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Millets: Nutritional composition, some health benefits and processing - A Review

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Abstract

Millets are a major food source in arid and semi-arid parts of the world. Millets are good sources of energy. They provide protein, fatty acids, minerals, vitamins, dietary fibre and polyphenols. Typical millet protein contains high quantity of essential amino acids especially the sulphur containing amino acids (methionine and cysteine). Processing millet by milling removes the bran and germ layers that are rich in fibre and phytochemicals, causing significant loss. The millets are source of antioxidants, such as phenolic acids and glycated flavonoids. Millet foods are characterized to be potential prebiotic and can enhance the viability or functionality of probiotics with significant health benefits. The nutritional significance of millets demands for an examination of the nutritional characteristics and functional properties of different millet cultivars as well as developing value added products from millets.

Key words: Millets, Composition, Protein, Health benefits, Processing

Introduction

Millets are one of the cereals asides the major wheat, rice, and maize. Millets are major food sources for millions of people, especially those who live in hot, dry areas of the world. They are grown mostly in marginal areas under agricultural conditions in which major cereals fail to give substantial yields (Adekunle, 2012). Millets are classified with maize, sorghum, and Coix (Job's tears) in the grass sub-family *Panicoideae* (Yang et al., 2012). Millets are important foods in many underdeveloped countries because of their ability to grow under adverse weather conditions like limited rainfall. In contrast, millet is the major source of energy and protein for millions of people in Africa. It has been reported that millet has many nutritious and medical functions (Obilana and Manyasa, 2002; Yang et al., 2012). It is a drought resistant crop and can be stored for a long time without insect damage (Adekunle, 2012); hence, it can be important during famine.

Discrepancies exist concerning classification of family millet, with some references giving the family name *Gramineae*, and others classifying it in the family *Poaceae*. There are many varieties of millets. The four major types are Pearl millet (*Pennisetum glaucum*), which comprises 40% of the world production, Foxtail millet (*Setaria italica*) (Yang et al., 2012), Proso millet or white millet (*Panicum miliaceum*), and Finger Millet (*Eleusine coracana*). Pearl millet produces the largest seeds and it is the variety most commonly used for human consumption (Mariac et al., 2006; ICRISAT, 2007). Minor millets include: Barnyard millet (*Echinochloa* spp.), Kodo millet (*Paspalum scrobiculatum*), Little millet (*Panicum sumatrense*), Guinea millet (*Brachiaria deflexa = Urochloa deflexa*), Browntop millet (*Urochloa ramosa = Brachiaria ramosa = Panicum ramosum*), Teff (*Eragrostis tef*) and fonio (*Digitaria exilis*) are also often called millets, as more rarely are sorghum (*Sorghum* spp.) and Job's tears (*Coix lacrima-jobi*) (ICRISAT, 2007; FAO, 2009; Adekunle, 2012).

In 2007, global millet production reached about 32 million tonnes with the top producing countries being: India (10,610,000), Nigeria (7,700,000), Niger (2,781,928), China (2,101,000), Burkina Faso (1,104,010), Mali (1,074,440), Sudan (792,000),

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Uganda (732,000), Chad (550,000) and Ethiopia (500,000) (FAO, 2009). According to FAO (2005), pearl millet production attained approximately 54% of the global production in 2004.

Millets represent a unique biodiversity component in the agriculture and food security systems of millions of poor farmers in regions such as Sub-Saharan Africa. Pearl millet is an important food across the Sahel, although, India is the largest producer of pearl millet (Bhattacharjee et al., 2007). Millets are often ground into flour, rolled into large balls, parboiled, and then consumed as porridge with milk; sometimes millets are prepared as beverages. *Roti*, made from pearl millet has been the primary food of farmers in Gujarat India (FAO, 2009). There is an emerging need for the world to feed its growing population, therefore, it is important to explore plants such as millets that are grown locally and consumed by low income households in places like India and the Sahel zone (Obiana, 2003). Cereals, in particular, millet based foods and beverages are known worldwide and are still part of the major diet in most African countries (Obilana and Manyasa, 2002; Amadou et al., 2011). The present review summarizes the nutritional composition of millets some health benefits, and the use of millets in the food industry.

Nutritional composition of millet grains

Millets are unique among the cereals because of their richness in calcium, dietary fibre, polyphenols and protein (Devi et al., 2011). Table 1 represent amino acids content in different types of millets. Millets generally contain significant amounts of essential amino acids particularly the sulphur containing amino acids (methionine and cysteine); they are also higher in fat content than maize, rice, and sorghum (Obilana and Manyasa, 2002). In general, cereal proteins including millets are limited in lysine and tryptophan content and vary with cultivar. However, most cereals contain the essential amino acids as well as vitamins and minerals (Devi et al., 2011; FAO, 2009).

Plant nutrients are largely used in the food industry, and cereal grains constitute a major source of dietary nutrients worldwide (Amadou et al., 2011a; Izadi et al., 2012).

Modification of a protein is usually realized by physical, chemical, biological such as fermentation or an enzymatic treatment, which changes its structure and consequently its physicochemical and functional properties (Lestienne et al., 2007; Amadou et al., 2011b). Table 2 represent the content of different varieties of millet, foxtail, fonio, proso, pearl and finger millets.

Table 1. Amino acid profiles of different millet grains variety (Foxtail, Proso, Pearl and Finger millet).

Amino acids (g/100g)	Foxtail millet (defatted flour) (a)	Proso millet (Dehulled Grain) (b,c)	Pearl millet (true prolamine) (c)	Finger millet (native grain) (d)
Essential Amino Acid				
Isoleucine	4.59	4.1	5.1	4.3
Leucine	13.60	12.2	14.1	10.8
Lysine	1.59	1.5	0.5	2.2
Methionine	3.06	2.2	1.0	2.9
Phenylalanine	6.27	5.5	7.6	6.0
Threonine	3.68	3.0	3.3	4.3
Valine	5.81	5.4	4.2	6.3
Histidine	2.11	2.1	1.7	2.3
Tryptophan	NA	0.8	1.2	NA
Nonessential Amino Acid				
Alanine	9.30	10.9	8.1	6.1
Arginine	3.00	3.2	0.9	3.4
Aspartic acid	7.71	6.2	6.2	5.7
Cystine	0.45	NA	0.8	NA
Glutamic Acid	22.00	21.3	22.8	23.2
Glycine	2.91	2.1	0.7	3.3
Serine	4.56	6.3	5.4	5.3
Tyrosine	2.44	4.0	2.7	3.6
Proline	5.54	7.3	8.2	9.9
*PER(b)	0.80	1.10	1.60	2.00

*Protein Efficiency Ratio (PER). NA: not available. References: (a) Kamara, *et al.* (2009); (b) Bagdi et al., 2011; (c) Saldivar (2003); (d) Devi et al. (2011).

Table 2. Proximate composition of millet grain varieties.

Component (g/100g, dry basis)	Foxtail millet flour	Fonio whole grain	Proso millet dehulled grain	Pearl millet whole grain	Finger millet native grain
Protein	11.50	9–11	11.58	14.8	8.2
Ash	0.47	1–1.1	NA	1.64	2.7
Fat	2.38	3.3–3.8	4.9	4.86	1.8
Total CHO*	75.2	84–86	80.1	59.8	83.3
Crude fiber	NA	NA	0.7	12.19	3.5
References	Kamara et al. (2009)	Vodouhe et al. (2003)	Bagdi et al. (2011)	Taylor et al. (2010)	Devi et al. (2011)

*Carbohydrate (CHO). NA: not available.

Badau et al. (2005) reported that the phytic acid content of the unmalted pearl millet grain ranged from 2.91% to 3.30%. The total dietary fibre (22.0%) of finger millet grain were reported relatively higher than that of many other cereal grains (e.g. 12.6%, 4.6% and 12.8% respectively for wheat, rice, maize and sorghum (Shobana and Malleshi, 2007; Siwela et al., 2010). However, the dietary fibre content in pearl millet ranges between 8 to 9% (Taylor, 2004).

Bagdi et al. (2011) analyzed the composition of free and bound lipids in proso millet (*Panicum miliaceum*) flours and brans. In the free lipids, hydrocarbons, sterol esters, triacylglycerols, diacylglycerols, and free fatty acids were present (Bagdi et al., 2011). The predominant fatty acids in the free lipids were linoleic, oleic, and palmitic acids, though, in the bound lipids, monogalactosyl diacylglycerols, digalactosyl diacylglycerols, phosphatidylethanolamine, phosphatidyl serine, and phosphatidyl choline were tentatively identified (Bagdi et al., 2011). Saldivar (2003) studied the content of total lipids, lipid classes and fatty acids composition in small millets, such as foxtail millet (*Setaria italica*), proso millet (*Panicum miliaceum*), and finger millet (*Eleusine coracana*). They reported the total lipid content in the foxtail, proso, and finger millets ranged from 5.2 to 11.0% (dry basis), while it ranges from 5.1 to 8.3% in the little, kodo, and barnyard millets (Saldivar, 2003). In addition, examination of some millet cultivars from Tunisia and Mauritania by Ibrahima et al. (2004) showed that the fatty acid profile of the millet lipid is mainly characterized by the presence of high levels of linoleic, oleic and palmitic acid. However, palmitoleic acid (C16: 1), stearic acid (C18: 0) and linolenic acid (C18: 3) were less represented. Other fatty acids are identified in trace amounts (arachidic acid C20: 0, behenic acid C22: 0, erucic acid C22: 1). The work of Liang et al. (2010) presented the general properties of foxtail millet oil and its fatty acid profile. It is apparent that millet oil could be a good source of natural oil rich in linoleic acid and tocopherols (Liang et al., 2010; Amadou et al., 2011c). The main polyphenols in cereals are phenolic acids and tannins, whilst flavonoids are present in small quantities; they act as antioxidant and play many roles in the body immune system defence (Chandrasekara and Shahidi, 2010; Devi et al., 2011). Whole cereal grains are considered a rich source of fibre. However, foods from grains have marked differences in the amount and type of dietary fibre (Shukla and Srivastava, 2011). The dietary fibre content in cereal-based food varies greatly, depending on the extent of milling. Finger millet shows relatively higher than other cereals carbohydrate (72%) comprises of starch as the main constituent and the non-starchy polysaccharides which amounts to 15–20% of the seed matter as an unavailable carbohydrate dietary fibre content and complements which are the health benefits of the millet (Devi et al., 2011). The main function of dietary carbohydrate is to supply energy (Devi et al., 2011). Millets are good sources of magnesium and phosphorus. Magnesium has the ability to help reduce the effects of migraine and heart attacks, while, phosphorus is an essential component of adenosine triphosphate (ATP) a precursor to energy in the body (Badau et al., 2005; Liang et al., 2010; Devi et al., 2011).

Millet in probiotic and prebiotics foods

Probiotics aid the existing flora, or help repopulate the colon when bacteria levels are reduced by antibiotics, chemotherapy or disease. FAO/WHO stated that probiotics are “lives microorganisms which when administered in adequate amounts confer a health benefit on the host” though, this should also specify genus, species and strain level, as well as a safety assessment. Most of probiotic foods generate fatty acids, vitamins and other vital nutrients that improve the body's resistance against pathogens microorganisms (FAO/WHO, 2001; Abd El-Salam et al., 2012). Fermented foods are thus, important to human beings all over the world with between 20 to

40% of food supply being from fermented foods (Anukam and Reid, 2009; Rivera-Espinoza and Gallardo-Navarro, 2010; Amadou et al., 2011a). Lei and Michaelsen (2006) reported an interesting intervention study in Northern Ghana using spontaneously fermented millet product as a natural probiotic treatment for diarrhea in young children. Millet *koko* is an African spontaneously fermented millet porridge and drink, characterized by Lei and Jacobsen (2004) as a potential probiotic product as well as *Mangisi, Kunu-zaki and Uji* a thin, lactic acid-fermented porridge (Amadou et al., 2011a).

Prebiotics are non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and/or activity of one, or a limited number of bacteria in the colon (Laminu et al., 2011; Abd El-Salam et al., 2012). Food ingredients classified as prebiotics must not be hydrolyzed or absorbed in the upper gastrointestinal tract, need to be a selective substrate for one, or a limited number of colonic bacteria, must alter the microbiota in the colon to a healthier composition and should induce luminal, or systematic effects that are beneficial to the host health (Lei and Jacobsen, 2004). Cereals, in particular millet-based fermented foods and beverages, have been extensively studied and form a major part of the diet in most African countries (Rivera-Espinoza and Gallardo-Navarro, 2010). Malting induces important beneficial biochemical changes in the millet grain. *Jandh* is just like *Koko* produced by steeping pearl millet overnight, discarding the steep water, wet-milling the millet grains together with spices such as ginger and chili pepper, water is added to the milled materials to make thick slurry. *Fura* is dough made from millet flour, it is hand molded into balls, placed inside a cooking pan containing boiling water, and cooked for 30 min at atmospheric pressure then the balls are kneaded again while still hot until a smooth, slightly elastic mass is obtained. *Mangisi* is a sweet-sour beverage made from naturally fermented millet mash. Moreover, unfermented millets foods and beverages such as *Dambu* a steamed granulated dumpling; *Masvusvu* a sweet beverage traditionally made from unfermented malted finger millet and *Ragi roti*, known as finger millet *roti* is an unleavened flatbread (Amadou et al., 2011a; Rivera-Espinoza and Gallardo-Navarro, 2010).

Some potential health benefits of millets

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 phytate, which is associated with reduced cancer risk (Coulibaly et al., 2011). These health benefits have been partly attributed to the wide variety of potential chemopreventive substances, called phytochemicals, including antioxidants present in high amounts in foods such as millets (Izadi et al., 2012).

Millet is gluten-free, therefore an excellent option for people suffering from celiac diseases often irritated by the gluten content of wheat and other more common cereal grains. It is also useful for people who are suffering from atherosclerosis and diabetic heart disease (Gélinas et al., 2008). Choi et al. (2005) and Park et al. (2008) reported that protein concentrate of Korean foxtail millet and proso millet significantly elevated plasma adiponectin and HDL cholesterol levels and caused major decreases in insulin levels relative to a casein diet in type 2 diabetic mice. Furthermore, proso millet also improved glycemic responses and plasma levels (Park et al., 2008). In addition, proso millet protein concentrate has protective effects against D-galactosamin-induced liver injury in rats (Ito et al., 2008). Choi et al. (2005) and Park et al. (2008) concluded that proso millet protein could be a potential therapeutic intervention in type 2 diabetes. Devi et al. (2011) review the nature of polyphenols and dietary fiber of finger millet and their role with respect to the health benefits associated with millet.

Chandrasekara and Shahidi (2010) 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., 2011; Quesada et al., 2011; Kamara et al., 2012). Millets extract from the seed coat where reported to have shown high antibacterial and antifungal activity compared to whole flour extract due to high polyphenols content in seed coat (Viswanath et al., 2009; Xu et al., 2011). Free radical quenching potential of different millets kodo millet, finger millet, little millet, foxtail millet, barnyard millet (*kudiraivali*), great millet (*jowar*) and their white varieties were revealed to have significant antioxidant activity by 1, 1, Diphenyl -2-picrylhydrazyl (DPPH) method (Devi et al., 2011; Quesada et al., 2011; Kamara et al., 2012). Moreover, Kamara et al. (2012) reported different radical scavenging activities of fractionated foxtail millet protein hydrolysate.

Millet in the industry

Millets have good grain qualities suitable for processing. Processing of the grain for many end uses involves primary (wetting, dehulling and milling) and secondary (fermentation, malting, extrusion, glaking, popping and roasting) operations. Being a staple and consumed at household levels, processing must be considered at both traditional and industrial levels, involving small, medium and large-scale entrepreneurs (Obilana and Manyasa, 2002; Hamad, 2012). Dehulling is not favorable to millets due to their small grains sizes. In addition, dehulling causes nutrients loss. All the Millets can be milled by hand grinding (household level) or machine milling (cottage, small-to-medium scale service and large scale industrial). Millet and sorghum malt production is a traditional practice in Africa, where malt is used in lactic acid- and alcoholic-fermented beverages and infant food production (Adekunle, 2012). Traditional malting processes in many developing countries involve three main operations: soaking, germination, and drying. The duration and conditions of each operation are highly variable, resulting in highly variable malt and derived product quality (Vidya et al., 2012). *Burukutu* and *Pito* are traditional African beers differ from Western beer types in several ways: they are often sour less carbonated and have no hops; these beer are products of both at traditional and industrial level (Anukam and Reid, 2009; Amadou et al., 2011a). The emerging principal uses of millets as an industrial raw material include production of biscuits and confectionery, beverages, weaning foods and beer (Laminu et al., 2011; Anukam and Reid, 2009). Grits, flour, and meals from cereals such as millet, sorghum, and corn are now common items in the market. Soft biscuits and cookies are being made using sorghum, maize and wheat composites, while cakes and non-wheat breads have become a subject of increasing scientific and technological enquiry, showing encouraging results (Akeredolu et al., 2005; Hama et al., 2011; Laminu et al., 2011; Vidya et al., 2012).

In the infant weaning food sector, in spite of unlimited potential, progress has been slow, as the installed capacity for industrial malting is limited. Many brands of beer in the underdeveloped countries market have substantial content of local cereal such as millet to reduce the cost of imported barley. The industries are confronted with a number of problems which tend to diminish product qualities and affect overall utilization. For instance, in the nonalcoholic beverage and weaning food sectors, storage quality of the grain, nutritional losses after processing, high cost of imported equipment and variation among cultivars are some of the problems militating against improved utilization of millet in the developing countries (Akeredolu et al., 2005; Laminu et al., 2011; Adekunle, 2012). In a weaning process there is always the need to introduce soft, easily swallowed foods to supplement the infant's feeding early in life. A process weaning diet from pearl millet-conophor nut flour was found to promote growth in a clinical experiment (Akeredolu et al., 2005); whereas, weaning food blends prepared from fermented pearl millet/roasted cowpea in 70:30 and 60:40 ratios were reported to have resulted in lower levels of phytic acid and higher in vitro protein digestibility of the weaning food blends (Laminu et al., 2011).

Conclusion

Millets are still the staple food for millions of poor people in Africa and Asia. Like many other cereals, millets are high carbohydrate energy content and nutritious, making them useful components of dietary and nutritional balance in foods. Combination of millets with other sources of protein would compensate the deficiency of certain amino acids such as lysine. Successful improvement of these attributes would be a crucial key to expand the spectrum of applications of millet grains. Future trends should focus on the millet consumption in the developed countries that could help its industrial revolution.

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