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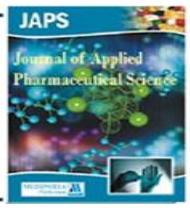

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Potential Functional Implications of Pearl millet (*Pennisetum glaucum*) in Health and Disease

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ABSTRACT

Pearl millet (*Pennisetum glaucum*), also known as Bajra, is one of the four most important cereals (rice, maize, sorghum and millets) grown in tropical semi-arid regions of the world primarily in Africa and Asia. Our aim is to review the potential health benefits of pearl millet. Desk reviews from Gujarat Agricultural Universities, libraries, PubMed and other web sources, key informant interviews of farmers (n=30), local leaders (sarpanch) (n=30) and women (n=960) from pearl millet belt of Banaskantha district of Gujarat. Pearl millet is rich in several nutrients as well as non-nutrients such as phenols. It has high energy, has less starch, high fiber (1.2g/100g, most of which is insoluble), 8-15 times greater α-amylase activity as compared to wheat, has low glycemic index (55) and is gluten free. The protein content ranges from 8 to 19% and it is low in lysine, tryptophan, threonine and the sulfur-containing amino acids. The energy of millet is greater than sorghum and nearly equal to that of brown rice because the lipid content is generally higher (3 to 6%). Pearl millet can be recommended in the treatment of celiac diseases, constipation and several non-communicable diseases. Nutritional studies on the population living in the pearl millet belts of the world and clinical trials on the impact of pearl millet in specific disease conditions are needed.

Keywords: Pearl millet, review, health, Banaskantha, NCDs

INTRODUCTION

Pearl Millet (Pennisetum glaucum), also known as Bajra, is a cereal crop grown in tropical semi-arid regions of the world primarily in Africa and Asia (Figure 1). Bajra is well adapted to production systems characterized by low rainfall (200-600 mm), low soil fertility, and high temperature, and thus can be grown in areas where other cereal crops, such as wheat or maize, would not survive. In its traditional growing areas, pearl millet is the basic staple for households in the poorest countries and among the poorest people (Figure 2). It is also one of the most drought resistant crops among cereals and millets. Pearl millet is generally used as a temporary summer pasture crop or in some areas as a food crop (http://www.wmo.int). Pearl millet is one of the four most important cereals (rice, maize, sorghum and millets) grown in the tropics (Figure 3) and is rich in iron and zinc, contains high amount of antioxidants and these nutrients along with the antioxidants may be beneficial for the overall health and wellbeing.

Our aim of the study is to review the potential health benefits of pearl millet. This work is a part of a larger ongoing project on "Background Nutritional Studies on Pearl Millet - Gujarat, funded by CIAT/IFPRI/Harvest Plus, USA.

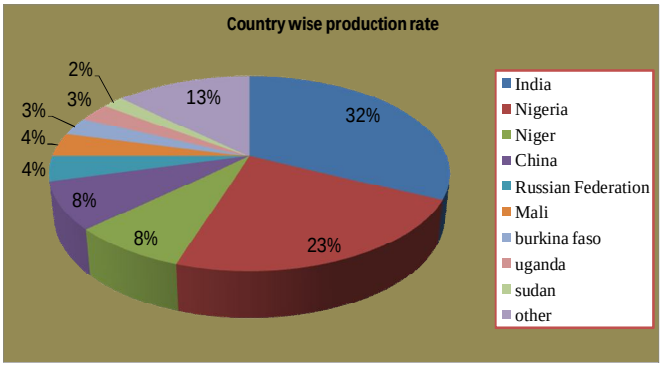

Fig 1: Millet production rate of the world.

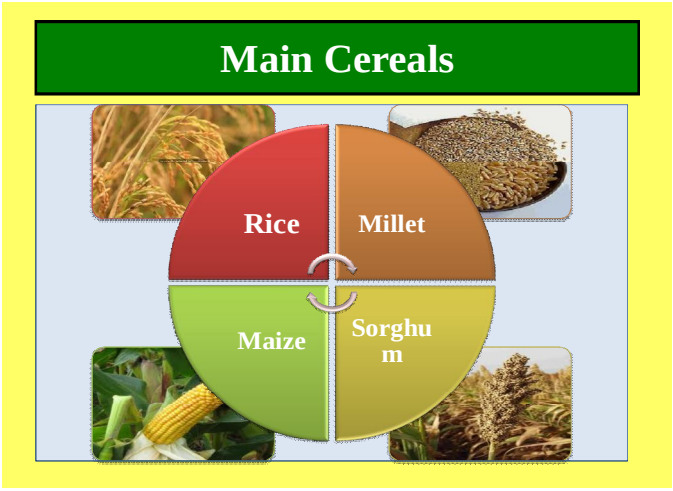

Fig 2: Pearl millet is one of the important cereals grown in the tropics.

Fig 3: Pictures of Banaskantha woman preparing pearl millet rotla (bread).

METHODS AND MATERIALS

Desk reviews were collected from personal visits to Gujarat Agricultural Universities namely: 1) Junagadh Agricultural University (JAU) Jamnagar center 2) Anand Agricultural University (AAU) 3) Navsari Agricultural University (NAU) and 4) Sardarkrushinagar Dantiwada Agricultural University (SDAU); PubMed and other web sources and libraries across the state.

RESULTS

Nutritional value of Pearl Millet

The following section describes the nutritive value of pearl millet in comparison with the commonly consumed cereals such as wheat, rice, maize and sorghum (Table 1).

Table 1: Nutritive value of pearl millet in comparison with commonly consumed cereals.

CONSTITUENT	PEARL MILLET	WHEAT	RICE	SORGHUM	MAIZE
Protein(g)	11.6, 11.8*, 8 # , 11**	11.8	6.8	10.4	4.7
Fat(g)	5.0 , 4.8*, 2.4# , 5.0**	1.5	0.5	1.9	0.9
Crude fiber(g)	1.2, 2.3* , 2.2**	1.2	0.2	1.6	1.9
Carbohydrates(g)	67.5, 67*, 57# , 69**	71.2	78.2	72.6	24.6
Minerals(mg)	2.3	1.5	0.6	1.6	0.8
Calcium(mg)	42 , 42* , 25**	41	10	25	9
Phosphorous(mg)	296	306	160	222	121
Iron(mg)	8 , 11*, 3.0**	5.3	0.7	4.1	1.1
Zinc(mg)	3.1 , 2.2#	2.7	1.4	1.6	-
Sodium(mg)	10.9 , 5#	17.1	-	7.3	51.7
Magnesium(mg)	137 , 106#	138	90	171	40
Vitamin A(mcg)	132	64	0	47	32
Thiamine(mg)	0.33 , 0.38* , 0.30 # , 0.3**	0.45	0.06	0.37	0.11
Riboflavin(mg)	0.25 ,0.21*, 0.15**	0.17	0.06	0.13	0.17
Niacin(mg)	2.3 , 2.8* , 3.2# , 2.0**	5.5	1.9	3.1	0.6
Folic acid(mcg)	45.5	36.6	8	20	-
Vit C(mg)	0	0	0	0	6

* Hulse. Laing and Pearson. 1980: United States National Research Council/National Academy of Sciences. 1982. USDA/HNIS. 1984.
# ***Source:*** http://www.wholehealthmd.com/refshelf/*Foods view/1,1523,72,00.html,*
*****Source***: Cultivated plants, primarily as food sources – *Sorghum and Millets* - Irén Léder, Nutrtive value of Indian Foods, NIN, 2003

Energy

Pearl millet is a rich source of energy (361 Kcal/100g) which is comparable with commonly consumed cereals such as wheat (346 Kcal/100g), rice (345Kcal/100g) maize (125 Kcal/100g) and sorghum (349Kcal/100g) as per the Nutritive value of Indian foods (NIN, 2003).

Macronutrients

Carbohydrate: The carbohydrate content of pearl millet is 67.5 g/100g, which is lower than wheat, rice and sorghum, but higher than maize (Table 1) as per the Nutritive value of Indian foods (NIN, 2003). The germ of pearl millet has much larger percentage of the total kernel than the germ of sorghum (17.4% in millet and 9.8% in sorghum). This difference explains that pearl millet has lower starch and higher protein and oil content as compared to sorghum. Starch represents about 56 to 65% of the kernel and is about 20 to 22% amylose; free sugars range from 2.6 to 2.8% of the grain. The main sugar in pearl, foxtail, finger, and proso millets is sucrose. Pearl millet has high fiber content (1.2g/100g, NIN, 2003). Most of the dietary fiber is insoluble interestingly; α-amylase activity is 8 to 15 times greater in pearl millet than in wheat (Sheorain and Wagle, 1973). Pearl millet has a lowest

glycemic index (55) as compared to sorghum, finger millet and mungbean (Mani et al, 1993).

Proteins: The protein content of pearl millet is comparable to wheat (11.6 vs 11.8 g/100g), is higher than rice (6.8 g/100g), sorghum (10.4 g/100g) and maize (4.7 g/100g) as per the Nutritive value of Indian foods (NIN, 2003). It has a better amino acid balance than sorghum, it is low in lysine, tryptophan, threonine and the sulfur-containing amino acids (Figure 4-6).

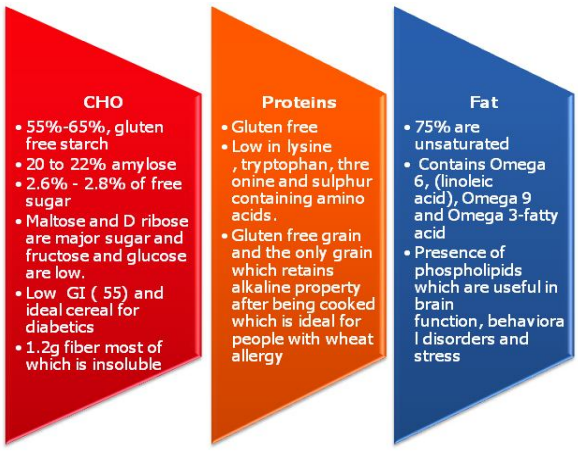

Fig 4: A summary of the macronutrient content of pearl millet.

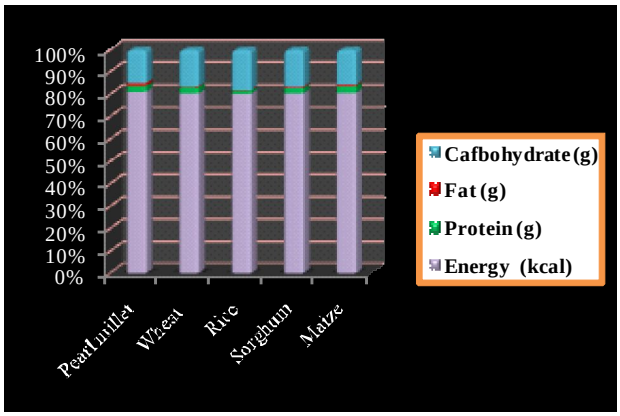

Fig 5: Macronutrient content of pearl millet in comparison with wheat, rice, sorghum and maize.

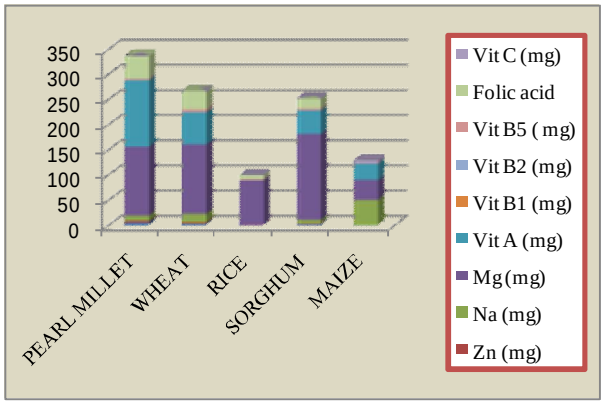

Fig 6: Micronutrient content of pearl millet in comparison with wheat, rice, sorghum and maize.

Finger, teff, and kodo millets have similar amounts of lysine to pearl millet. However, as compared to maize, pearl millet is 8-60% higher in crude protein and 40% richer in amino acid lysine and methionine. The lysine content of pearl millet is 21% greater than corn and 36% greater than sorghum (Irén Léder, 2004).

Fractions of protein in millets are as follows: albumins and globulins from 22 to 28%, prolamin and prolamin-like 22 to 35%, and glutelin and glutelin-like 28 to 32% of total N. The prolamin fraction in pearl millet is smaller than sorghum. Pearl millet is gluten free grain and is the only grain that retains its alkaline properties after being cooked which is ideal for people with wheat allergy (Irén Léder, 2004).

Adeola and Orban (1994), reported that the nitrogen intake and absorption were higher (P<0·05) for pearl millet as compared to corn and the digestibility of nitrogen was similar for pearl millet and corn. Net protein utilization (NPU) was lower (P<0·05) in pearl millet when compared to corn (corn, 44·8%; PMA, 34·6%; PMB, 39·9%). Digestibility of the essential amino acids, arginine, threonine, valine, isoleucine and lysine were higher in pearl millet than corn.

Llipids: Pearl millet is richer in fat content (5 mg/100g, NIN 2003) as compared to most grains (Table 1), 75% of the fatty acids are unsaturated. Omega 3, linolenic acid (C18:3n-3) (LNA) comprises 4% of the total fatty acids in this oil (Burton et al, 1972, Rooney, 1978), giving it a higher content of n-3 fatty acids than other cereal grains. Corn is notably deficient in n-3 fatty acids, with LNA comprising only about 0.9% of total fatty acids. Nutritionally important *n*–3 fatty acids include α-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA), all of which are polyunsaturated.

Adeola and Orban (1994) have reported that the fat digestibility was much higher in pearl millet than corn. Lai & Varriano-Marston (1980a) and Kaced et al (1984) have reported that pearl millet has large germs which give rise to rapid development of fatty acid in whole pearl millet meal, mainly due to action of lipase which causes bitterness and makes meal unacceptable within 5-8 days after milling.

Micronutrients

Vitamins and minerals: Pearl millet contains various essential micro nutrients needed by the body. Overall mineral content of pearl millet is 2.3 mg/100g which is high as compared to commonly consumed cereals (Table 1). It is rich in B-vitamins, potassium, phosphorous, magnesium, iron, zinc, copper and manganese (NIN, 2003). Dried, matured kernels do not contain vitamin C and the B vitamins are concentrated in the aleurone layer and germ. Removing the hull by decortication reduces the levels of thiamine, riboflavin and niacin by about 50% in the flour. Niacin in cereals is found in free and bound forms and can be synthesized from tryptophan. The niacin content of the hulled millet seed is still significant. This is why the PP vitamin insufficiency disease, pellagra, is not found in areas where millet is consumed in great

quantities. Pearl millet, along with other grains, contains oxalic acid, which forms an insoluble complex with calcium, thereby reducing biological availability of this mineral. Calcium concentration in pearl millet is quite low, and the presence of oxalate can exacerbate the deficiency (Irén Léder, 2004).

Non-nutrient value of Pearl Millet

Millets have the following anti-nutrient components: polyphenols and tannin, phytic acid and phytate, goitrogens, and oxalic acid. Polyphenols and tannin compounds are concentrated in the bran. There is a strong relationship between the tannin levels and in-vitro protein digestibility. Decortication significantly decreases the amount of tannins with a corresponding increase in protein digestibility (Irén Léder, 2004). Millet changes color reversibly from grey to yellow-green at alkaline pH, and partially reversibly from grey to creamy white under acidic conditions due to the presence of phenolic compounds (glucosylvitexin, glucosylorientin, vitexin) (Reichert, 1979).

Potential health benefits of Pearl Millet

Due to its chemical composition, Bajra has been attributed to having several health promoting abilities which are listed below (Table 2).

Table 2: Possible health benefits of pearl millet on various diet related diseases/ disorders and deficiency.

DISEASE/PROBLEM	POSSIBLE BENEFIT	POSITIVE FACTOR IN PEARL MILLET
Anemia	May Help in increasing the Hb	High iron content (8mg/100g) High Zinc content (3.1mg/100g)
Constipation	May help in dealing with constipation	High fiber (1.2g/100g)
Cancer	Anti cancer property Inhibit tumor development	Antioxidant property, high flavonoids
Diabetes	Help in dealing with diabetes	Has Low glycemic index
Celiac	Anti allergic	Gluten free
Diarrhea	Probiotic treatment	Lactic acid bacteria
NCDs	Inhibits DNA scission, LDL cholesterol, liposome oxidation and proliferation of HT-29 adenocarcinoma cells.	Flavonoids, phenolics, Omega 3 fatty acids

Bajra and Anemia

Pearl millet contains high amount of Iron (8mg/100g) and Zinc (3.1mg/100g), (NIN, 2003) which may help to increase the Hb levels. However the presence of several non-nutrients such as phytates and polyphenols may decrease the bioavailability of iron. Use of household processing technologies such as popping, germination, fermentation as described above may lead to reduction of these non-nutrients and further leads to increase in bioavailability of iron and zinc (Sharma and Kapoor, 1996).

Bajra and Constipation

The high fiber content (1.2g/100g) of pearl millet (NIN 2003) can be extensively used to prepare healthy foods for people who needs high fiber diet, especially it is helpful in obesity and dealing with problem of constipation.

Bajra and Cancer

Pearl millet contains high level of antioxidants namely the phenolic compounds and may have anticancer property. Sripriya et al (1996) reported the phenolic content of 51.4 and 43.1 mg/100g DW of pearl millet and sorghum respectively. Sharma and Kapoor (1996) have reported the phenols in pearl millet grains as 608.1mg/ 100g and that in pearl millet flour as 761mg/ 100g. Phenolic compound especially flavanoids, have been found to inhibit tumor development (Huang and Ferraro 1992). These compounds are concentrated in the pericarp and testa. Since traditionally, the entire pearl millet grain is milled, products made out of the flour would provide the health benefits of the flavonoids and phenols.

Bajra and Diabetes

Pearl millet has a very high amylase activity, about 10 times that of wheat. Maltose and D-ribose are the predominant sugars in the flour, while fructose and glucose levels are low (Oshodi et al 1999).

Diet is considered to be the cornerstone in the management of diabetes mellitus and more so in the case of noninsulin-dependent diabetes mellitus (NIDDM) in which the primary derangement is of carbohydrate metabolism, with secondary abnormalities of lipid and protein metabolism. Dietary management of diabetes involves the reduction of postprandial hyperglycaemia and good glycaemic control. The concept of glycaemic index (GI) emerged as a physiological basis for ranking carbohydrate foods according to the blood glucose response they produce on ingestion, and was introduced by Jenkins et al (1981). Mani et al (1993) have reported that pearl millet (*Penniseteum typhoideum*), has the lowest GI (55) as compared to Varagu (*Plaspalum scorbiculatum*) alone and in combination with whole and dehusked greengram (*Phaseolus aureus Roxb*), Jowar (*Sorghum vulgare*) and Ragi (*Eleusine coracana*). Foods with a low glycemic index are useful to manage maturity onset diabetes, by improving metabolic control of blood pressure and plasma low density lipo protein cholesterol levels due to less pronounced insulin response (Asp, 1996). Several pearl millet based novel food products can be developed and traditional recipes need to be promoted for the diabetic patients.

Bajra and other non-communicable diseases

The presence of omega-3 fatty acids in pearl millet as compared to any other cereal grain highlights its potential in prevention and treatment of cardiovascular diseases, diabetes, arthritis and certain types of cancer. Researchers found that certain *n*−3 fatty acids are also converted into eicosanoids, but at a much slower rate. Eicosanoids made from *n*−3 fatty acids are often referred to as anti-inflammatory, but in fact they are just less inflammatory than those made from *n*−6 fats. If both *n*−3 and *n*−6 fatty acids are present, they will "compete" to be transformed, so the ratio of long-chain *n*−3:*n*−6 fatty acids directly affect the type

of eicosanoids that are produced. They cause a reduction in the concentration of triglycerides in blood, improve immune response, brain and eye function, and infant development (Kinsella et al, 1990; Simopoulos, 2000). Mammals cannot synthesize *n*−3 fatty acids, but have a limited ability to form the "long-chain" *n*−3 fatty acids EPA (20-carbon atoms) and DHA (22-carbon atoms) from the "short-chain" eighteen-carbon *n*−3 fatty acid ALA.

Pearl millet is likely to be non-toxic; however pennisetins, the class of prolamins in pearl millet, differ from somewhat homologous prolamin, zeins in maize and kafirins in sorghum (Marcellino et al, 2002).

Chandrasekara and Shahidi (2011) revealed that the phenolic extract of kodo millet exhibited higher inhibition activities against oxidation of LDL cholesterol and liposome than that of pearl millet. They demonstrated that dehulled grains of millet and hulls inhibited DNA scission, LDL cholesterol, liposome oxidation and proliferation of HT-29 adenocarcinoma cells. Bound phenolic extracts showed considerable bioactivity and release of these compounds in the colon upon microbial fermentation and, hence, may impart health benefits locally. Hydroxycinnamic acids, mainly ferulic and p-coumaric acids (ranged from 17.8 to 1685 µg/g defatted meal and from 3.5 to 680 µg/g defatted meal, respectively) may contribute to the observed action of millet phenolics in addition to hydroxybenzoic acids and flavonoids identified in pearl millet.

Bajra and Allergies

Pearl millet is a gluten free grain and is the only grain that retains its alkaline properties after being cooked which is ideal for people with wheat allergies. Pearl millet grains are all very high in calories—precisely the reason they do wonders for growing children and pregnant women (www.icrisat.org).

Gluten intolerance persons (Celica) allergic to gliadin, aprolmine specific to wheat and some other common grains, comprise approximately 500,000 persons in the United States or 1 in every 541 people (based on US census bureau resident population estimate, 1998).

More complete characterization of sorghum and pearl millet proteins and their functionality would provide useful information for marketing celiac foods.

CONCLUSIONS

Potential health benefits and its possible neutraceutical properties of pearl millet have been highlighted in this paper. Pearl millet serves as a major staple food for many populations around the globe, however, it is still considered poor man's food and does not find place in the food purchase lists of the elite. Millets, which are currently consumed in the rural and tribal areas of the world, need to be popularized. Unique health foods as well as traditional foods made from pearl millet need to be promoted.

Further studies on nutritional studies on the health of the population living in the pearl millet belt (Figure 7) and the impact of pearl millet on general as well as therapeutic nutrition need to be commenced owing to its potential function as high energy food during celiac diseases, diabetes, constipation and non-communicable diseases. Studies on the bioavailability and bioefficacy of millet phenolics upon absorption need to be undertaken.

Fig 7: Women from pearl millet consumption and production belt of Banaskantha, Gujarat, India.

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