and cheap in cost. Millets contain many major and minor nutrients like carbohydrate, good protein, fat, dietary fibre, vitamins and minerals as well as antioxidant and phytochemicals. The importance of this study undertakes to concern and developing specific agenda for these crops which must be recognized as an important food and introduce the millets as a nutritious food, fulfillment of the nutritional need of global population and to find ways to consume the millets nutritionally, effectively and to reduce the problems of malnutrition and other health problems. This study focused to reducing some anti-nutrients which diminish the acceptability, digestibility and bioavailability of nutrients and improve the nutrients of millets for nourishing the health. Household food processing strategies are used for improving the nutritional quality to promote millet utilization for future prospective.

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

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