Pearl Millet: Potential Nutraceutical Properties of Pearl Millet and its Utilization in Various Food Products: A Review

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ABSTRACT

Pearl millet (*Pennisetum glaucum*), also called bajra, is an important cereal crop cultivated in the tropics. It is a very hardy crop and can adapt to even very low rainfall. This review paper deals with the discussion of nutraceutical, functional properties and antidiabetic properties of pearl millet. Pearl millet is popular for its nutraceutical property. The bioactive compounds present in pearl millet indicate the efficacy and capacity of the nutraceutical property present in pearl millet. Several products prepared from pearl millet flour were found to induce low glycemic index when compared to wheat flour and many of the few acids present, produced antioxidant activity. Different types of sweet, savoury food products and beverages prepared from pearl millet grains and their flours provide higher potential due to their profound nutritional benefits which include rich dietary fibres, minerals and high protein content. As a result of being a viable low cost crop with several added benefits such as lower incidence of developing mycotoxins, resistance to high temperatures and low rainfall requirements pearl millet is an accessible alternative for consumers in need of highly nutritious, low priced and sustainable food products.

Key words: Antidiabetic properties, Bioactive compounds, Functional properties, Nutraceuticals, Pearl millet.

Millet is a term used to collectively denote a variety of grain crops that produce small grains (FAO and ICRISAT, 1996) that are about 1/4 to 1/10th the size of a wheat grain (Taylor, 2016). They are grown in arid and semi-arid regions and can tolerate and grow in harsh conditions like infertile and dry soil with low water holding capacity, high temperature and low rainfall (FAO and ICRISAT, 1996).

They were first seen in Africa and Eurasia but now are cultivated in many parts across the world. There are about 13 millet species that are cultivated and millets are gaining popularity due to the health benefits they provide especially for their high content of phenolic phytochemicals. They are also gluten free making it a component in many multigrain diets in Western countries. Some of the most popular millets include pearl millet, foxtail millet, proso millet, finger millet, fonio and teff grains (Taylor *et al*., 2016).

The production of millets in the world was around 27.67 MT in the year 2000 and increased to around 28.37 MT in 2019. The production of millets in India was around 10.07 MT in the year 2000 and increased to around 10.23 MT in the year 2019 (FAOSTAT).

Pearl millet (*Pennisetum glaucum*) also called as bajra, is a millet grown mainly in India, Nigeria and several other parts of Africa (Taylor *et al*., 2008). It is also known by the names Bulrush millet, Cattail millet, Babala, Bajra/ bajira in different regions (Taylor *et al*., 2016). Pearl millet was seen to have a higher ceiling temperature for grain yield compared to other cereals showing its resilience and suitability for cultivation in semi-arid regions (Djanaguiraman *et al*., 2017). It is an important cereal crop cultivated in the tropics. It is a very hardy crop and can adapt to even very low rainfall of up to 200-600 mm, high temperature and infertile soil making it cultivable where rice and wheat cannot grow. It is often referred to as coarse grain cereals (Rai *et al*., 2008) and it serves as a staple diet in economically backward countries (Nambiar *et al*., 2011).

Pearl millet is a true caryopsis where the pericarp tightly adheres to the seed coat. It has an average weight of about 8 mg (National Research Council, 1996).

Nutritional composition

Pearl millet is a good source of iron and zinc and can be effectively put to use in the manufacture of nutrient rich foods to combat micronutrient deficiencies. However, the antinutrients present in it could interfere with the availability of these nutrients to the body (Krishnan *et al*., 2018) (Table 1).

Physical properties

Pearl millet is a small grain and can be up to 2 mm long and has a 1000 kernel weight of around 8 g (20% of a wheat kernel) (Taylor *et al*., 2016). It gets its name due to its pearly white appearance though it may exist in different

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colors like brown, yellow and purple and is ovoid to tear shaped. The kernel is naked and the germ is quite large compared to other cereal grains (Taylor *et al*., 2008) (Table 2).

The physical properties of pearl millet that has been studied in Table 2.

Nutraceutical property of pearl millet

Nutraceuticals umbrella a wide range of bioactive compounds that provide certain functional properties in the body. The term nutraceuticals (like pharmaceuticals) is used for such bioactive compounds from food sources which have a protective effect against degenerative diseases in its isolated form. Essential nutrients can be considered nutraceuticals if they provide benefits beyond their essential role in normal growth or maintenance of the human body. Nutraceuticals encompass phenolic compounds, phenolic acids, flavonoids, phytic acid, carotenoids and tocopherols, phytosterols and arabinoxylans. Chauhan *et al*. (2021) analyzed that the total polyphenol, total flavonoid and tannin content of native pearl millet are indicated to be 10.2 mg/g, 5.54 mg/g and 5.93 mg/g respectively as they are a vital source of antioxidants and play a predominant role in preventing oxidative stress occurring in the body due to free radicals and prevent diseases related to oxidative stress such as CVD and cancer (Chauhan *et al*., 2021).

Total polyphenol content of native pearl millet was 2.58 mg/g. Native grain showed a total flavonoid content of 2.35 mg/g

Antioxidant activity

Pearl millet is rich in antioxidants and fiber and has potential beneficial effects against cancer, cardiovascular disease and aging which are caused due to the generation of harmful oxygen species such as free radicals and peroxides that damage the cells. Polyphenolic profile of native pearl millet by HPLC showed compounds in native pearl millet grains of which 7 were identified as protocatechuic, syringic, p280 coumaric, ferulic, sinapic, salicylic and t-cinnamic acid. Concentration of sinapic acid (501 µg/g) was highest among the identified phenolic acids of pearl millet, followed by salicylic acid (182 µg/g).These acids present in native pearl millet contribute significantly to the antioxidant property of pearl millet. The availability of nutrients and bioactive components is likely to be influenced by processing methods (Hithamani and Srinivasan, 2014). Several traditional household food-processing methods (thermal processing, sprouting and fermentation) can be used to enhance the availability of micronutrients in plant based diets. These strategies could improve the physicochemic al accessibility of nutrients from the food matrix, decreasing the content of antinutrients (Hotz and Gibson, 2007).

Antidiabetic effect/hypoglycemic effect/α-amylase activity

Pearl millet finds several uses in preparing various types of health foods and food ingredients. The crop contains a relatively higher proportion of insoluble dietary fiber. This causes slow release of sugar, thus making the food products prepared from them especially suitable for those suffering from or prone to diabetes. For instance, various pearl millet-based food products were found to have a lower glycemic index (GI) than those based on potential applications in foods for diabetic patients. The glycemic index of products like biscuit, chapati, dhokla, instant idli and pasta were found to be 58.1; 48.0; 38.0; 52.1; 54.1 respectively when compared with products prepared with wheat flour as control (Mani *et al*., 1993).

Pearl millet is rich in several nutrients as well as non-nutrients such as phenols (Nambiar *et al.,* 2012). It has high energy, less starch, high fiber (1.2 g/100 g, most of which is insoluble), 8-15 times greater α-amylase activity as compared to wheat, has low glycemic index and is gluten free.

Pearl millet has high fiber content (1.2 g/100 g,) (NIN, 2003). Most of the dietary fiber is insoluble interestingly;

Table 1: Nutritional composition of pearl millet.

Component	Amount (per 100g edible portion)
Moisture (g)	8.97±0.60
Protein (g)	10.96±0.26
Ash (g)	1.37±0.17
Fat (g)	5.43±0.64
Total dietary fibre (g)	11.49±0.62
Carbohydrate (g)	61.78±0.85
Energy (KJ)	1456 ±18
Thiamine (mg)	0.25±0.044
Riboflavin (mg)	0.20±0.038
Niacin (mg)	0.86±0.10
Pantothenic acid (mg)	0.50±0.05
Biotin (µg)	0.64±0.05
Total folates (µg)	36.11±5.05
Ergocalciferol (D_2) (µg)	5.65±0.27
Phylloquinone (µg)	2.85±0.63
Lutein (µg)	26.69±8.72
β-Carotene (µg)	28.23±9.42
Calcium (mg)	27.35±2.16
Iron (mg)	6.42±1.04

Source: Indian Food Composition Tables, NIN - 2017.

Table 2: Physical properties of pearl millet.

Property	Mean value
Length (mm)	3.522
Width (mm)	2.590
Thickness (mm)	2.100
Geometric mean diameter (Dm)	2.664
Sphericity (Φ)	0.755
True density (kg/m^3)	1267.236
Bulk density (kg/m^3)	852.644
Weight of 1000 grains (g)	9.896

Source: TB, Surpam and IL, Pardeshi (2020). Determination of engineering properties of pearl millet (Bajra).

α-amylase activity is 8 to 15 times greater in pearl millet than in wheat (Sheorain and Wagle, 1973). The concept of glycaemic index (GI) introduced by Jenkins *et al*. (1978) and Mani *et al*. (1993) have reported that pearl millet (*Penniseteum typhoideum*), has the lowest GI (55) as compared to Varagu alone and in combination with whole and dehusked green gram, 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 lipoprotein 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.

Traditional food products

The simplest and common way of utilizing pearl-millet in traditional foods include thick porridge (fermented and unfermented), thin porridge (gruel), flat and unfermented bread such as chapati (Tara Satyavathi *et al*., 2017).

Porridge

Porridges prepared from pearl-millet flour as such as kambu koozh, originated from Tamil Nadu and other millet based porridges that find its origin from Africa such as ben-saalga, oko, uji, ugali, bogobe, obushera, bouillie and koko are the major pearl millet based food products widely consumed (Adebiyi *et al*., 2016). The consistency of the porridge ranges between thick and thin, depending upon the concentration of flour (10%-30%). Different types of porridges may be prepared by cooking the millet flour in boiling water followed by vigorous stirring. These products may also differ in flavor and pH (Taylor *et al*., 2016).

A survey conducted among 318 households in Burkin Faso (South Africa), Ben-saalga and Ben-kida are traditional pearl-millet based fermented gruels that are most commonly consumed as complementary foods. Samples of fermented gruel made from pearl millet from 48 production units presented a decrease in the factors responsible for reducing nutrient bioavailability or ±-galactosides. Lactic acid production was evident and it was responsible for the fermentation of the gruels which was detected by the presence of d (-) lactate in all the samples (Mouquet *et al*., 2008).

Ben-saalga prepared from pearl millet flour, groundnuts, malted barley flour, sugar, ginger and mint proved to be a better formulation of the gruel. It provided an appropriate balance of high energy density and macronutrients at a suitable consistency (Tou *et al*., 2006).

Breads

Flatbreads are traditional and popular gluten-free pancake-like products prepared from fermented or unfermented pearl millet flour. Combination of fermented pearl millet flour and lukewarm water is used to produce Lohoh (Osman, 2011).

Pearl millet flour fortified with soy flour and other ingredients used in the preparation of flat breads resulted in a product with high puffing, protein efficiency ratio, minimal thickness and other physical parameters such as uniform texture and color (Tara Satyavathi *et al*., 2017).

Pasta

The effect of utilizing pearl millet flour (PMF), finger millet flour (FMF) replacing Durum wheat semolina showed positive results in the developed product in terms of nutrition. The pasta developed from 20% pearl millet presented a higher nutritional value but showed increased loss of solids, reduction of weight and firmness (Gull *et al*., 2015).

Formulation of wheat-based noodles incorporated with pearl millet flour and guar gum which is prepared from a blend of wheat and pearl millet flour in the ratio 90:10 and with guar gum (2%) resulted in nutritionally superior noodles as compared to control. Incorporation of pearl millet improved the textural attributes such as increased firmness and lowered the losses that occur during cooking (Deshmukh *et al*., 2021).

Sweets

Traditional Indian sweet Ladoo (Singh *et al*., 2008) was developed from two different variations. The product prepared from 100% popped pearl millet had increased cellulose and lignin content in ladoos. The ladoos prepared from popped pearl millet enriched with dehulled chickpea and groundnut had significantly higher calcium (65.51±0.49 mg/100 g), phosphorus (168.26±1.82 mg/100 g) and iron content (4.89±0.06 mg/100 g).

Weaning foods

Weaning foods formulated from pearl-millet malt, wheat and roasted rice in the ratio (50:30:10) was considered palatable and acceptable in terms of sensory properties. The formulation resulted in better water holding capacity, two-fold increase in mineral content and more dispersibility. The product was more digestible as compared to wheat flour based weaning food. The nutritional value of the developed weaning food from pearl millet was found to show increased crude fibre content, protein content by 20%, doubling of iron and zinc and calcium content (Talib *et al*., 2017).

Fura

Fura prepared from dehulled pearl millet flour through extrusion showed an increased hydration rate of 63.9% at 28°C when compared with fura prepared traditionally which showed a hydration rate of around 15.8% at 28°C. Fura prepared from pearl millet flour through extrusion when compared with traditionally prepared fura, remained acceptable even after 12 weeks' storage in polyethylene and cellophane bags at 30±2°C as these products are generally short shelf-life products (Taylor and Francis, 2006).

Traditional snacks and RTE-Snacks

Pearl millet flour utilized in the formulation of kibbeh, a popular Mediterranean snack prepared by replacing whole-wheat flour resulted in products with better oxidation stability during storage for 90 days at -18°C. It also proved as a good alternative and was acceptable among individuals with celiac disease,

increased nutritional value and sensorial quality in addition to being a gluten-free product (Brasil *et al*., 2015).

Formulation of biscuits from pearl millet flour from two different processing methods- germination and fermentation enhanced the overall nutritional quality of the product and yielded lower bulk density (Adebiyi *et al*., 2016).

Development of Ready-to-eat (RTE) breakfast cereals from puffed wheat, popped amaranth, honey, raisins, sugar, water, flaxseeds and sunflower seeds enriched with popped pearl-millet aided in improving the overall nutritional quality of the product. The addition of popped pearl millet increased the folate content in the developed product (Kumari *et al*., 2019).

Ready-to-eat snacks prepared from a blend of whole pearl millet (81.68%), finger millet (7.02%) and decorticated soy bean blended extrudates were developed. The pearl millet expanded in a twin screw extruder, presented better sensory characteristics and also aided in the production of low cost extrudates (Balasubramanian *et al*., 2012).

Pearl millet based prebiotics and probiotics

Indigenous food blends prepared from pearl millets by a combination of germination followed by fermentation with a probiotic organism is a prospective processing method for developing products with increased nutritional quality and health benefits (Sonia *et al*., 2015).

Prebiotics and Probiotics have positive effects on human health by promoting immune-health benefits which includes suppression of autoimmune diseases, allergic reactions as well as reduction of inflammatory bowel diseases and antimicrobial action (Todd *et al*., 2012).

In a study conducted, to characterize probiotic properties of bacteria isolated from flour and batter samples of sorghum and pearl millet, a total of nine isolates such as *Bacillus pumilus*, *Bacillus subtilis*, *Bacillus amyloliquefaciens*, *Sphingobacterium thalpophilum*, *Bacillus cereus* and *Brevibacterium* sp. indicated that the selected bacteria isolates had an increased potential to develop new probiotic foods with health benefits (Rajyalakshmi *et al*., 2017).

The isolated strains of Lactobacillus in Kimere, a fermented dough based food prepared from millets, was inoculated in yoghurts and distributed to the needy children in Kenya. The observations resulted in a reduced aflatoxin intoxication on consumption of 200 mL for a week of the probiotic yoghurt (Nduti *et al*., 2016).

In a research study, (Surve *et al*., 2018), Rabadi prepared from soaking naturally fermented flour of pearl millet in buttermilk resulted in good quality attributes within a very short period of fermentation by improving the nutritive value of the product through the process. Rabadi fermentation results in the reduction in polyphenol content and phytic acid content of pearl millet which presents an enhanced digestibility of carbohydrates, proteins and increased the bioavailability of minerals in the fermented product.

Probiotic strains of *Lactobacillus fermentum* isolated from the grains of fermented pearl millet, provided prominent antimicrobial activity against Staphylococcus aureus as well as Listeria monocytogenes (Owusu *et al.,* 2015).

Non-alcoholic beverages

Kunu-zaki, commonly consumed in Northern Nigeria is a non-alcoholic beverage produced mainly from millets. It is a low viscous product with a milky cream texture and a sweet-sour taste (Adelekan *et al*., 2013).

Kunu-zaki formulations were produced from pearl millet cultivar, ginger, black pepper, hot pepper and 5% malt from six different pearl millet cultivars and one sorghum cultivar. *Saccharomyces cerevisiae*, *Klebsiella aerogenes* and *Aspergillus niger* were the microorganisms isolated from all the kunu- zaki formulations. Addition of 5% malt from pearl-millet cultivars improved the taste and texture of kunu-zaki formulations. This addition did not affect the microbial count of kunu-zaki formulations (Badau, 2007).

CONCLUSION

Pearl millet is a powerhouse of nutraceutical properties that helps in treating various conditions in the body when consumed in the right manner with suitable pre-treatment and processing. This review paper provides an overview of pearl millet and its nutraceutical properties and the ways in which it could be tapped and utilized in simple ways ranging from porridge, breads, pasta, sweets, weaning foods, fura, snacks, prebiotic and probiotic foods and non-alcoholic beverages.

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