Plant Archives Vol. 25, No. 1, 2025 pp. 681-687 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.1.102

PEARL MILLET AND ITS PROCESSED PRODUCTS: A REVIEW

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(Date of Receiving-31-11-2024; Date of Acceptance-20-02-2025)

ABSTRACT

Pearl millet is an underutilized coarse cereal but it is a nutrient rich crop and has great potential to be grown in adverse climatic conditions. But it have some anti-nutrients factors (polyphenols, phytate, and tannin) which are responsible for its limited utilization and reduced bioavailability of nutrients and short storage period of products due to higher lipase enzyme activity. However the main aim of this paper is focus on different processing techniques (Dehulling, Milling, Malting and Blanching) which help to improve availability of nutrients and reduced the quantity of anti-nutritional ingredients. Apart this various type of value added products of pearl millet are discussed which can be helpful for improving the scope and palatability of pearl millet.

***Key words*:** Processing, Dehulling, Milling, malting, Blanching, Fermentation, anti-nutritional factors.

Introduction

Pearl millet or *Bajra* is an underutilized coarse cereal crop (Krishnan and Meera, 2017) grown for food and forage purpose (Arora *et al*., 2003) mainly in African and Asian countries (Nambiar *et al*., 2011). Pearl millet is native of Africa and successfully cultivated in India It is a staple food of 90 million poor people and extensively grown on 30 million hectare area in the arid and semi-arid tropical regions of Asia and Africa. It accounts for almost half of the global millet productivity. About 95% of total production produced in developing countries in which India secured first rank in production of pearl millet (Pawase, 2021). The grains, ground or softened by soaking in water, find use to a limited extent as animal feed. The green plant serves as excellent fodder and is cultivated in development countries only for animal feeding. The straw is also used as fodder but is of inferior quality.

In India it is mainly grown in *kharif* season (June/ July to September /October) in Karnataka, Rajasthan, Uttar Pradesh, Haryana, Gujarat, Madhya Pradesh and Maharashtra, which accounts for about 90 per cent of total national production. About 85 per cent of pearl millet produced in the country is used as food and it constitutes the staple diet of nearly 10% of the Indian population.

It is a hardy crop and can be grown in adverse climate condition (high temperature and drought situation, low soil fertility) due to this quality it is grown in those regions where rice, wheat, maize and other cereal crops fail to survive and play an important role to defeat hunger and malnutrition in Africa and southeast Asia. Globally, it is sixth most significant cereal crop after rice (*Qryza sativa*) wheat (*Triticum aestivum*), maize (*Zea mays*), barley (*Hordeum vulgare*) and sorghum (*Sorghum bicolor*). It is mainly cultivated on marginal lands under rain fed conditions and can sustain and produce a significant amount of grain even in drought prone areas (Nambiar *et al*., 2011).

Being a C_4 plant it possesses high photosynthetic efficiency, more ability to fix inorganic CO_2 high efficiency in water utilization and more dry matter production capability. Thus crop has survival under adverse agro climatic conditions using fewer inputs and earning more profits. With other C_4 plants such as maize and sorghum it can account for 30 per cent of global terrestrial carbon fixation (Choudhary *et al.*, 2020). It also possesses several advantages such as early maturity, drought tolerance, and minimal inputs and usually free from biotic and abiotic

stresses. It has inherent ability to endure high temperatures up to 42ºC during the reproductive phase makes it suitable for growth in extremely hot summer thus making it a climate resilient crop.

The changing climate is leading to an increase in global average temperature affecting agriculture production worldwide. Further it directly influences biophysical factors such as plant and animal growth along with the different areas associated with food processing and distribution. Assessment of effects of global climate changes and deployment of new tools and strategies to mitigate their effect is crucial to maximizing agricultural production to meet our food demands of the increasing population. In this context, pearl millet is most useful as it is a nutritious, climate change ready crop with enormous potential for yielding higher economic return

Taxonomic Classification and Structure of Pearl Millet Grain

Table 1: Taxonomy of Pearl Millet

Family	*Poaceae*
Subfamily	*Panicoideae*
Tribe	*Paniceae*
Subtribe	*Panicinae*
Section	*Panicillaria*
Genus	*Pennisetum*
Species	*Glaucum*

The relative distribution of the pearl millet is 8.4% of the pericarp, 75% of the endosperm and 16.5% of the germ. The coarse grain contain 8-10% husk. In millets, "the aleurone layer is a single layer of cells which lies just below the testa". Thus, the proportion of the pearl millet's endosperm to germ is about 4.5:1. (Abdelrahman *et al.*, 1984). An endosperm is regarded as the largest part of the cereal grain and it acts as a storage tissue.

Colours of the grain are grey, white, yellow, brown and purple. Shape varies from ovoid, elliptical, hexagonal and globular. The texture of the millet kernel is controlled by the size of floury and corneous endosperm. More floury than corneous endosperm is found in soft-textured kernels however, solid kernels have more thickly filled corneous endosperm. Cultivars with higher amounts of corneous endosperm are preferred for porridge making (Rooney *et al.*, 1986). In pearl millet, wide variations exist among the kernel textures (floury, very soft, corneous, and very hard endosperm).

Nutritional Importance of Pearl millet

It has very high nutritional content and is a good source of energy, carbohydrates cruds fiber, resistant starch (RS), soluble and insoluble dietary fibers. In comparison with other cereals pearl millet had higher protein (9-13%), fat (5-8%) starch (62-70%) energy 300Kcal per 100 g mineral (2.3 mg/100g) (Suma and Urooj, 2017).

Pearl millet starches have amylase content ranging 2.86-21.5% and higher swelling power and solubility. In different pearl millet cultivars the starch content ranged from 62.8 to 70.5%, soluble sugar from 1.2 to 2.6% and amylase from 21.9 to 28.8%. Free sugars like glucose, fructose, sucrose and raffinose are present in a range of 1.2 to 2.5%. Monosaccharides like arabinose, xylose, glucose and uronic acids are found in the non-starch polysaccharide fraction of the pearl millet. Protein quality of pearl millet grain is higher in term of tryptophan and threonine content (Elyas *et al.*, 2002). It has better essential amino acid profile of protein in comparison with other cereals such as maize and rice and it also a good source of minerals like potassium, phosphorus, magnesium iron zinc copper and manganese (Krisna and Meera, 2017).

It has 44% PUFA and rich in oleic acid 25% linoleic acid 45% and linolenic acid 4% which are considered best for health (Singh *et al.*, 2012). It is also a rich source of vitamins such as B1, B2, B3. Table 2 clearly indicates that proximate composition of pearl millet is very much comparable with other cereals. Mineral and fat content of pearl millet is more in comparison with other cereals. It is a gluten free grain that retains alkaline properties even after being cooked and thus good for people suffering from gluten allergy. It contains a higher quantity of slowly digestible starch (SDS) and RS that account for lower glycemic index (GI) and is much preferred in recent times of transforming diets, food habits and the food industry (Satya vathi *et al.*, 2020). It acts as a probiotic food for micro flora present in out body and keeps us away from constipation. It is also capable of lowering Cholesterol due to the presence of niacin in its grain. It contributes to an antioxidant activity with phytates

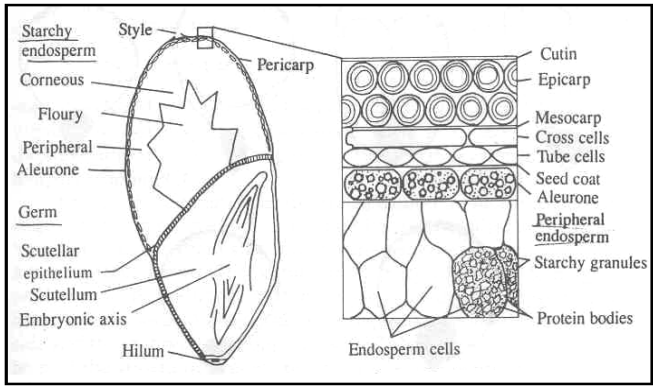

Fig. 1: Schematic cross-sectional view of pearl millet grain.

Table 2: Comparative proximate composition of Pearl millet with major Cereals (on dry basis) per 100 g of edible portion.

Name of Cereal	Moisture (g)	Protein (g)	Fat (g)	Minerals (g)	Fibre (g)	Carbohydrates (g)
Pearl Millet (*Bajra*) *Pennisetum typhoideum*	12.4	11.6	5.0	2.3	1.2	67.5
Barley *Hordeum vulgave*	12.5	11.5	1.3	1.2	3.9	69.6
Maize (dry)*Zea mays*	14.9	11.1	3.6	1.5	2.7	66.2
Oat meal*Avena sativa*	10.7	13.6	7.6	1.8	3.5	62.8
Rice (raw, hand pounded)*Oryza sativa*	13.3	7.5	1.0	0.9	0.6	76.7
Rice (raw, milled)	13.7	6.8	0.5	0.6	0.2	78.2
Wheat (whole)*Triticum aestivum*	12.8	11.8	1.5	1.5	1.2	71.2

polyphenols consumption of various types of millets in considered prefect against certain types of cancer, Cardio Vascular Diseases (CVD's), and various age-related diseases. Due to these useful properties pearl millet is popular among health conscious people all over the world. Due to its nutritional perspectives pearl millet has been renamed as nutria cereal (gazette of India, No. 133 dated 13 April, 2018).

So, it is called as power house of nutrition and can be help to prevent many diseases like diabetes, obesity, anemia, constipation, improve the capacity of digestive system and reduce blood pressure.

Anti-nutrients- Pearl millet is nutritious crop but it has some anti-nutrient factors (phytate, polyphenols and tannin) which reduce the bioavailability of minerals in gastrointestinal track (Nour *et al*., 2014) for instance polyphenol combined with Iron and form a complex in gastrointestinal tract which reduce the absorption of Iron (Krisna and Meera, 2017). Besides this presence of polyphenolic pigments in pericarp, aluerone layer and endosperm create unpleasant gray colour and taste in flour and processed products. The off flavor develops in flour and processed product due to lipase enzyme activity present in pericarp, and aluerone layer in grain (Yadav *et al.*, 2012). Reduction of these anti-nutritional factors extends the shelf life of flour and processed products of pearl millet (Prashant *et al*., 2021). To make pearl millet edible for human consumption it is necessary to process the grains by using various processing techniques.

Processing of Pearl millet

Processing is any conscious unit operation resulting in minor or major alteration in the natural shape, size, and colour, sensory and chemical characteristic of natural produce. It is done to improve the quality and self-life of a product.

Dehulling: It is a process in which outer layer, husk and pericarp of grains are removed. In pearl millet and other millets the amount of husk is varies 1.5 to 29.3 percentage (Jaybhaya *et al*., 2014). Previously dehulling of millets for domestic purpose was done manually but in present various type of mechanical hullers are used for this purpose. Process of dehulling reduces the nutrient content (protein, fat, insoluble dietary fiber, ash, lysine, tryptophan and other amino acid) of pearl millet. This may be due to removal of pericarp and germ during decortication (Rathi *et al*., 2004). El Hag *et al*., (2002) studied the effect of dehulling on nutritional profile of two cultivars of pearl millet (Standard and Ugandi) and reported that protein, phytic acid and polyphenols of both cultivars considerably reduced after dehulling. However digestibility of protein of both variety (Standard and Ugandi) increased up to 79.1 and 78.6 percentage respectively. Hama *et al*., (2011) studied the effect of decortication methods (Manual and Mechanical) on nutritional composition of pearl millet kernels and compared it with abrasive decortication method. Results showed that no significant difference was observed in these traditional methods. Dharmraj *et al.*, 2014 reported that decorticated millet can be cooked in less time (6 minute) compared to without decorticated millet because dehusked seed is small in size and have larger surface area.

Milling: Milling is a process in which grains dehulled and ground into smaller particles or flour to improved palatability, reduce cooking time, and create many other processed food products. Milling of pearl millet is slightly difficult because its grain is small and germ sturdily embedded along with endosperm (Abdelrhman *et al*., 1983). Grains of pearl millet can be milled by hammer mill and produce rough flour which limits its utilization in different processed product (baked and steam food products). However flour produced by roller mills can be easily used to developed various type of steamed and baked food product (Rai *et al*., 2008). Grinding of grain with roller mill also responsible for damages of starch granules (Singh and Raghuvanshi, 2012). Central Food Technology Research Institute (CFTRI) has developed a new techniques for enhancing the keeping quality of pearl millet flour, which comprised moist heat treatment of grain followed by drying to 10-12 percentage moisture and then dehulling up to the preferred degree of

pulverization is carried out. After treatment, various pearl millet cultivars showed improvement in their milling characteristics due to high proportion of floury endosperm (Savita *et al*., 2017). Thus milling process at a standard level has a positive impact on quality of product developed by pearl millet and increased the opportunities of value addition of pearl millet grains.

Heat treatment: Heat treatment is a process by which grains of pearl millet subjected to dry heat which significantly reduce activity of lipase enzyme which is responsible for the breakdown of glycerides and free fatty acid profile (Arora *et al.*, 2002) and responsible for bitterness and rancidity in flour of pearl millet and reduced storage life of flour. Jalgaonkar *et al*., (2016) pearl millet treated at 110°C for 60 sec. using screw extruder, and reported that beyond this limit grains started puffing and burning. According to Sun *et al.,* (2014) dry heat treatment at 100°C for 120-minute increased iron availability and reduced polyphenol and fatty acid content in pearl millet compared to raw grains. Yadav *et al*., (2012) reported that lipase activity in pearl grains significantly decreased by using microwave heating (18% moisture level) combination of dry heat (20h) and acid treatments (18h) had negative effect on lipase activity and reduced free fatty acid and fatty acidity of pearl millet flour up to 28 days of storage period (Savita *et al*., 2017)

Thus heat treatment in pearl millet gives positive effect because it increases bioavailability of nutrients and reduced activity of quality deteriorates factors (lipase enzyme activity).

Blanching: Blanching in pearl millet is very effective process for reducing inhibitory factor, enzymatic activity and increased shelf life of pearl millet flour without nutrient losses. Singh *et al*., (2006) reported that biscuits prepared by blanched flour of pearl millet had high calcium, phosphorus, iron and manganese content, low in anti-nutrients and high digestibility as compared to malted flour biscuits. Bhati *et al*., (2016) reported that blanching treatment at 100±5°C for 90 seconds improved color, iron availability (2.19 to 3.29mg/100g) and reduced free fatty acid (44.56 to 20.59mg/100g). Thus blanching process at appropriate temperature and time in pearl millet improve sensory as well as nutrient availability

Malting: Malting is the process of Physical and nutritional modification of grain through steeping, germinating and kilning (drying). Malting process increased energy level, vitamin content and improved digestibility of nutrient Preetika *et al*., (2004). In germinated grain complex carbohydrates broken down in to simple carbohydrates (oligosaccharide or disaccharide) because germination process hastens activity of amylase enzyme which is responsible for splitting of complex carbohydrates in to simple carbohydrates Singh *et al*., (2015).

Germinated grain flour had low water holding capacity and high energy density which is a suitable for infant food, weaning foods and can be used for the production of various type of milk based beverages and confectionary product like cakes, biscuits etc. (Shobana *et al.*, 2013). A study was conducted by Nithya *et al*., (2007) on effect of processing method on nutritional and anti-nutritional quality in pearl millet. It was found that sprouting process reduced the anti-nutritional factors (phytic acid, tannin and total phenols) and maintain nutritional profiles of grains. Adebiyi *et al*., (2017) revealed that biscuits of malted flour had high crude protein, crude fiber, energy value compared to biscuits prepared with untreated pearl millet flour. Bhati *et al*., (2016) reported that malting process before milling improved availability of nutrients (iron, protein) and reduced anti-nutrition factors (polyphenols, free fatty acid).

Fermentation: Fermentation is a desirable process for improvement the sensory as well as nutritional composition of pearl millet products. Magdi and Osman (2011) prepared bread by pearl millet flour and reported that during the fermentation (24h) carbohydrate, amino acids (glycin, lysine, arginine) and anti-nutritional factors (trypsin, amylase inhibitors and phytic acid) significantly decreased but tannin content increased in flour. Khetarpaul & Chauhan (1990) revealed that pearl millet flour fermented by yeasts (*S. diastaticus*,. *S. cerevistiae*) and lactobacilli (*L. brevis, L fermentum*) reduced starch content with increased total soluble sugar (reducing and non-reducing sugar) and protein digestibility of pearl millet flour. Hassan *et al.*, (2006) studied the effect of processing techniques on the pearl grain cultivars and reported that processed grain when subjected to fermentation digestibility was found to increase whereas anti-nutritional factors were found to decrease.

Acid treatment: Dark gray colour is a crucial problem of pearl millet grains which limits it utilization among various processing techniques. Acid treatment is a very effective technique to control this problem and improve bioavailability of nutrients. Arora and Kawatra (2003) reported that pearl millet grains subjected to acid treatment (0.2N HCL for 6, 12, 18, 24 h) with increase in duration mineral content like phosphorus, iron, calcium content decreased significantly but bio availability of these minerals increased. Bhati *et al.*, (2016) treated pearl millet grains with 0.2N HCL solution for different duration (6,

12, 18, 24 h) and reported that iron content decreased with duration but colour improved compared to raw grains.

Utilization of pearl millet

Generally, millets are never eaten raw and hence processing plays an important role in making it edible and digestible. Pearl millet is consumed after dehusking and cooked in the same way as rice. More commonly, it is ground into flour and made into *chapaties*. It is also made into thin porridge. The grain is sometimes eaten after it is parched, the product being similar to popcorn. The grain is suitable for the preparation of malt. An intoxicating drink is obtained from its malted seeds. Some processed products of pearl millet are (Rao *et al*., 2016) are summarized below-

1. **Bajra flour:** It can be used for preparation of various type of value added products. *Bajra* flour contains 6.1% protein, 2.2% fat, and 1.5% fiber and can be stored up to two months at ambient temperature. Recovery of flour is about 89% of total grain weight.
2. **Bajra puffs:** Pearl millet puff is a product which is a resultant of explosive puffing where grain is extended to maximum expansion consistent with grain density. Puffs are greenish in colour and crispy in nature.
3. **Semolina (Rawa/ suji):** semolina are the ready to cooks foods prepared by milling of clean dry grain and used preparation of various type of dish like *khichadi, rawa laddu, upma*. According to the size of particles semolina can be categorized in to three grade coarse semolina (68-72% yield), medium semolina (71-76% yield) and fine semolina (74-80%). It can be stored up to four months after roasting
4. **Laddu:** It is an Indian sweet made from mixture of roasted flour/semolina, low calories sugar, dry fruit, ghee and cardamom.
5. **Bread:** It is a product prepared by mixing a mixture of flour (50% pearl millet and 50% wheat flour), water, fat, salt, and yeast until the mixture gets converted in to dough followed by baking and finally converted in to loaf. Flour of pearl millet is gluten free which affected the raising quality of bread so *bajra* flour should be mixed with wheat flour. Millets bread is rich in fiber, minerals so it is beneficial all age group of peoples. Average nutrient composition of millets bread is 7.4% protein, 12.3% fat and 0.8% dietary fiber.
6. **Cake:** It is a product which is prepared by mixing a mixture of millets flour (pearl millet, finger millet and foxtail millet) or single millet flour with good quality fat, sugar, eggs and chocolate/vanilla essence.
7. **Cookies:** Cookies are popular ready to eat product and prefer all age group of peoples. It is prepared using pearl millet flour, sugar, milk solid and good quality fat salt and natural identical flavoring substance by using planetary mixture, automatic cookies making machine and rotary oven.
8. **Flakes:** Extruded Flakes are Ready-To-Eat products prepared using twin-screw hot extruder which combines heating with the act of extrusion to create round shaped product which is further flattened in roller flaker machine. The extruded Flakes is made from bajra, wheat and corn flour. The snack can be coated with desired spices to create variations in the taste and flavor.
9. **Lassi:** *Bajra lassi* is made by combining bajra flour and milk, then processing, inoculating with sufficient lactic culture, and fermenting to the correct acidity level.
10. **Vermicelli:** Sorghum/Finger millet /Foxtail millet /Pearl millet semolina and refined wheat semolina are blended in the mixing compartment of the vermicelli-making machine and blended with water for 30 minutes and extruded. Wheat is added as the less gluten content of millets requires minimum percentage of wheat for preparing vermicelli.
11. **Pizza base:** Pizza is a Ready to eat (RTE) product which is prepared by mixing a mixture of flour, yeast, salt fat and flavoring ingredients (parsley) until the mixture gets converted into dough, which is followed by baking the dough. Millet pizza has been prepared at Indian Institute of Millet Research (IIMR) Hyderabad, India using 50% sorghum, pearl millet, finger millet or foxtail millet flour, 50% fine wheat flour, adding superior quality fat, yeast, salt and sugar; and also adding all the millets together with varied proportions.

Conclusion

Methods of processing have positive impact on the nutritional availability of pearl millet grain as well as in its various product and reduces the content of anti-nutrients and provide lot of opportunities to convert pearl millet in

to various type of proceeds products which can play a vital role defeating malnutrition situation in different countries (especially in developing countries) and generate a source of income of farmers at national as well as global level.

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