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Amazing Health Benefits of Pearl Millet (*Pennisetum glaucum* L. R. Br.)

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ABSTRACT

Pearl millet [Pennisetum glaucum (L.) R.Br.], locally known as bajra is a nutritious coarse grain cereal. Pearl millet is the 4th most important grain crop in India which can be predominantly grown as stable food, feed and fodder. Due to its rich composition of minerals and proteins. Pearl millet benefits are good for diabetic and anemic, lowers cholesterol, weight and prevents gallstone formation. Along with wheat flour even bajra was included in the regular diet. It is known to have a very high fiber content which makes it healthier. Pearl millet requires surprisingly low amounts of water to grow. This millet is completely gluten free. Pearl millet is very powerful in controlling diabetes. Pearl millet is gluten-free with well-balanced protein and microelements such as Ca, Fe, Zn and lipids are a good option to protect from celiac. Pearl millet is rich in antioxidants phytates, phenols, and tannins which can contribute to antioxidant activity important in health, aging, and metabolic syndrome.

Keywords: LDL, SDS, Gluten, Liginin and Phenolics.

INTRODUCTION

Bajra or Pearl Millet (*Pennisetum glaucum*) a superfood because of its gluten-free and nutrient-rich properties.

It is believed to domesticated over 5000 years ago in Africa and it spread all across the world becoming one of the major cereal crops. It is known to have a very high fiber content which makes it healthier. It is used as a regular meal in places like Rajasthan, Gujarat. Now a day's it is gaining its importance back [Yadav et al., 2019]. Now bajra are recommended by many health professionals, It is also not very expensive millet which can reduce its consumption. People are becoming more and more conscious about the fact of bajra having various good effects on the body. In the world, it ranks 6th after rice, wheat, maize, barley and sorghum in terms of area under cultivation. In India, pearl millet crop occupies 7.12 mha and ranks third in area after rice and wheat among the cereals. In India, Rajasthan, central Maharashtra, northern Karnataka, Gujarat, Uttar Pradesh, Haryana and Tamil Nadu are the major bajra growing states in the rainy season. Pearl millet is an upright bunch grass that tillers from the base and has an extensive root system that provides drought tolerance. Stems are 1/2–1 inch diameter. It is a leafy plant with leaf blades that are 8–40 inches long and 1/2-3 inches wide. The ligule, or junction of leaf blade to leaf sheath, is a fringe of hairs 0.08–0.1 inch long. The sheath has very sparse hairs at the base of the collar and is often hairless. The inflorescence (flower) is a single raceme-4-20 inches long-that resembles the flower of the aquatic plant known as cattail. The fruit (or caryopsis) is cylindrical, white or pearl in color, or sometimes yellow or brown, and occasionally purple [Yadav et al., 2019, Chandrasekara and Shahidi, 2011].



Pearl millet (*Cenchrus americanus*, commonly known as the synonym *Pennisetum glaucum*; also known as 'Bajra' in Hindi, 'Sajje' in Kannada, 'Kambu' in Tamil, 'Bajeer' in Kumaoni and 'Gero' in Hausa) is the most widely grown type of millet. It has been grown in Africa and the Indian subcontinent since prehistoric times. Since prehistoric times, pearl millet has been grown prominently in Africa and Indian Subcontinent. It is believed that pearl millet originated in Africa and was later introduced to India. The earliest archaeological evidences show that millet was cultivated in India around 2000 BC; hence, domestication in Africa must have taken place before that. Its origin can be trailed back to North Africa, specifically in Ethiopia but the center of diversity for the crop was in the Sahel zone of West Africa. From there, its cultivation subsequently spread to east and southern Africa, and southern Asia.

Millet is an important food staple in Africa where it is used to make a traditional flatbread known as injera [Malik, 2015]. The ground millet seeds are used for making the Indian flatbread, called roti. In the middle ages, millet was a staple grain in Europe, especially in countries in Eastern Europe. It was introduced in the United States in the 19th century. Millet is popular as birdseed and livestock fodder in Western Europe and North America, but it has recently gained popularity as a delicious and nutritious grain due to its nutritious benefits and gluten-free status. Currently, India is the leading commercial producer of pearl millet, followed by China and Nigeria. Along with wheat flour even bajra is included in the regular diet. Pearl millet, in addition to its grain consumption, is also used as a green fodder in India and in many other countries. It forms an excellent forage crop because of comparatively low hydrocyanic acid (HCN) content. The green fodder is rich in protein, calcium, phosphorus and other minerals. Its fodder when fed green to the animals has easy digestibility than the chaffed straw. It is also used as feed for poultry and green fodder or dry karvi for cattle. Much of pearl millet's success in surviving through the ages has been its ability to produce well in hot, arid, drought prone areas where most crops fail. This adaptation reflects pearl millets origin in the Sahel-region of Africa, where growing conditions are difficult. Pearl millet is dubbed as a "Diamond in the Rough" because of its adaptation to very low rainfall areas [Malik, 2015, Basavaraj et al., 2010].

Nutritional value of Pearl Millet

The most widely grown millet, the pearl millet, is known for its culinary uses as well as health benefits. Pearl millets, earlier known as 'bird food', come in several delicious flavors. What is unique about this cereal is that it may be as creamy as mashed potatoes or as fluffy as rice. In India, pearl millets are regarded as one of the major sources of dietary energy and nutritional security for poor farmers and consumers. Apart from offering excellent taste, these millets contain essential mineral and nutrients, which provide the body with a variety of advantages. Millets are ancient grains. Mankind has known its nutritional value for centuries. They are naturally gluten-free. Millet can also be used as a healthier alternative to rice and in salad recipes or as a side dish. Pearl Millet is rich in protein, fiber, essential minerals viz. P, Fe and Mg. Due to its rich composition of minerals and proteins, pearl millet has many health benefits. Pearl millet is very powerful in controlling diabetes. Because of its high fiber content, it tends to digest slowly and release glucose slower rate than other foods. This helps at а in maintaining healthy blood sugar levels for a long period. Pearl millet is a rich source of fiber, flavonoids, phenolics, and Ω 3 fatty acids.

These compounds stop lipid peroxidation thus subsequently reduces total cholesterol and LDL-cholesterol, as well as a decrease in the triglyceride. Pearl millet has higher slowly digestible starch (SDS) [Basavaraj et al., 2010]. It helps in improving the blood glucose level and also provides stable energy to patients with type 2 diabetic. Along with this the low carbohydrate, high fiber, mineral as well as leucine also positively affect toward healthy diet for diabetics. Pearl millet contains a high amount of Fe and Zn which may help to increase the Hb levels. The high mineral of pearl millets helps in improving the digestive capacity. It also contains high fiber which seems to be beneficial as a food ingredient to suppress appetite, prevent obesity-associated inflammation, and relieve constipation. Therefore pearl millet flakes could be an ideal snack for obese and calorie-conscious people.

The high fiber content in pearl millet is also known to reduce the risk of gall stone occurrence. This is because of the reduction in intestinal transit time, aided by means of the intake of fiber. It additionally reduces the secretion of bile acid, which is thought to reason gallstones. Pearl millet is known to rich in a high concentration of magnesium which helps reduce the severity of respiratory problems for asthma patients and is also effective in reducing migraine attacks. Celiac disease is the chronic inflammation of the small intestines due to an immune response to gluten. Pearl millet is gluten-free with well-balanced protein and microelements such as calcium, iron, zinc, and lipids are a good option to protect from celiac. Pearl millet is rich in antioxidants phytates, phenols, and tannins which can contribute to antioxidant activity important in health, aging, and metabolic syndrome [Basavaraj et al., 2010, Pearl millet, 2015].

Compound	Amounts/ 100 g.
Water	8.67 g
Energy	378 kcal
Protein	11.02 g
Total lipid (Fat)s	4.22 g
Carbohydrates	72.85 g
Dietary Fiber	8.5 g
Vitamins	
Folates	85 μg
Niacin	4.72 mg
Riboflavin	0.29 mg
Thiamin	0.42 mg
Vitamin B-6	0.38 mg
Vitamin E	0.05 mg
Vitamin K	0.9 μg
Minerals	
Calcium	8 mg
Iron	3.01 mg
Magnesium	114 mg
Phosphorous	285 mg
Zinc	1.68 mg
Sodium	5 mg
Potassium	195 mg

According to the United States Department of Agriculture (USDA), per 100 grams of Pearl millet contains the following components.

Because of its rich nutrient profile, bajra roti has turned into a healthy alternative for whole wheat rotis. Although the calories in bajra roti are slightly higher, the increased protein and essential nutrient content more than make up for it, and it is highly recommended to include it in everyday diet.

Pearl millet has deep root system so it extract soil nutrient and holds higher nutritional value than the other cereal crops such as wheat, rice, maize and sorghum. Mineral-wise, this crop contain high amount of iron, zinc, magnesium, copper, manganese, potassium and phosphorous. It is good source of energy, with calorific value of361 Kcal/100g and high in fiber content (1.2g / 100g) (Singh et al. 2018). Protein content in pearl millet is higher and it is also a good source of vitamin-B, Vitamin-A, folic acid, calcium and magnesium. Pearl millet grain has high fat content than other cereal cause poor keeping quality of the product. The chemical composition of pearl millet along with other traditional cereal crops is given in Table 1.





Chemical Structure of important Constituents of Pearl millet



Health Benefits of Pearl Millet

Products of pearl millet Pearl millet cereals are used to produce various conventional foods. Most widely available traditional pearl millet includes porridge and flatbreads (Roti). Other foods are also available in market such as alcoholic beverage (opaque beer or Dogon millet beer, chibuku shake, mbeg, merissa) and non-alcoholic drink (pombe, pito, boza, kunun Zaki, bushera, mahewu, oskikundu, marewa). Pearl millet flour is traditionally used by Indian housewives to prepare variety of different products like Laddoo, chips, wadi, bread, cake etc.

Millets are a great source of starch, making it a high-energy food. It is also an excellent source of protein and fiber. It is said that the amino acids in the pearl millet are more easily digestible than the ones found in wheat. Due to essential nutrients such as methionine (an amino acid), B complex vitamins (niacin, thiamin, and riboflavin), folic acid, lecithin, essential minerals viz. K, Mg, Mn and Zn, millets are very effective in several roles. Niacin reduces cholesterol while magnesium is essential for maintaining good heart health, as it lowers blood pressure and reduces the risk of heart attacks. Pearl millet is a rich source of phosphorus, which plays an important part in the structure of body cells. Phosphorus, found in pearl millets, is a significant component of several necessary compounds including adenosine triphosphate (ATP). This element is also a crucial component of nucleic acids, which are the building blocks of the genetic code. Phosphorus is a constituent of lipidcontaining structures such as cell membranes and nervous system structures. Recent studies have proven that regular consumption of pearl millets help in preventing gallstones in women. They contain insoluble fibers which not only speed up intestinal transit time but also reduce the secretion of bile acids. Pearl millets are known to increase insulin sensitivity and lower the level of triglycerides. Regular intake of millets provides protection against breast cancer in pre-menopausal women. Apart from that, it has also shown a considerable reduction in the occurrence of wheezing and asthma in children. Millets contain an essential phytonutrient, lignin, which is very beneficial for the human body. Consumption of pearl millets helps in minimizing the risk of type 2 diabetes. Being a good source of magnesium, millets act as a cofactor in a number of enzymatic reactions [feedipedia.org. 2015].



Pearl millet benefits have a lot. Pearl millets are a rich source of antioxidants, their consumption offers a great deal of protection against free radical-mediated diseases such as cancer, arthritis, cardiovascular disease, diabetes, and Alzheimer's disease. Millet is an excellent food for babies from six months of age. Here we are going to discuss the benefits of pearl millet.

Pearl Millet Benefits

Pearl Millet Promotes Heart Health

Pearl millet has a high magnesium and potassium content, making it an ideal food for people with high blood pressure. It contains about 34% and 8% of the recommended daily intake (RDI) of magnesium and potassium respectively in 100 grams. Research has shown that magnesium lowers the blood pressure of people with hypertension. Potassium, on the other hand, reduces the effect of sodium in the body which ultimately reduces the body's blood pressure.

Pearl Millet Manages Diabetes

The millet had a low glycemic index of 55 when compared with sorghum, finger millet, and mung bean – Low glycemic index foods cause your blood sugar to rise gradually, not quickly, after eating them. Foods with a low glycemic index reduce insulin response and improve low-density lipoproteins (LDL) levels in the body which is useful for preventing diabetes and other metabolic disorders.

Pearl Millet Prevents Cancer

Pearl millet contains omega-3 fatty acids and antioxidants. Its antioxidant component is mostly phenolic compounds, especially flavonoids. Antioxidants play an important role in the body's defense system against harmful by-products in the body. Studies have reported the number of phenols in pearl millet grains as 608.1mg/100g and that in pearl millet flour as 761mg/100g. The whole grain millets contain more phenols concentrated in the outer pericarp and testa of the seed.

Pearl Millet Prevents Anemia

Pearl millet contains high amounts of iron and zinc which may help increase the production of hemoglobin in the blood. However, the presence of non-nutrients, like phytates and polyphenols may inhibit the bioavailability of iron.

But when the millet is soaked and fermented, the bioavailability of zinc will increase because the level of non-nutrient will reduce.

Pearl Millet Prevents Celiac Disease

This millet is also ideal for people with celiac disease. Celiac disease occurs in the small intestine of gluten-intolerant individuals, where it interferes with the body's ability to absorb the nutrients from the food you eat. It is gluten-free and retains its alkaline properties after cooking which is good for people with wheat, barley, or rye allergies.

Pearl Millet Promotes Digestive Regularity

Due to its high water and fiber content, pearl millet prevents constipation and ensures a healthy digestive tract. Pearl millet is also known to reduce the risk of gall stone occurrence. The insoluble fiber content in millet reduces the production of excessive bile in our system. An excessive amount of bile secretion in our intestine often leads to aggravating the condition of gallstones.

Pearl Millet Promotes Weight Loss

Pearl millet promotes weight loss because of its high fiber content. Due to its fiber content, it gives a feeling of satiety for a longer period by helping the grain to move slowly from the stomach to the intestine, thus preventing overeating.

Pearl Millet Provides Energy

It also provides a good amount of protein, fatty acids, minerals, vitamins, dietary fiber, and polyphenols. Typical millet protein contains a high quantity of essential amino acids especially sulfur-containing amino acids (methionine and cysteine). Gero is considered one of the best cereal plant-based protein sources.

Pearl Millet Protects Gut Health

Pearl millet may help prevent stomach ulcers. Stomach ulcers are caused by excess acidity in the stomach after food intake. It is one of the very few foods that retain its alkalinity after cooking and this helps to make the stomach alkaline, thus preventing stomach ulcers.

Effect of Processing Techniques on Pearl Millet

Pearl millet contains rich nutrients as more to the major cultivated cereal crops. However, major factors which restrict its utilization are the presence of anti-nutritional factors (phytate, tannins and polyphenols) which reduce availability of minerals. Pearl millet having poor keeping quality due to the presence of lipase activity which affects the acceptability of the product in market. The researchers therefore, more concentrate on the effect of various processing techniques to enhance nutrient composition and shelf life of pearl millet. Those processing techniques are described below; Decortication: It is a mechanical operation to remove pericarp and bran layer from the pearl millet grain. It reduces an anti-nutritional factor phytate, tannin and polyphenols also some minerals and vitamins, but the process enhance the bioaccessability of minerals. Decortication improves the colour and palatability of the processed product. Various researchers have studied the effect of decorticationon nutrient composition of pearl millet. Goyal et. al., (2017) observed the impact of decortication on phytate content in pear imilet grains and concluded that phytate deposition occurs in the endosperm and bran fractions but is substantially denser in endosperm fractions than bran fraction. Tiwari et. al., (2014) studied the effect of premilling treatments on storage stability of pearl millet flour and it was found that during pearling for 5 to 30min, the pearled content from the grain varied from 16 to 34 %.

Their findings are clear that phytic acid, total polyphenol, iron and zinc decreased as the pearling period increased. El Hag et. al. (2002) Examined dehulling effect on two (Standard and Ugandi) pearl millet cultivars. Their results showed that both varieties had substantially lowered the protein, polyphenols as well as phytic acid contents after dehulling due to removal of outer layers.

Effect of Blanching

Blanching is one of the most effective pre-milling procedures for enhancing the shelf life of final product. It could be slow down the enzymatic activity without having much effect on its nutritional composition. Bhati et. al. (2016) found that 90s of blanching treatment may be used for the product development because of high in- vitro iron 3.29 mg/100grams, great reduction in free fatty acid content (20.57) and for improving the color of pearl millet. Singh et. al., (2006) showed that blanching reduce inhibitory factors, rancidity, and bitterness in biscuits prepared from pearl millet. Archana et. al., (1998) reported when blanched at 98 °C for 30 sec, pearl millet showed a substantial reduction in polyphenols (from 764.45 to 544.45 mg/100 g) and phytic acid content (from 833.42 to 512.10 mg/100 g) that could be due to the leaching of polyphenols and phytate ions into the soaking medium under the influence of gradient concentration. Milling: Milling is the process of separating endosperm, bran and germ. This practice converts endosperm into small and fine particles to facilitate the production of fine flour. Hammer mill and roller mill can be used for reducing the particle size. Milling is used to process pearl millet flours with different particle size distribution, but it causes the release of fatty acids present in the germ that are susceptible to oxidation and thus decreases the shelf life of the flour (Tiwari et. al., 2014). Abdelrahman et. al., (1983) studied on roller mills can be used for the production of low fat pearl millet grits. This process was accompanied by decorticating, tempering and milling of the grains through finely corrugated rolls which rotate in opposite direction and resulted in an average yield of 61% grits(from whole grains) with 1.2 % fat content.

According to a study conducted by Pushparaj and Urooj (2011), two cultivars of pearl millet (Kalukombu and Maharashtra Rabi Bajra) when subjected to milling (whole flour, bran rich fraction and semi-refined flour) showed higher percentage of in vitro protein digestibility found in bran rich fraction. These finding showed that tannin might not only be responsible for lower protein digestibility and various factors such as interaction of proteins with non-protein components and proteins themselves can also affect protein digestibility

Effect of Heat Treatments

Heat treatment is one of the most important pre-milling treatments in case of pearl millets before development of convenience food because it has very less shelf life and helps as an important driver to increase its utilization on a day-to-day basis. Yadav et. al., (2012) stated that microwave heating at a moisture level of 18 % for 80 s reduced lipase activity of pearl millet flour may be due to the high temperature of the sample (107.6 °C) by converting microwave energy into thermal energy. In addition, microwave- treated flour that is suitable for up to days of storage (15-35 °C) packed in LDPE than the control flour that only has a shelf life of 10 days. Bhati et. al., (2016) noted that the iron bio availability was maximum at 100°C for 120 minute-DHT (63.47 %). Tiwari et al. (2014) investigated that heat treatment (pre-treatments) significantly reduced phytic acid by 43.68 %, and polyphenol but had no significant reduction in iron and zinc.

Ezhilarasi and Nazni (2018) concluded that thermal pre-milling treatments roasting (110° C for 60 sec) and boiling (1:1 grain is to water) in a pan for 15 min enhanced the functional attributes of pearl millets and significantly lowered the anti-nutrients namely tannin and trypsin inhibitor activity while the bioavailability of pearl millet nutrients increases. Problems associated with pearl millet Despite rich in high nutritive value, its shelf life is limited because high content of lipid in the grain. Pearl millet can be stored for longer periods without significant quality adjustments if the kernel remains intact (Kaced et. al., 1984; Kachare and Chavan, 1992) but the guality of the meal deteriorates rapidly once the grain is decorticated and ground. Deterioration occurs because the fat content with highly active lipases contributes to hydrolysis of fats resulting in rancidity of the pearl millet product causing unpleasant odor and taste. Both hydrolytic and oxidative changes are reported in the lipid of the flour, resulting in release of free fatty acids and formation of peroxide, causing rancidity and bitterness (Kaced et. al., 1984). Therefore the pearl millet flour cannot be stored for long period of time and also become a problem for women to grind flour on daily basis. Rancidity also limited the commercial use of pearl millet product. Thus, research is needed to increase shelf life of pearl millet products.

CONCLUSION

Dieticians and Nutritionist are trying their best to promote this particular millet and increase its consumption by educating its benefits among all groups of people. Awareness among the people helps to create a positive attitude towards this millet. It is also called as pearl millet. It is not expensive like pearl but it's definitely has pearl like quality which is beneficial to the body. By any nutritional parameter, millets are miles ahead of rice and wheat In terms of their mineral content, compared to rice and wheat. Each one of the millets has more fibre than rice and wheat. Some as much as 50x that of rice. Finger millet has thirty times more Calcium than rice while every other millet has at least twice the amount of Calcium compared to rice. In their Iron content, foxtail and little millet are so rich that rice is nowhere in the race. While most of us seek a micronutrient such as Beta Carotene in pharmaceutical pills and capsules, millets offer it in abundant quantities. The much privileged rice, ironically, has zero quantity of this precious micronutrient. Bajra Khichdi tastes good with vegetables with slightly chewy texture from the bajra. It is heaty in nature, so it is good to consume in limits and best when consumed in winters. This Bajra khichdi recipe is one of the staple foods in Rajasthan, India, and is great for weight loss. Pearl millet is an important cereal crop as it is rich in nutrition with capability to grow at harsh climacteric condition. A sudden climate changes and other natural disasters can create food security problem which raises the price of foods and also reduces the availability of food materials. In this condition pearl millet is an alternative nutritious crop for the poor men which provide enough nutrition for active and healthy life. It is cheap source of nutrition when compared to other major cereal crops. While having its nutrition and health benefits, utilization of this crop is restricted due to some anti-nutrition factors and poor keeping quality. Therefore, the aim of this review is to provide the information about nutritional profile, processing techniques, health benefits, products and problem of pearl millet in order to bring the great potential of this important small grain to producers and consumers.

Pearl millet grains are gluten-free, higher in dietary fiber with a low glycemic index. Similar in lipid content to maize. It has a higher content of essential amino acids (leucine, isoleucine, and lysine) than other traditional cereals.

The antioxidants nature of this millet helps in lowering blood pressure, cardiovascular diseases, prevention of cancer and diabetes.

Pearl millet contains n–3 and n–6 fatty acid which gets converted into eicosanoids. This compound helps in the reduction of triglycerides in the blood, improves immune response, brain and eye function, and infant development. Pearl millet is gluten-free with well-balanced protein and microelements such as calcium, iron, zinc, and lipids are a good option to protect from celiac. Pearl millet is rich in antioxidants phytates, phenols, and tannins which can contribute to antioxidant activity important in health, aging, and metabolic syndrome.

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REFERENCES

- Yadav, M., Rengasamy, R.S. and Gupta, D. (2019). Characterization of Pearl Millet (*Pennisetum glaucum*) waste, *Carbohyd Poly*, 21(2):160-168.
- Chandrasekara, A. and Shahidi, F. (2011). Bioactivities and Antiradical Properties of Millet Grains and Hulls. *J Agri Food Chem*, 59, 9563 – 9571.
- Malik, S. (2015). Pearl millet Nutritional value and medicinal uses! 1(3):414-418.
- Basavaraj, G., Rao, P., Bhagavatula, S. and Ahmed, W. (2010). Availability and utilization of pearl millet in India. *J SAT Agric Res* 8: 1-6.
- Pearl millet (*Pennisetum glaucum*), grain- Feedipedia. feedipedia.org. 2015https://www.feedipedia.org/node/724
- Adebiyi, J., Obadina, A., Adebo, O. and Kayitesi, E. (2018). Fermented and malted millet products in Africa: Expedition from traditional/ethnic foods to industrial value added products. *Critical reviews in Food Science and nutrition*, 58(3):463–474.
- Asp, N.G. (1996). Dietary Carbohydrate: Classification by Chemistry and Physiology, *Journal* of Food Chemistry, 7:9-14.
- Berwal, M.K., Verma, K., Goyal, P. and Chugh, L.K. (2017). Impact of Decortication on Phytate Content inPearl Millet Grains. *Journal of Nutrition and Food Science* 2:006.
- Bhati, V., D., Bhatnagar, V. and Acharya, V. (2016). "Effect of pre-milling processing techniques on pearl millet grains with special reference to in-vitro iron availability", *Asian Journal of Dairy and Food Research*, 35(1):76-80.
- **Ezhilarasi, I.C. and Nazni, P. (2018).** Effect of thermal pre-milling treatment on pearl millet and incorporation of *psyllium* husk in the formulation of vermicelli. *International Journal of Food Science and Nutrition*, 3(5):80-85.
- Huang, M.T. and Ferraro, T. (1992). Phenolics compounds in food and cancer prevention, In: Phenolic Compounds in Food and Their Effects on Health II, ACS Symposium Series, 507: 8–34.

- Jukanti, A.K., Laxmipathi Gowda, C.L., Rai, K.N., Manga, V.K. and Bhatt, R.K. (2016). Crops that feed the world 11. Pearl Millet (*Pennisetum glaucum* L.): an important source of food security, nutrition and health in the arid and semi-arid tropics. *Food Sec.* 8:307–329.
- Kaced, I., Hoseney, R.C. and Varriano-Mortson, K. (1984). Factors affecting rancidity in ground millet (*Pennisetum americanum*). *Cereal Chemistry* 61: 187-192.
- Malik S. (2015). Pearl Millet-Nutritional Value and Medicinal Uses. International Journal of Advance Research and Innovative Ideas in Education, 1(3): 414-418.
- Nambiar, V.S., Dhauk, J.J., Sareen, N., Shahu, T. and Desai, R. (2011). Journal of Applied *Pharmaceutical Science* 01(10):62-67.
- Pushparaj, F.S. and Urooj, A. (2011). Influence of Processing on Dietary Fiber, Tannin and in Vitro Protein Digestibility of Pearl Millet. *Food and Nutrition Sciences*, 02(08): 895– 900.
- Ragaee, S., Abdel-Aal, E.M. and Noaman, M. (2006). Antioxidant activity and nutrient composition of selected cereals for food use. *Food Chem* 98(1):32–8.
- Rai, K.N. and Gowda, C.L.L. and Reddy, B.V.S. and Sehgal, S. (2008). Adaptation and Potential Uses of Sorghum and Pearl Millet in Alternative and Health Foods. *Comprehensive Reviews in Food Science and Food Safety*, 7 (4):320-396.
- Savita Rani, Singh, R., Sehrawat, R., Kaur, B.P. and Upadhyay, A. (2018). Pearl millet processing: a review, *Nutrition and Food Science*, 48 (1):30-44.
- Singh, G., Sehgal, S., Kawatra, A. and Preeti (2006)."Mineral profile, anti-nutrients and in vitro digestibility of biscuit prepared from blanched and malted pearl millet flour". *Nutrition and Food Science*, 36(4):231–239.
- Singh, N., Singh, S.P., Kumar, M., Kanhiya, K. and Kumar, A. (2018). Nutri Cereal Pearl millet: Way Forward. Int. J. Curr. Microbiol. App. Sci 7(6): 578-581.
- Tiwari, A., Jha, S., Pal, R., Sethi, S. and Krishan, L. (2014). Effect of pre-milling treatments on storage stability of pearl millet flour. *Journal of Food Processing and Preservation*, 38 (3): 1215–1223.
- Yadav, D.N., Anand, T., Kaur, J. and Singh, A.K. (2012). Improved Storage Stability of Pearl Millet Flour Through Microwave Treatment. *Agric Res* 1(4):399–404.