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Review

The effect of commercial and traditional milling on the nutritional content, antioxidant activity and sensory properties of pearl millet products

Abstract

The aim of the current research is to investigate the effects of traditional and commercial milling on the nutritional composition, antioxidant activity and sensory properties of pearl millet. Proximate analysis was carried out according to the methods of the Association of Official Analytical Chemists (AOAC). Antioxidant activity was determined by DPPH assay. Sensory evaluation of porridge prepared using flour from differently milled pearl millet was conducted using a 5-point hedonic scale. Proximate analysis data obtained were in the following ranges: moisture (7.00 – 11.63%), ash (1.00 – 1.83%), protein (5.66 – 11.10%), fat (3.10 – 4.53%), fibre (5.79 – 9.77%), available carbohydrates (61.15 – 78.45%) and energy (1395.86 – 1544.57 kJ/100g). For each of the proximate analysis parameters, values are significantly ($p<0.05$) different among raw, traditionally and commercially processed flours. However, no significant ($p>0.05$) differences were obtained in the ash and fat contents of raw and commercially milled millets. Total carbohydrate contents of raw, traditionally and commercially milled millets ranged from 65.26 – 80.33% and were significantly ($p<0.05$) different. Antioxidant activities of the differently milled pearl millet products ranged from 5.68 – 18.63% and were significantly ($p<0.05$) different. The overall acceptability scores of traditionally and commercially milled pearl millet were significantly higher ($p<0.05$) than that of raw pearl millet. Commercially milled pearl millet had higher ash, fibre, fat and protein content and antioxidant activity than traditionally milled grain.
However, traditionally milled pearl millet had higher carbohydrate content and overall acceptability than the raw and commercially milled cereal. Use of commercial milling is recommended as it retains most of the nutrients compared to traditional milling.

Keywords: Pearl millet, traditional milling, commercial milling, nutritional properties, antioxidant activity, sensory properties

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Introduction

Millets belong to the grass family poaceae. They are a group of cereal crops that produce small edible seeds and are mostly grown for human consumption. Millets can be grown in harsh climatic conditions and form a staple food in many developing countries, including the semi-arid tropics of Africa and Asia [1]. Food security in these countries depends on improved production, better storage, availability, nutritional composition and utilization of technology for millets [2]. The pearl millet plant grows up to four metres high and produces seeds that are white, grey, pale yellow or yellow in colour. Pearl millet grains are ovoid shaped and about 3 – 4mm long, which is longer than other millets. Millet grains weigh 1.4 – 2.5 g [3]. Overall, the structure of pearl millet is like that of sorghum [4], except that they differ in size as sorghum grain is larger, has a larger endosperm and smaller germ than pearl millet [5]. The pearl millet grain is made up of three main components: the pericarp (7.2 – 10.6%); the germ (15.5 – 21%) and the endosperm (71 – 76%) [5].

Knowledge of the nutritional value of food is important to inform a diet sufficient for growth and development. It also helps in providing a solution to the large-scale problem of food insecurity, malnutrition and diet quality, particularly in developing countries [6]. Millets are known as grains of high nutritional value compared to rice and wheat [7] and can be grown in harsh climatic conditions. In southern Africa, pearl millet is grown for its high yields and high nutritional content.

Pearl millet has an ash content of 2.5%, fibre content of 2.5%, protein content of 12%, available carbohydrates of 69% and 5% fat content [8, 9]. The nutritional advantages of pearl millet are its high fat and lysine contents that are comparable to some high-lysine corn varieties [3]. The high protein content of pearl millet makes it an important source of protein for consumers suffering from protein deficiency.

Phenolic compounds and dietary fibre are found mostly in the bran layers of pearl millet and are known to have antioxidant properties. Fermentation and germination may increase antioxidant activity in pearl millets. High-molecular weight tannins are said to have a higher antioxidant activity compared to other naturally occurring antioxidants [10].

Pearl millet is mainly regarded as food for the poor, resulting in limited commercial processing and marketing. Millets and other underutilized crops have the potential to improve food security especially in countries that experience drought because the small grains are generally drought resistant. If fully utilized, they can produce various food products [11].

Pearl millet is mostly used to prepare traditional foods such as fermented or unfermented porridges in Africa. Pearl millet may also be malted, used wholly or partially decorticated in the traditional or industrial brewing of opaque beer. In traditional beer preparation, malted pearl millet is the cereal ingredient. Sorghum malt is the major carbohydrate source while pearl millet is used as a cereal adjunct in the commercial production of opaque beer. The small size of the pearl millet is a disadvantage in large-scale industrial malting plants [11].

Pearl millet is also grown as animal fodder in south-east US and in some parts of Southern Africa [3]. In Southern African countries, millet is used as an ingredient in a thick porridge called sadza and fritters. Pearl millet is also used for preparation of gruels and steamed cakes for feeding infants and children aged 1 – 12 years [3].

A combination of pearl millet and legumes can also be malted to produce weaning foods. Composite flour of pearl millet and wheat has also been used for making bread. Up to 30% pearl millet was used successfully in making bread in Senegal [12].

Pearl millet may be milled commercially or traditionally to produce flour. In the traditional milling process, a wooden pestle and mortar is used in the decortication of pearl millet to produce flour [13]. During this traditional processing, the pearl millet is steeped, decorticated and dried in the sun to increase shelf-life [14]. In commercial milling, pearl millet is steeped, decorticated, dried, roasted and ground into pearl millet flour using hammer mills, which produce large, non-uniform particles [11]. It is well known that processing methods significantly alter the physicochemical composition of food grains and consequently their nutritional value [15]. Germination and fermentation of pearl millet increases the total protein content of the grain products [16, 15]. The carbohydrate content decreases during fermentation, while germination and roasting significantly (p<0.05) increases the carbohydrate level, resulting in a significant increase in the energy density of the flour [16]. Considering the influence of processing on the nutritional characteristics of cereal flours, the aim of the current research was to investigate the effect of commercial and traditional milling on the nutrient content, antioxidant activity and sensory properties of pearl millet.

Materials and methods

Reagents

The following reagents were used: sulphuric acid, copper sulphate tablets, boric acid, zinc granules, sodium hydroxide, hydrochloric acid, bromocresol green indicator, petroleum ether, ethanol, methanol, 2, 2-Diphenyl-1-picrylhydrazyl (DPPH) and gallic acid. The reagents were of analytical grade and were procured from Sigma Aldric (Germany).

Sample collection

Five kilograms of pearl millet were purchased from Chikwanha Produce Market in Chitungwiza, Zimbabwe. Chitungwiza is a satellite town located 25 km south-east of Harare. Traditional processing was performed using a pestle and mortar. Commercial milling was performed using a roller mill.

Sample preparation

Raw (control): 500 g pearl millet was ground using a laboratory pestle and mortar until ready for analysis.

Commercially milled pearl millet: 500 g pearl millet was sorted and cleaned. It was conditioned and pounded using a pestle and mortar. The chaff was separated from the grain through winnowing. The pearl millet was then roasted in an oven for five minutes at 180°C. After roasting, it was milled using a roller mill.

Traditionally milled pearl millet: 500 g pearl millet was sorted and cleaned. It was conditioned and pounded using a pestle and mortar. It was then washed to separate the chaff. The pearl millet was then roasted in the oven for five minutes at 180°C. After roasting, it was milled using a pestle and mortar. It was sieved to get pearl millet flour and the remains were discarded. The pearl millet flour was sun-dried.

Proximate analysis

The raw (control), traditionally milled and commercially milled flours of pearl millet were analysed in triplicates for moisture, ash, crude fibre, fat and crude protein according to the methods of AOAC [17]. Two grammes of pearl millet flour were used for each analysis. Moisture contents of the pearl millet flours were quantified by oven-drying to constant mass at 105°C. Ash was determined by combusting the samples in porcelain crucibles placed in a muffle furnace (Gallenkamp, England) at 550°C until a grey-white ash formed. Total nitrogen was determined by the Kjeldahl method and crude protein was obtained by multiplying the total nitrogen content by a factor of 6.25. Crude fat content of the samples was determined by

the Soxhlet method, using petroleum ether as the extracting solvent for 6 hours. The solvent was evaporated on a water bath in a fume hood, followed by oven-drying and weighing. Crude fibre was determined by digesting the sample in 1.25% sulphuric acid, then 1.25% sodium hydroxide followed by filtration and drying in a porcelain crucible placed in an oven.
The crucible was cooled in a desiccator, weighed and placed in a muffle furnace at 600°C for 1 hour. Crude fibre was calculated as percentage loss in weight on ashing.
Available carbohydrate was calculated by subtracting the sum of crude protein, crude lipid, crude fibre and ash from 100% of each dry weight sample [18].
The energy value of the samples was calculated as follows: Energy value of food (KJ per 100 g) = [(% available carbohydrates × 17) + (% protein × 17) + (% fat × 37)][18]. The total carbohydrate content of the pearl millet flours was determined according to the phenol sulphuric acid method as described by previous researchers [19].

Antioxidant activity

Phenolic compounds, which mainly contribute to antioxidant activity, were extracted from traditionally milled, commercially milled and control samples of pearl millet. Two grams of each sample were finely ground and suspended in 10 ml of cold 50% methanol in a 50 ml conical flask suspended in ice [20]. The solution was ultra-sonicated for 15 minutes and centrifuged (Eppendorf 5810R, Germany) for 10 minutes at 3000 rpm. The supernatant was placed into 25 ml bottles for further analysis.

We then added 3 ml of 0.1 Mm DPPH methanolic solution to 1 ml of each extracted sample [21, 22]. The mixtures were incubated for 30 minutes in the dark. Colour change from deep violet to pale yellow was read as absorbance at a wavelength of 517 nm using a spectrophotometer (Shimadzu Corporation, Tokyo Japan, Model UV-3101PC). Absorbance values of gallic acid standard solutions were used to construct a calibration curve and antioxidant activity was expressed as percent inhibition of DPPH radical.

Sensory evaluation

For sensory evaluation, the three different pearl millet samples were used to prepare porridge. Five hundred grams of pearl millet flour were added to a pot with 250 ml of cold water to form a paste. An additional 3 litres of hot water was added to the pot while stirring until the desired thickness was reached. Cooking oil (3 ml) and salt (3 g) were then added.
The paste, which thickened into porridge, was heated for 45 minutes after which 75 g of sugar was added.

Twenty-five students from the Department of Nutrition Dietetics and Food Science of the University of Zimbabwe volunteered to participate in the assessment as panellists.
The panel consisted of both female and male participants aged 21 – 23 years. The pearl millet porridge samples were coded from A to C and each panellist was given a score sheet.
A glass of water was presented to each panellist to rinse their mouth after each tasting session.
The overall quality of the porridge was evaluated using the 5-point hedonic ranking scale, with scores ranging from 1 (extremely dislike) to 5 (extremely like) [23].

Data analysis

Data obtained from the study's various parameters was subjected to variance analysis (p<0. 05). One direction Analysis of Variance (ANOVA) evaluated the mean values of the untreated, traditionally milled and commercially milled pearl millet. The generated data was expressed as mean ± standard deviation.
The statistical analysis was performed using version 16 of SPSS.

Results and discussion

Proximate composition

The results of proximate analysis of pearl millet meals are presented in **Table 1**.

Table 1 Nutrient composition and antioxidant activity of products of milled pearl millet samples from Chikwanha Produce Market in Chitungwiza, Zimbabwe

Pearl millet sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	Total carbohydrates (%)	Available Carbohydrates (%)	Energy kJ/100g	Antioxidant Activity (%)
Raw	11.63±0.46[a]	1.83±0.29[a]	11.1±0.58[a]	4.53±0.50[a]	9.77±0.25[a]	65.26±0.75[a]	61.15±0.10[a]	1395.86±0.60[a]	18.632±0.08[a]
Traditionally milled	7.00 ±0.00[b]	1.00±0.10[b]	5.66±0.58[b]	3.10±0.10b	5.79±0.33[b]	80.33±2.52[b]	78.45±0.17[b]	1544.57±0.23[b]	5.68±0.04[b]
Commercially milled	10.00±0.23[c]	1.6±0.10[a]	9±1.00[c]	4.10±0.17[a]	8.36±0.31[c]	70.66±0.58[c]	66.80±0.50[c]	1440.30±0.50[c]	11.44±0.70[c]

All parameters are presented based on dry weight of the samples as percentages. Values are means of three analyses. Values are represented as means with standard deviations. Different superscript letters in the same column implies means are significantly different (p<0.05). Same superscript letters in the same column implies means are not significantly different (p>0.05).

The milling processes resulted in the loss of nutrients [24]. Overall, the proximate analysis results showed that there was a significant difference (p<0.05) in the macronutrient content of raw, traditionally milled and commercially milled pearl millet. This was caused by the degree to which the pericarp and germ were removed during the milling process. Decortication has major effects on nutritional composition of pearl millet from the traditional and commercial processes.

Moisture

Raw, traditionally milled and commercially milled pearl millet had moisture contents of 11.63±0.46%, 7±0.10% and 10.14±0.23% respectively (**Table 1**). Untreated pearl millet had the highest moisture content. Commercial milling resulted in higher moisture retention compared to traditional milling method. Statistical analysis revealed that the raw, traditionally and commercially milled pearl millet meals had significantly different moisture contents (p<0.05). Commercially milled pearl millet had the highest moisture content and traditionally milled pearl millet had the lowest moisture content. The moisture content differed among the meals due to differences in the extent of exposure of the samples to heat treatment during milling. High moisture content increases the microbial activity which deteriorates the product during storage.

Ash

Ash content of the millet flours ranged from 1.00±0.10 to 1.83±0.29% and increased in the following order: traditionally milled<commercially milled<raw. The ash contents of the three differently processed flours were significantly different (p<0.05). However, no significant difference was observed between ash content of raw and commercially milled flours (p>0.05), implying that commercial milling did not have a significant effect on the ash content of the meals. The ash content of millet flours from the current study ranging from 1 g – 1.83 g/100 g are lower than a level reported for pearl millet flours (2.3 g/100 g) [25]. The high ash content in commercially milled pearl millet may be due to the presence of elevated bran, which is the main contributor of minerals [26]. This implies that commercially milled pearl millet could be useful in the development of food products to manage micronutrient deficiency.

Crude protein

Raw pearl millet had the highest protein content (11.1±0.58%), followed by commercially milled pearl millet (9±1.00%) and traditionally milled pearl millet (5.66±0.58%) (**Table 1**). The traditional and commercial milling process significantly influenced the protein content of pearl millet (p<0.05). The protein content of raw, traditionally and commercially milled pearl millet in the current study are within the previously reported range of 6 – 21% for pearl millet protein [24]. Pearl millet is gluten free and retains its alkaline properties when cooked, which make it beneficial to consumers allergic to gluten [11].

Crude fat

Commercially milled pearl millet flour had a higher fat content of 4.10±0.17% than the traditionally milled flour, which had 3.10±0.10%, while raw pearl millet had the highest content at 4.53±0.50% (**Table 1**). Raw, traditionally and commercially milled grain flour had significantly different contents of fat (p<0.05). However, crude fat contents of raw and commercially milled millet meals were not significantly different (p>0.05), indicating that the milling method had no significant effect on the crude fat contents of the flours.

The fat content of raw, traditionally and commercially milled pearl millet obtained in the current study fall within the reported range of 1.5 – 6.8 g/100g [12]. The high fat content of pearl millet is due to the large germ size [27]. Decortication reduces lipid content. A decrease in fat content from 5.2% before decortication to about 4% after decortication was reported by Hardiman and Mallet [28]. This extended the shelf life of pearl millet flour [29]. Reduction of fat content in processed flour is necessary for consumers suffering from cardiovascular diseases and diabetes who are advised to follow a low-fat diet.

Crude fibre

Raw, traditionally milled and commercially milled pearl millet had fibre concentrations of 9.766±0.25%, 5.79±0.33% and 8.363±0.32% respectively (**Table 1**). Raw pearl millet had the highest fibre content while traditionally milled pearl millet had the lowest content. The contents of crude fibre in the three flours were significantly different (p<0.05). Raw and commercially milled pearl millet considered in the present study had higher fibre concentrations than the reported range of 1.5 to 7.3 g/100g for pearl millet, while traditionally milled millet was within the range [12]. The high fibre content of the millet flours has the potential to reduce obesity and constipation. Fibre is also important in the prevention of heart disease, colon cancer and management of diabetics [30]. It plays an important role of increasing the moisture content of pearl millet product by binding water [25].

Total carbohydrates, available carbohydrates and energy

Carbohydrate is a major nutrient in pearl millet. The total carbohydrate and available carbohydrate content in the pearl millet flours ranged from 65.26 – 80.33 g/100g and 61.15 –78.45 g/100g respectively (**Table 1**) and tally with values reported in literature of 50 – 84% [14]. The total carbohydrate concentrations of the raw, traditionally milled and commercially milled millet flours were significantly different (p<0.05). Traditionally milled flour had higher total carbohydrate content than commercially milled flour.

The available carbohydrate content of pearl millet flours from kernels subjected to traditional and commercial milling were significantly higher ($p<0.05$) than that of raw pearl millet. The traditionally milled pearl millet meal had the highest available carbohydrate content. This is due to loss of ash and fat during decortication as there was removal of the pericarp and the germ, whereas starch remained in the endosperm [3, 31].

The energy of the raw, traditionally and commercially milled millet flours ranged from 1395.86±0.60 to 1544.57±0.23 kJ/100g and were significantly different ($p<0.05$). Traditionally milled flours had higher energy content than the commercially milled product. This is probably due to high available carbohydrates in traditionally milled pearl millet compared to commercially milled pearl millet.

Antioxidant activity

Raw, commercially and traditionally milled pearl millet had antioxidant activity of 18.632±0.08%, 11.44±0.70% and 5.68±0.04% respectively that are significantly different ($p<0.05$) (**Table 1**). Commercially produced pearl millet flour is darker in colour and has a higher concentration of antioxidants compared to traditionally processed pearl millet flour [14]. This can be attributed to its higher extraction rate, whereby the pearl millet flour will have a higher phenolic content compared to traditionally milled flour which is excessively decorticated [14]. The antioxidant activity among pearl millet components is believed to be in the following descending order: hull >whole grains >dehulled grains. It is evident in this study that raw pearl millet had the highest antioxidant activity followed by commercially milled pearl millet and lastly traditionally milled pearl millet. Phenolic compounds and dietary fibre are mainly found in the bran layers. They have antioxidant properties needed for good health and play an important role in ageing and metabolic syndrome [11]; antioxidants in millet inhibit glycation and cross-linking of collagen thereby offering protection against ageing [32]. The risk of some types of breast cancer is reduced by flavonoids, which can inhibit tumour development [32]. These results will help consumers when choosing pearl millet flour formulations.

Sensory evaluation

For each of colour, taste and overall acceptability scores, there was no significant difference ($p>0.05$) between porridge made from traditionally milled and commercially milled millet flours (**Table 2**).

Table 2 Sensory evaluation for raw, traditionally and commercially milled pearl millet from Chikwanha Produce Market in Chitungwiza

Pearl millet sample	Colour	Texture	Taste	Overall acceptance
Raw	1.10±0.00^a	3.14±0.00^a	1.05±0.00^a	1.76±0.00^a
Traditionally milled	4.25±0.76^b	4.40±0.75^a	4.12±1.04^b	4.25±0.52^b
Commercially milled	3.65±0.69^b	3.67±0.67^a	3.7±0.69^b	3.67±0.48^b

Parameters based on the sensory attributes of the pearl millet samples. Values represented as means with standard deviations. Different superscript letters in the same column implies means are significantly different ($p<0.05$). Same superscript letters in the same column implies means are not significantly different ($p>0.05$).

Porridge made from traditionally milled flours had the highest scores for all the attributes assessed while porridge made from raw millet flour had the lowest acceptability scores for all attributes. Acceptability scores for texture of raw, traditionally and commercially milled pearl millet porridge were 3.14±0.00, 4.40±0.75 and 3.67±0.67 respectively. There were no significant differences among scores for texture of porridge prepared from raw, traditionally milled and commercially milled flours, implying that processing method had no significant effect on this attribute ($p>0.05$).

Acceptability score for colour was high

for traditionally and commercially milled pearl millet and there was a significant difference between raw pearl millet and the other two treatments. The most-liked darker colour of commercial pearl millet porridge may be attributed to its slightly higher extraction rate resulting in the flour containing more of the pericarp where phenolic compounds are concentrated. Decortication improves the texture and shelf life of pearl millet meal [33].

It was also noted that decortication of pearl millet considered in the current study improved sensory properties like taste. Acceptability scores for the taste and texture were high for traditionally and commercially milled pearl millet and there was a significant difference between raw pearl millet and the other two samples. The traditionally milled pearl millet meal produced sour porridge, which was preferred by consumers in terms of texture and taste. Commercially processed pearl millet porridge lacked the preferred sour taste. Overall acceptability scores for traditionally and commercially processed pearl millet porridge were higher than raw pearl millet-based porridge and there was a significant difference ($p<0.05$) between raw pearl millet product and the other two samples.

Conclusion and recommendations

Commercial milling produced a pearl millet flour of higher nutritional value compared to that produced by traditional milling. Traditional pearl millet flour was preferred as it produced sour porridge with a good texture compared to commercial pearl millet flour which had less bran. Pearl millet flour produced by commercial milling had a higher concentration of antioxidants compared to pearl millet flour produced by traditional milling. Use of commercial milling is recommended as it retains most of the nutrients compared to traditional milling. Since traditional milled flour is preferred by most consumers, its nutritional composition may be boosted by mixing it with commercially milled flour. Fortification of the traditionally milled flour can also retain some of the lost nutrients. Further research should involve the design of a commercial milling process which results in commercially milled flour with the sour taste and lighter colour preferred by consumers.

Conflict of interest

The authors declare that they have no conflict of interest.

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