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Impact of household processing methods on the nutritional characteristics of pearl millet (*Pennisetumtyphoideum*): a review

Abstract

Pearl millet contains 300Kcal of energy, 9-13% protein, 5-8% fat and 62-70% starch. The energy density of pearl millet grain is relatively higher compared with maize, wheat, or sorghum. The higher energy density in pearl millet is attributed to the presence of higher fat content. It is also high in polyunsaturated fats and linolenic acid. Minerals including calcium, phosphorus, magnesium, manganese, zinc, iron and copper are found to be higher in pearl millet compared to corn. It has favorable amino acid balance with high level of essential amino acids and superior in vitro pepsin digestibility values makes pearl millet highly nutritious. Although, pearl millet is nutritionally superior compared to cereals, it is underutilized and neglected due to non-availability in convenience form. The major limitations in producing various pearl millet products are the small grain size, the large germ and presence of various anti-nutrients, poor digestibility of proteins & carbohydrates and low palatability. Processing plays an important role in enhancing digestibility and nutritive value of pearl millet. The present review focuses on the impact of simple household processing methods on the nutritional quality of pearl millet.

Keywords: pearl millet, processing, bioaccessibility, nutrients, antinutrients

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Introduction

Processing is one of the key aspects that make food palatable and easily digestible. It is inevitable that all foods undergo some processing from farm to fork nonetheless; the process should not strip off its nutrients. Food processing is defined as converting raw materials into usable or cooked form with the aim of extending shelf life of the product, bring variety in the diet, provide nutrients required for health and generates income for the manufacturing company. Generally this cannot be achieved by using a single type of processing and hence multiple methods are used such as hurdle concept. Consumers demand for high quality food that is fresh with extended shelf life has led to the development of hurdle technology using multiple hurdles which has least effect on product quality. Processing is categorized based on the temperature. Ambient temperature processing includes cleaning, sorting & grading, size reduction, mixing & forming, separation & concentration of food components, genetic modification, and irradiation. Processing techniques employing high temperature include blanching, pasteurization, heat sterilization, evaporation & distillation, extrusion, dehydration, smoking, frying and baking.[1] Traditional/household processing methods include milling, boiling, pressure cooking, roasting, germination etc. As a result of these processing methods, many changes may take place with respect to its physical, biochemical or functional properties, sensory characteristics and microbiological changes. The present review emphasizes the effect of common, simple household processing techniques on the nutrients and anti-nutrients of pearl millet (*Pennisetumtyphoideum*).

Pearl millet can be used as food, feed and fodder. It can be grown under harsh ecological conditions. It is superior to major cereals, in terms of energy value, protein, fat and minerals content.[2] Utilization of pearl millet is limited due to non-availability in ready to use form. It is mostly available in form of whole flour for preparation of roties (unleavened Indian bread) or porridge.

Taxonomic classification of pearl millet[3]

Family-Gramineae

Sub-family-Panicoideae

Tribe-Panciceae

Genus-Pennisetum

Species-Americanum

Synonimia-Pennisetumtyphoideum (Burm) Staph & Hubbard

Pennisetumtyphoiidium Rich

Pennisetumglaucum (L) R. Br.

Pennisetumspicatum (L) Koern

Pearl millet, Bulrush millet, Bajra (India), Mwele (East Africa), Kalasat (Burma)

(Source: http://www.aicpmip.res.in)

Pearl millet belongs to the family Gramineae. It was classified into 2 sub species *Panicumglaucum* and *Panicumameicanium*by Linnarus. The two names commonly used in the past were *Pannisetumtypoidus* (Burm) and *Pennisetumglaucum* (L) R.Br. The first name is used today as a synonym for the crop.

Pearl millet in India is grown as a single season crop. Cultivation predominantly takes place on marginal lands and un-irrigated lands. According to FAO statistics,[4] the world production of millets is 26,702,000 metric tons from an area of 33,692,000 hectare. Pearl millet is recognized as being the most widely grown of all the millet types. India is one of the top producers of millets followed by Nigeria for the year 2000 to 2009. Global production of pearl millet exceeds 10million tons per year, to which India contributes to nearly half. Pearl millet (*Pennisetumtyphoideum*) is widely grown due to its tolerance to harsh growing conditions. Karnataka is one of the major pearl millet growing states in India however the area for production has declined over the years. Other major pearl millet producing states are Gujarat, Maharashtra and Rajasthan that also have the highest pearl millet consumers.[5,6]

Nutritionally pearl millet is superior to major cereals in terms of high quality protein, fat, dietary fiber and minerals (calcium, iron, zinc).[7,8] Pearl millet contains about 9 to 13% protein, which is higher than rice (7.2%) barley (11.5%), maize (11.1%) and sorghum (10.4%).[9] It contains up to 8% fat which is more than wheat, rice, barley and sorghum.[10] The essential amino acid profile of pearl millet protein displays higher lysine, threonine, methionine and cystine than in proteins of sorghum and corn.[11] The native *Kalukombu* (K) variety of pearl millet (locally grown in India) contains 9.3% protein, 4.8% fat and 2.0% ash while hybrid Maharashtra Rabi bajra (MRB) has higher protein (10.2%) and fat (5.4%) content. Iron content (6.4%) is high in MRB while K is high phosphorus (327.8%).[12] 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%. The grain is gluten-free. Free sugars like glucose, fructose, sucrose and raffinose are present in a range of 1.2 to 2.5%. Monosaccharide's like arabinose, xylose, glucose and uronic acids are found in the non-starch polysaccharide fraction of the pearl millet.[13–16] Pearl millet is an important source of thiamin, niacin, riboflavin, fat-soluble vitamin E (2mg/100g) and vitamin A which is typically about 24 Retinol Equivalents, mainly located in the germ.[14]

Processing methods

Decortications

Decortication is a process of removing the fibrous pericarp of the millet. First, the outer layer of the seed coat is abraded off then the inner layer is scraped away.[17] Decortications of pearl millet remove the outer part amounting up to 20-22% of weight of the whole grains.[18]

Milling and sieving

Florence et al.[21] reported the effect of milling on nutrients, antinutrients and mineral bioaccessibility. Two commercial pearl millet varieties were milled into whole flour, semi refined flour and bran rich fraction. The bran rich fraction had higher concentration of fat and ash content. It was high in minerals including calcium, phosphorus and antinutrients like phytate. Semi refined flour was low in antinutrients which enhanced mineral bioaccessibility. It had some desirable nutritional qualities of both whole flour and refined flour. Because of its fine texture and nutritive value, semi refined flour could be used in baked products while, bran rich fraction could be used as a functional ingredient in formulation of value added products.[21]

Impact of processing on the nutrient composition

It is well known that processing methods significantly alter the physicochemical composition of food grains and thereby nutritional value.

Functional properties

The knowledge of physical properties of pearl millet is important in determining its suitability in food product development as well as designing equipment in handling of the millet. Bran rich fraction, a byproduct of pearl millet milling, was characterized by high water and oil holding capacity indicating its suitability as a bulking agent in functional food formulations. Germination of pearl millet resulted in lighter and finer flours with high bulk density, desirable attributes in infant/health food formulations.[22]

Protein content

While unprocessed pearl millet was found to contain low % IVPD (45.5-49.3)g/100g, milling (bran rich fraction), roasting and germination considerable improved protein digestibility to about 80%.[23,24] Roasting a dry-heat treatment was beneficial in terms of retaining nutrients particularly proteins. Dehulling of pearl millet grains increased IVPD due to removal of anti-nutritional factors in the dehulled flour while, cooking as well as combination of dehulling & cooking of pearl millet significantly reduced IVPD.[23–27] Natural fermentation for 72h at 20, 25 and 30°C reduced phytic acid and increased polyphenols in pearl millet flour and also improved *in vitro* protein digestibility.[28] Decreased protein content in pearl millet due to fermentation was attributed to the action of moulds and anaerobic bacteria, which degraded proteins and converted them to ammonia. However, fermentation of pearl millet improved *in-vitro* protein digestibility (IVPD) due to partial degradation of complex storage proteins to more simple and soluble products and also due to the degradation of tannins, polyphenols and phytic acid by microbial enzymes.[2,29,31] Ionizing radiation in combination with cooking reduced IVPD.[27,32] Higher protein digestibility after radiation treatment may be due to augmented accessibility to enzymatic attack or also due to inactivation of protein aqueous anti-nutritional factors.[33] On the other hand, studies have reported that fermentation increased the crude protein content of pearl millet flour.[24] Consequently, protein digestibility may be decreased or increased without destroying amino acids.[34] Therefore radiation does offer a good treatment for millet to decrease or eliminate anti-nutritional factors with consequent increase in their digestibility and thereby increase utilization of proteins.

Germination increased total protein in pearl millet while, malting reduced the protein content. This could be due to loss of low molecular weight nitrogenous compounds during the steeping process and rinsing of the grains. The increase in nitrogen solubility index during malting was observed which could be due to gradual degradation of reserve protein into amino acids and short peptides caused by elevating the levels of protease enzymes which caused an increase in IVPD. Increase in IVPD of germinated millet can be attributed to an increase in soluble proteins as a result of partial hydrolysis of storage proteins by proteases. Such partially hydrolyzed storage proteins are more easily available for pepsin attack.[35] The decrease in anti-nutrients like phytic acid may have also contributed to the high levels of IVPD. Although a change in the amino acid profile was observed due to germination, the total amino acid content remained the same since the protein content did not change. However, the lysine content of one pearl millet variety (SDMV 91018) increased throughout germination. The difference in lysine content could be due to slight differences in the proportion of germ in the pearl millet varieties investigated. The increase in the lysine content of the protein in one of the germinated pearl millet variety is related to the transamination (change of one amino acid into another one) which may have occurred during germination affecting the amino acid profile of pearl millet. This transamination was also reported in sorghum.[36] The level of leucine in pearl millet malts was generally higher than the FAO Scoring Pattern.[37] Amalgamation of dehulling and cooking of pearl millet led to low protein digestibility.[25–27]

Impact of processing on starch

Natural fermentation of pearl millet at 20, 25 and 30°C for 72h improved starch digestibility (*in-vitro*), the highest being at 30°C.[28] While fermentation for 14h at 37°C reduced starch due to the action of α-and β-amylases produced by microorganisms.[2] Fermentation by yeasts (*S. diastaticus; S. cerevistiae*) and lactobacilli (*L. brevis; L. fermentum*) at 30°C for 72h improved starch and protein digestibility (*in-vitro*) of pearl millet flour. The flour fermented by *Saccharomyces diastaticus*, a starch hydrolysing yeast, had highest starch digestibility.[38]

Debranning increased starch in pearl millet due to removal of bran while, soaking, dry heat treatment and germination reduced starch content. Reduction of starch caused by soaking and germination due to activation of amylase during these treatments resulted in the hydrolysis of starch. Autoclaving ruptured starch granules, which facilitated the amylolytic hydrolysis of starch granules resulting in improved starch digestibility. Soaking, debranning, and germination respectively reduced starch digestibility while coarse grinding significantly improved starch digestion. Dry heat treatment did not cause any significant changes in the starch digestibility. A higher value of starch digestibility on soaking was due to leaching of antinutrients (phytic acid and polyphenols) that inhibited amylase. Similarly debranning removed the antinutrients with bran and hence improved starch digestibility. Germination resulted in an improved starch digestibility due to activation of amylase, which accelerates the hydrolysis of starch. Starch digestibility of ground pearl millet was significantly lower than the diet containing the ungrounded (Whole seeds) pearl millet due to variation in enzyme accessibility to starch granules.[39,40]

Impact of processing on mineral content

Cereals and millets are the primary sources of minerals in most vegetarian diets, secondary sources being legumes. Total and bioavailable mineral content is negatively influenced by inherent factors such as phytate, tannin, and fiber as well as by processing, such as cooking, boiling, roasting or germination. Digestion and absorption of iron improved upon heat processing by softening the food matrix, releasing of protein bound iron and thus facilitating its absorption. In addition, it is also likely to modify inherent factors that inhibit mineral absorption (phytate and dietary fiber, especially the insoluble fraction).[2,41] Bioavailability of minerals is an important function in food. Processing has a positive impact through destroying inhibitors and favorably altering food components into complex ligands for metal ions thus augmenting availability. Conversely the impact can also be negative by neutralizing enzymes that degrade inhibitors or by generating insoluble metal compounds (e.g. oxidation, precipitation). The total amount of nutrients in food does not reflect the amount that is available for absorption. Bioavailability or biological availability describes the proportion of a nutrient in food that can be utilized for normal body function.[42]

Soaking, boiling and germination of pearl millet respectively reduced phytate phosphorus and increased calcium, magnesium, iron and zinc. Solubility of minerals was higher in soaking and germination than in boiling. Roasting considerably improved iron and zinc content. Milling of pearl millet into whole flour, semi refined flour & bran rich fraction influenced bioaccessible mineral content. Due to partial separation of the bran fraction, semi refined flour had low antinutrients and thereby enhanced mineral bioaccessibility. Pearl millet grains subjected to abrasive decortications improved iron and zinc *in-vitro* availabilities of whole millet flour due to phytate degradation. Germination, common household technique reduced anti-nutrients and improved nutritional and functional properties of pearl millet and also the mousy odor of damp millet was eliminated. Germinating pearl millet for 72hours increased extractability of minerals which represents mineral bioavailability.[8,23,39,43,44]

Impact of processing on antioxidants

Antioxidant components and antioxidant activities of pearl millet was reported by Florence et al.[43] Pearl millet was subjected to various processing methods such as milling, boiling, pressure cooking, roasting and germination respectively. The bran rich fraction showed high antioxidant activity due to presence of high tannin, phytic acid and flavonoid levels. Heat treatments such as boiling, pressure cooking and roasting exhibited significantly ($P \leq 0.05$) higher antioxidant activity reflecting the high flavonoid content.

Conclusion

Pearl millet (Pennisetumtyphoideum) ranks third after wheat (Triticumaestivum) and rice (Oryza sativa) and is documented as most widely grown. It is the basic staple food in the poorest countries and is used by the poorest people. Nutritionally, pearl millet makes an important contribution to human diet due to high levels of calcium, iron, zinc, lipids and high quality proteins. Nevertheless, its usage and popularity is limited due to the presence of anti-nutrients (phytate, oxalate and tannins) as they have a negative influence on the bioavailability of minerals, poor digestibility of proteins and carbohydrates.[14] Generally, millets are never eaten raw and hence, processing plays an important role in making it edible and digestible. This review focused on the impact of processing on the nutritive value of pearl millet. Decorticated by traditional hand pounding or abrasive decortications influenced the chemical composition of the kernels. It prevented nutrient losses and enhanced the bioavailability of the micronutrients. Pearl millet semi refined flour was low in antinutrients which improved mineral bioaccessibility. Because of high dietary fiber, mineral and fat, bran rich fraction could be used as a functional ingredient in formulation of value added products. Germinated pearl millet flour was lighter and finer with high bulk density, which is a desirable attribute in infant/health food formulations. Household processing methods such as soaking, boiling and germination lowered phytate phosphorus and increased calcium, magnesium, iron and zinc content. Heat processing such as boiling, pressure cooking or roasting exhibited significantly ($P \leq 0.05$) higher antioxidant activity. Considering the various processing methods reported in this review, it was apparent that simple household techniques may be employed to improve the nutritional quality of pearl millet by making the nutrients more digestible and bioavailable as well as enhancing the flavor and taste of the product.

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Conflict of interest

The author declares no conflict of interest.

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