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Health and immunity boosting sorghum properties and its applications in food industry: A review

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Abstract
Sorghum is a major cereal in the semi-arid regions of the world where it is an important food and feed crop. Sorghum species (*Sorghum vulgare and Sorghum bicolor*) are members of the grass family. Sorghum is a gluten-free cereal and forms the staple diet of a majority of the populations living in the semi-arid tropics. Sorghum contains various phenolic and antioxidant compounds that could have health benefits, which make the grain suitable for developing functional foods and other applications. Recently, sorghum grain has been used to develop functional foods and beverages, and as an ingredient incorporated into other foods. The objective of this review is to provide a comprehensive understanding of nutrition and phenolic compounds derived from sorghum and their related health effects, and demonstrate the potential for incorporation of sorghum in food systems as a functional component and food additive to improve food quality, safety, and health functions.

Keywords: Sorghum, nutritional value, bioactive compound, health benefits, functional food

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is known under a variety of names: *jowar* in India, *great millet* and *guinea corn* in West Africa, *kafir corn* in South Africa, *dura* in Sudan, *kaoliang* in China and *milo* or *milo-maize* in the United States. Sorghum belongs to the tribe *Andropogonae* of the grass family *Poaceae*. Origin of sorghum is Northeast quadrant of Africa (Ethiopia-Sudan border). Sorghum crop is environmentally-friendly as it is water-efficient, requires little or no fertilizers or pesticides and is biodegradable (FAO, 1995).

Sorghum is cultivated for different purposes, USA which is a major producer of sorghum; the grain is used mainly as animal fodder, while in Africa and India, the grain is considered as a major food source and forms the staple diet for large populations living in the semi-arid regions in Asia and Africa where, sorghum is produced for human consumption and it is almost the only source of energy and protein in those regions (Taylor *et al*., 2011) [2]. Lack of gluten in sorghum gives a significant importance to tackle the present day scenario of Celiac Disease (CD) occurrence (Kasarda 2001) [3]. Previous study revealed that Grain sorghum contains phenolic compounds like flavonoids (Shahidi and Naczk, 1995) [4]. which have been found to inhibit tumour development (Huang and Ferraro, 1992). The starches and sugars in sorghum are released more slowly than in other cereals (Klopfenstein and Hoseney, 1995) [5]. and that could be beneficial to diabetic patients.

Indian sorghum grain found to contains 11.9% moisture, 10.4% protein, 1.9% fat, 1.6% fibre, 72.6% carbohydrates and 1.6 per cent minerals. The major minerals present in the grain are calcium, magnesium, potassium and iron (Shakuntala and Shadaksharaswamy, 2001).

Sorghum is one of the important food cereals providing energy, protein, vitamins and powerful antioxidants. The main constituents of sorghum that affect to quality of food are starch and protein (Taylor *et al*., 2006) [6].

Compared to rice, *jowar* is richer in protein but the equality is not as good as rice protein. Since cereal and legume proteins are complementary to each other, *jowar* and any legume in the ratio of 70:30 will give better nutritional value (ICRISAT, 2012) [10].

Nutritional value of sorghum

The chemical composition of sorghum decides its nutritive value of product. Sweet sorghum is considered rich in glucose and fructose as well as in fibre and iron, with a fairly high protein level and also a good source of phosphorus and thiamine which have higher acceptability with respect to other sorghum varieties.

Grain sorghum is rich in fiber and minerals apart from having a sufficient quantity of carbohydrates (72%), proteins (11.6%) and fat (1.9%). Starch is the major constituent of the grain. Grain sorghum protein contains albumin globulin (15%), prolamin (26%) and glutelin (44%). Sorghum does not contain gluten and hence the dough does not have stickiness, to roll with the chapatti roller. The flour from sorghum is gluten free and is a safe energy source for people allergic to gluten. Minimal amounts of flavan-4-ols and phytic acid are present in white sorghum (Chavan and Patil, 2009) [7].

The proximate composition of four sorghum hybrid varieties. They reported that the mean values of various constituents of grains for moisture 13.6%, ash 1.75%, crude fat 3.34%, crude fibre 3.47%, protein 11.59%, starch 68.42 and tannins 1.35%. Fabre *et al.* (1981) [8].

The chemical composition of sorghum during his analysis and found that carbohydrate 72%, protein 11.6%, fat 1.9% and fiber content was 1.5%. Proximate composition generally represents the nutritional quality of product. It is necessary to observe the proximate composition of grain so as to judge the nutritional quality of final product Patil *et al*. (2010) [9]

Sorghum protein varies from 4.4 to 21.1% with a mean value of 11.4%. Sorghum grain is known for its hardness compared to other food grains. The hardness of the grain is due to higher content of protein prolamin. Prolamin content varies from 3.6 to 5.1%. Starch is the major constituent of grain accounting for 56-75% of the total dry matter in the grain. The total content of soluble sugars of sorghum grain ranged from 0.7 to 4.2% and the reducing sugars from 0.05 to 0.53%. Fat content in sorghum grain varies from 2.1 to 7.6%, crude fibre from 1.0 to 3.4% and ash from 1.3 to 3.3%. The physico chemical characterization of sorghum accessions showed a wide variation in protein (7.99 to 17.8%), lipids (2.52 to 4.76%), starch (51.88 to 85%), and amylose (12.30 to 28.38%) Ratnavath and Patil (2013).

According to them sorghum is primarily composed of high levels of insoluble fiber with low levels of β-glucans and soluble fiber. These components were account for 6.7-7.9% insoluble and 1.23% soluble fiber of the grain Rooney and Serna-Sadivar (2000).

Sorghum Millet for functional food

The bound phenolic acids have low bioavailability, because of the extensive covalent bonds that are resistant to enzymatic digestion (Saura-Calixto, 2010) [19]. Moreover, because the bound phenolic acids are part of cell wall components, the concentration of bound phenolic acids is also directly linked to the grain hardness, with higher concentrations being associated with harder grain (Chiremba *et al.*, 2012) [14].

Flavonoids are mainly found in sorghum bran, and the types and concentrations are associated with the pericarp color and thickness and presence of pigmented testa (Awika *et al*., 2005; Dykes *et al.*, 2005) [15-16].

Flavones are yellow-colored flavonoids commonly found in fruits, vegetables, legumes, and also in cereal grains. Although cereal grains generally contain modest levels of flavones, they represent one of the main dietary sources of the flavones and thus play a significant role in the human diet (Zamora-Ros *et al.*, 2016) [20].

Flavanones are widely distributed in food plants with naringenin and its derivatives being the dominant ones. They are the main intermediates in the biosynthesis of flavonoids, but their presence in cereal grains is generally rare (Awika, 2017; Koes, Quattrocchio, & Mol, 1994) [17-18]. Sorghum appears to be an exception, and some sorghum varieties have been reported to have the highest levels of flavanones among food plants (Awika, 2017) [17]. The flavanone content in sorghum ranges from 0 to 2,000 μg/g.

Oxidative stress, which is an imbalance of free radicals and antioxidants, is the leading cause of various chronic diseases (Lee, Park, Zuidema, Hannink, & Zhang, 2011) [21]. The antioxidant activity of sorghum phenolic compounds seems to play a key role in the health promotion and disease prevention associated with sorghum consumption.

The inhibitory effects against the pro-inflammatory compounds is believed to be important for disease prevention. In addition, recent studies have shown that the combination of flavone apigenin and flavonol quercetin, as well as the apigenin-rich extract from sorghum and quercetin-rich extract from cowpea, has a strong synergistic anti-inflammatory effect by enhancing their bioavailability through the suppression of the phase II metabolism and ATP binding cassette membrane transporter function in cellular models (Agah *et al*., 2017; Ravisankar *et al*., 2019) [23, 22].

The phenolic compounds from sorghum have shown anticancer activity, and consumption of sorghum whole grain can reduce the risk of developing certain cancers (Chen, Cole, Mi, & Xing, 1993; Isaacson, 2005) [25, 48]. The anticancer activity of sorghum may be attributed to the potent antioxidant activity and phase II enzyme induction of its phenolic compounds (Awika *et al*., 2009) [24].

Sorghum whole grain is an excellent food for people with obesity and diabetes. Sorghum has a relatively low starch digestibility. As explained previously, this is because sorghum endosperm contains high levels of resistant and slowly digestible starch (Barros *et al.*, 2012; Taylor & Emmambux, 2010) [26, 28].

Sorghum also has potential antidiabetic activities. The phenolic extract from sorghum grain has been demonstrated to have inhibitory activity against digestion enzymes such as *Bacillus stearothermophilus* α-glucosidase, porcine pancreatic α-amylase, and human salivary α-amylase, therefore reducing the glycemic level. Some sorghums have even shown more robust α-glucosidase inhibitory activities than the common antidiabetic drug acarbose (Kim, Hyun, & Kim, 2011) [27].

Sorghum lipids of phytosterols and polycosanols have been shown to promote cardiovascular health by regulating the absorption, excretion, and synthesis of cholesterol. For example, incorporation of sorghum lipids into the diet of hamsters increased the excretion of cholesterol and its metabolites, and thus reduced the plasma and liver cholesterol levels in hamsters (Carr *et al.*, 2005; Hoi *et al*., 2009) [30, 49] These lipids have also been shown to influence the gut microbiota in hamsters, such as reducing the *Coriobacteriaceae* family, to reduce the cholesterol absorption (Martínez *et al.*, 2009) [29].

Sorghum grain has been reported to have the lowest raw starch digestibility due to restrictions in accessibility to starch caused by endosperm proteins (Rooney *et al.*, 1986) [31]. The digestibility of the starch, dependent on hydrolysis by pancreatic enzymes, determines the available energy content of cereal grain. The chemical nature of the starch, particularly the amylose and amylopectin content, is yet another factor that affects its digestibility.

Obesity is an ever-increasing problem in the western world and is related to several disease conditions including CVD and diabetes. As a result a plethora of weight loss regimens, diets, pills, etc., has emerged. However, such regimens do not seem to produce the desired effects and obesity cases are on the rise (Hill *et al*., 2003; Wyatt, 2003) [32, 34].

The phytosterols in the cereal brans are believed to contribute to beneficial effects. Other components of the whole grains, including polyphenols and fiber, also play a role in CVD prevention. For example, a cholesterol-lowering effect of tea and grape catechins and tannins is widely reported (Lin *et al*., 1986; Tebib *et al*., 1997) [33, 35].

In sorghum, wax comprises about 0.2% of the grain, generally higher than in other cereals. The policosanols represent 19-46% of the sorghum wax, with octacosanol (C28) (1) and triacontanol (C30) (2) as the most abundant (Bunger and Kummerow, 1951; Dalton and Mitchell, 1959; Avato *et al.*, 1990) [36-38]. The policosanols have cholesterol-lowering potency comparable to that of statins (currently popular but expensive and potentially harmful drugs) (McCarthy, 2002) [39]. Castano *et al.*, (2002) [40] reported that 10 mg/day of policosanol was more effective than 20 mg/day of lovastatin in reducing LDL cholesterol and raising HDL cholesterol levels.

Phytosterols are cholesterol (44)-like compounds that are structural components of plant cell membranes. In cereals grains they are mostly found in bran and are extractable as part of bran oil waxes. There is a considerable interest in these compounds due to their promotion of cardiovascular health, especially through their cholesterol-lowering properties. Cereal brans reported to have high levels of these compounds include rice (Rogers *et al*., 1993; Dunford and King, 2000) [42, 41] and corn (Moreau *et al*., 1996; Singh *et al.*, 2003) [43-44]. Quantitative data on sorghum phyto sterols are limited. Singh *et al*. (2003) [44] reported total phyto sterol levels of 0.5 mg/g for sorghum grain, compared to 0.9 mg/g for corn.

Sorghum millet for industrial application

Other varieties of sorghum are also used for food in various parts of the world, including parts of Africa, Central and South America, China, and India. In Eastern and southern Africa, for example, traditional sorghum varieties of moderate tannin content are widely grown and used for staple food and alcoholic beverages.

Selection of varieties meeting specific local food and industrial requirements from this great biodiversity is of high importance for food security, in developing countries in general, and particularly in West Africa, demand for sorghum is increasing. This is due to not only the growing population, but also the countries policy to enhance its processing and industrial utilization (Dicko *et al.*, 2006) [12].

The acquisition of good quality grain is fundamental to produce acceptable food products from sorghum. In many developing countries sorghum has traditionally been used in food products and various food items. For instance, in India, sorghum-based product types include *Roti* (unleavened flat bread), *Sangati* (stiff porridge), *Annam* (Rice-like), *Kudumulu* (steamed), *Dosa* (pancake), *Boorelu* (deep fried) and Thapala chakkalu (shallow fried). In addition, sorghum is often recommended as a safe food for celiac patients, which do not tolerate protein sequences contained in both the gliadins (Kagnoff *et al.*, 1982) [50] of wheat gluten. Therefore, the future promise of sorghum in the developed world is for wheat substitution for people with celiac disease or allergies to gluten. Sorghum provide a good basis for gluten-free breads and other baked products like cakes and cookies (biscuits) and in snacks and pasta (Taylor *et al.*, 2006) [6].

Sorghum is used in a variety of foods. The white food sorghums are processed into flour and other products, including expanded snacks, cookies and ethnic foods, and are gaining popularity in areas like Japan (United States Grains Council, 2001; Rooney, 2001) [46, 45]. In the US, the white sorghum products are used to a small extent to substitute for wheat in products for people allergic to wheat gluten (Fenster, 2003) [47].

Conclusion

Sorghum of having a high medicinal and functional value can be easily utilizable as a functional ingredient in processing of sorghum roti. Sorghum is a unique functional food having exceptional mix of essential gluten free, high fiber and low level of fat, In view of such a functional and medicinal values of sorghum sincere efforts were made to develop different type of food products.

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