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Review Article

NUTRACEUTICAL PROPERTIES OF GREAT MILLET- *SORGHUM VULGARE*

***S. K. Mathanghi**
Faculty of Food Sciences, College of Food and Dairy Technology,
TANUVAS, Chenai-52.
*******Author for Correspondence*

ABSTRACT
Nutraceuticals are natural bioactive, chemical compounds that have health promoting, disease preventing or medicinal properties. The nutrients in the sorghum millets have identified prospective for reducing the risk of coronary heart disease, diabetes, tumour incidence, cancer risk, blood pressure, reduces the rate of cholesterol and fat absorption, delaying gastrointestinal emptying and providing gastrointestinal health. Thus, the regular intake of sorghum millets and their processed products can make a payment to health endorsement and disease avoidance. The health promoting foods are promising for the economical growth of the country and nutritious foods of low cost may be processed for global utilization. The future of nutraceutical foods is bright for India as we have rich sources of raw materials, economically available human resources and the large local consumption. This paper reviews available information on sorghum phytochemicals, how the information relates to current phytonutrient research and how it has potential to combat common nutrition-related diseases including, cardiovascular disease and obesity.

INTRODUCTION
The term "Nutraceutical" was first coined by Dr. Stephen L. Defelice as "a product isolated or purified from foods and sold in medicinal forms. They have physiological benefit". Nutraceutical is a combination of 2 words, Nutrition and Pharmaceutical. Nutraceuticals are food product that provides health as well as medical benefits; including the prevention and treatment of disease. Phytochemicals and antioxidants are two specific types of nutraceuticals. Research has proved that foods with phytochemicals may help to provide protection from diseases such as cancer, diabetes, heart disease, and hypertension, e.g. carotenoids found in carrots. Antioxidants may be helpful in avoiding chronic diseases, by preventing oxidative damage in our body.

Classification of Nutraceuticals
Nutraceutical is a term used to describe product obtained from food sources that provides extra health benefits as well as basic nutritional value present in food. There are different types of products that come under the class of nutraceuticals. Dietary Supplements: A dietary supplement is a product that contains nutrients derived from food products .The "dietary ingredients" present in these products are: metabolites, vitamins, minerals, vitamins, herbs, and amino acids. Functional Foods: Functional foods are designed foods which provide enriched foods close to their natural state to consumer, rather than manufactured dietary supplements in liquid or capsule form. A process of making enriched food is called Nutrification. Functional foods provide required amount of vitamins, fat, carbohydrate, amino acid etc to body. Established requirement that functional food should possess are-
(1) They should be in their naturally-occurring form,
(2) They should be an essential part of our daily diet,
(3) Should regulate a biological process in hopes of preventing or controlling disease.

Nutraceutical Properties of Great Millet Sorghum
Sorghum is the fifth most important cereal crop in the world after wheat, rice, corn and barley. Sorghum is a rich source of various phytochemicals including tannins, phenolic acids, anthocyanins, phytosterols and policosanols. These phytochemicals have potential to significantly impact human health. Sorghum fractions possess high antioxidant activity in vitro relative to other cereals or fruits. These fractions may

offer similar health benefits commonly associated with fruits. Available epidemiological evidence suggests that sorghum consumption reduces the risk of certain types of cancer in humans compared to other cereals.

The high concentration of phytochemicals in sorghum may be partly responsible. Sorghums containing tannins are widely reported to reduce caloric availability and hence weight gain in animals. This property is potentially useful in helping reduce obesity in humans. Sorghum phytochemicals also promote cardiovascular health in animals. Such properties have not been reported in humans and require investigation, since cardiovascular disease is currently the leading killer in the developed world.

The phenolic acids (PA) of sorghum largely exist as benzoic or cinnamic acid derivatives. As in other cereals, the sorghum phenolic acids are mostly concentrated in the bran (outer covering of grain).The phenolic acids exist mostly in bound forms (esterified to cell wall polymers), with ferulic acid being the most abundant bound PA in sorghum and other cereals . Several other PA have been identified in sorghum including syringic, proto-catechuic , caffeic, p-coumaric , and sinapic as the more abundant The PA-like other phenols are thought to help in plant defense against pests and pathogens. The PA show good antioxidant activity in vitro and thus may contribute significantly to the health benefits associated with whole grain consumption.

Antioxidant Properties of Sorghum Phenols

Tannins from sorghum show powerful antioxidant activity in vitro. We also found that tannin (brown) sorghums had antioxidant activities higher than most non-tannin sorghums. High MW tannins have the greatest antioxidant activity in vitro (on a molar basis) among natural antioxidants.

This was attributed to the proximity of many aromatic rings and hydroxyl groups and the fact that tannins were not able to act as pro- oxidants. Procyanidin o-qui- none is capable of producing oligomeric compounds through various coupling reactions that retain the number of hydroxyl groups, unlike the simple flavanoid o-quinones that can act as prooxidants by forming re-active oxygen species through futile redox cycling.

A major concern about tannins though is that they may not be biologically effective antioxidants due to their large molecular size and their tendency to bind food molecules into insoluble complexes.

However, many researchers demonstrated that even when complexed with proteins, sorghum tannins retained at least 50% of their antioxidant activity. Such protein-complexed tannins may serve as free radical sinks in the digestive system thus sparing other antioxidants.

Phenolic Acids

In sorghum and other cereals, most of the PA are esterified to cell wall components and can only be extracted in meaningful quantities by alkaline hydrolysis. Such bound forms of phenolic acids were, until recently, considered unavailable for absorption. Human colonic esterases (mostly of microbial origin) are capable of releasing esterified diferulates and other hy- droxycinnamic acids from cereal brans. This implies that the bound PA are potentially bioavailable and the actual contribution of PA to health benefits associated with consumption of whole grains may be greater than previously assumed. In sorghum, bound PA generally account for over 85% of total PA. Adom and Liu (2002) also reported that more than 90% of ferulic acid (the most abundant PA in cereals) in corn,wheat, rice and oats exists in bound form.

Anthocyanins

Anthocyanins were reported to have low absorption compared to other flavanoids (Wu *et al.*, 2002). However significant absorption of these compounds was demonstrated. Most of these data were obtained for fruit anthocyanins which are thought to contribute significantly to the health benefits of fruit consumption. We have not found any work reporting bioavailability of the 3-deoxyanthocyanidins commonly found in sorghum. This is probably because these relatively rare anthocyanins were not considered to be of economic interest.

The high antioxidant capacity of black sorghums and their brans were correlated with their anthocyanin contents. Hence, anthocyanins may contribute significantly to any potential health benefits of these sorghums.

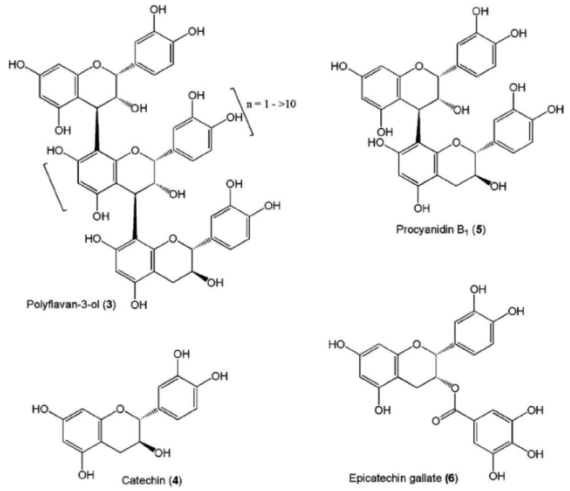

Figure 1: Structure of proanthocyanidins most commonly reported in sorghum

Sorghum	ORAC[a]
White grain	22
White bran	64
Red grain	140
Red bran	710
Black grain	220
Black bran	1000
CSC3*R28 grain	450
CSC3*R28 bran	2400
Sumac grain (brown)	870
Sumac bran (brown)	3100
CV%	6.8

[a] Oxygen radical absorbance capacity, fluorescein used as a probe.

Table 1: Antioxidant activities of sorghum grains

Boveris *et al.*, (2001) demonstrated that a 3-deoxyanthocyanidin (apigeninidin) isolated from soybean had strong dose-dependent quenching ability against ascorbyl and lipid radicals. Anthocyanins from fruits have been shown to possess several therapeutic benefits, including vasoprotective and anti-inflammatory properties , anti-cancer and chemoprotective properties, as well as anti-neoplastic properties. The sorghum anthocyanins should be investigated for any unique health properties.

Comparing Sorghum with Fruits

Blueberries are considered an excellent source of antioxidants (Heinonen *et al.*, 1998) and are commonly used as ingredients in various baked foods (e.g., muffins). Antioxidant activities of blueberries and other common fruits are compared to those of sorghum brans in Table 2. The sorghum brans show significantly higher values than the fruits. The high ORAC (oxygen radical absorbance capacity) levels in sorghum brans demonstrate a high potential of the sorghum brans compared to fruits as a source of natural antioxidants. The sorghum fractions can provide high antioxidant properties when used as ingredients in

Table 2: *Cholesterol*

Sample	ORAC[a] (dry wt)
Black sorghum bran	1010
Brown sorghum bran	2400–3100
Blueberries	87–870
Strawberries	356–400
Plums	452–600
Grapes	100
Watermelon	15
Orange	80–150

[a] μmol TE/g, using fluorescein as a probe.

cereal-based foods. However, comparable antioxidant properties do not necessarily translate into comparable health benefits.

Lowering Properties of Sorghum Phytosterols and Policosanols

In sorghum the free phytosterols identified include sitosterol, campesterol and stigmasterol. Esterified forms , with fatty acid chains of C14–C24 (Avato *et al.,* 1990) and ferulates (Singh *et al.,* 2003) were also identified in sorghum. Similar compounds are found in rice and corn brans. Stanol forms of the phytosterols (without a double bond at position 5) have also been reported in cereals (Ostlund, 2002).

These compounds are not as commonly studied as the sterols, but are reported to offer similar health benefits. Ostlund (2002) reported that the stanols comprise about 10% of phytosterols in diet. The policosanols have cholesterol-lowering potency comparable to that of statins (currently popular but expensive and potentially harmful drugs) (McCarthy, 2002). Castano *et al.,* (2002) 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. Other studies have shown similar benefits (reviewed by Gouni-Berthold and Berthold, 2002). They also report that the policosanols present no toxic effects even at high doses. Other positive benefits provided by policosanols include effects on lipid peroxidation, platelet aggregation and smooth muscle cell proliferation. The policosanols are destined to gain importance as natural, safe and effective dietary alternatives to statin medication. Efficacy and economic potential of the sorghum policosanols should be investigated.

Blood Thinning Effect

Lee and Pan, (2003) found that dietary tannin-sorghum distillery residues inhibited 63–97% of hemoglobin-catalyzed oxidation of linoleic acid in cultured mullet fish compared to soybean (13%) and rice bran (78%). Sorghum residues significantly improved blood-thinning and erythrocyte membrane integrity of the fish blood cells during winter, thus maintaining normal blood fluidity and preventing RBC hemolysis induced by H2O2. They attributed the prevention of RBC hemolysis to the antioxidant activity of the tannins and other polyphenols present in the sorghum residue.

Sorghum and Obesity

- Tannin reduce nutritive value include binding of food proteins and carbohydrates into insoluble complexes – indigestible
- Direct binding of digestive enzymes including sucrase, amylases, trypsin, chymotrypsin and lipases thus inhibiting their activity.

To use tannin sorghums in human diet to help fight obesity, the following need to be determined:

- Whether the effects observed in animals are reproducible in humans.
- The levels of tannins in sorghum necessary to produce desired effects.
- Potential side effects e.g., effects on availability of other essential micronutrients, especially divalent minerals like iron and how the effects can be overcome.
- How various food processing conditions affect potential activity of the tannins.

Sorghum and Cancer

In vitro studies have also revealed anti-carcinogenic properties of sorghum. Grimmer *et al.,* (1992) demonstrated anti-mutagenicity of sorghum polyphenol extracts. They found the high MW procyanidins (tannins) had the highest anti-mutagenic activity compared to lower MW tannins. Gomez-Cordovez *et al.,* (2001) showed that sorghum tannins had anti-carcinogenic activity against human melanoma cells, as well as positive melanogenic activity (melanogenesis is believed to help protect human skin against UV irradiation damage. The authors did not observe such melanogenic activity in red wine extracts.

Grimmer *et al.,* (1992) showed that polymeric tannins from sorghum had higher anti-mutagenic activity than the lower molecular weight tannins. Gomez-Cordoves *et al.,* (2001) showed that sorghum tannins increased melanogenic activity without increasing total melanin and reduced the formation of human melanoma colony cells. A recent study by Turner *et al.,* (2006) showed that black and tannin sorghum bran reduced colon carcinogenesis in rats. In their study, rats fed diets containing black or tannin sorghum bran had fewer aberrant crypts than those fed diets containing cellulose or white sorghum bran. The

reduction in colon carcinogenesis could be due to the antioxidant activity of the black and tannin sorghum bran. Studies are needed to determine which compounds are responsible for the anti-carcinogenic effects of sorghum.

The nitriloside compound is a crystalline structure which contains two units of glucose (sugar), one of benzaldehyde, and one of cyanate, which are tightly bonded together. Locked together in this natural state, it is completely inert chemically and has absolutely no effect on human tissue. There is only one substance that can unlock the nitriloside molecule and release the cyanate and benzaldehyde. That substance is an enzyme called "beta-glucosidase", which is known as the "unlocking enzyme". When the nitriloside molecule comes in contact with this enzyme in the presence of water, both the cyanide and benzaldehyde are released, which are high toxic by themselves. Now both of these substances working together are at least a hundred times more poisonous than either of them separately. This phenomenon is known in biochemistry as "synergism".

Perhaps the most interesting fact of all about this biochemical process is that the "unlocking enzyme" is not found anywhere in the body except at the cancer cells, where it is always present in large quantities, as much as one hundred times that of the normal cells. The result is that the nitriloside molecule is unlocked at the cancer cell site, releases its poisons to the cancer cell, and only to the cancer cell.

Another important enzyme in this process is called "Rhodanese", which is called the "protecting enzyme". This is because it has the ability to neutralize the cyanate by converting it instantly into nourishing by-products, which are actually beneficial and essential to health. But more than that, the protecting enzyme is found in great quantities in all parts of the body except at the cancer cell site, which prevents the cancer cells from being protected. On the other hand, healthy cells are protected, because of the excess of this enzyme which completely neutralizes the effect of the unlocking enzyme.

Arthritis and Rheumatism

The fact is nitriloside food factors also serve as biochemical mechanisms in African physiology to prevent rheumatism and arthritis. Once they enter into the blood stream, derivative compounds called "salicylates" are produced. This natural compound helps to fend off arthritis and rheumatism. Some African health practitioners including myself attest to the theory that many toxins bind to cell membranes and disturb cellular metabolic functions, and can cause tissue damage which contribute to many of the symptoms of rheumatism, arthritis, and muscle aches. Intestinal bacteria - "Proteus mirabilis", for example, an organism recently implicated in rheumatoid arthritis, is believed to be produced by the toxic waste in the body causing painful joint inflammations.

Whereas rheumatoid arthritis disease afflicts millions of people of African descent in the U.S., affecting one in 10, very few cases have been reported among the larger populations of tropical Africa. This has defied explanation in Western health sciences. According to African traditional medicine, rheumatism and arthritis is a disease reaction which creates inflammation caused by crystallized urine and toxic waste. These impurities accumulate around the joints, bone lining and connective tissues. Arthritis is waste in the bone joints while rheumatism is waste in the muscles. Both of these diseases are caused by the same thing - excessive fat and meat, synthetic foods, and a poor diet deficient in thiocyanates and nitrilosides.

CONCLUSION

Sorghum is a rich source of various phytochemicals including tannins, phenolic acids, anthocyanins, phytosterols and policosanols. These phytochemicals have potential to significantly impact human health. Sorghum fractions possess high antioxidant activity in vitro relative to other cereals or fruits as stated by many researchers. These fractions may offer similar health benefits commonly associated with fruits. Available epidemiological evidence suggests that sorghum consumption reduces the risk of certain types of cancer in humans compared to other cereals. The high concentration of phytochemicals in sorghum may be partly responsible.

Sorghums containing tannins are widely reported to reduce caloric availability and hence weight gain in animals is reduced. This property is potentially useful in helping reduce obesity in humans also. Sorghum phytochemicals also promote cardiovascular health in animals. Such properties have not been reported in humans and require investigation, since cardiovascular disease is currently the leading killer worldwide.

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