Pearl Research Journals

Journal of Agricultural Science and Food Technology
Vol. 11 (1), pp. 1-6, July, 2025
ISSN: 2465-7522
Research Paper
https://doi.org/10.36630/jasft_25010
http://pearlresearchjournals.org/journals/jasft/index.html

Does Processing Influence the Nutrient and Antinutrient Compositions of Pearl Millet Grains?

Charles Hannatu[1], Makinde O. John[1*], Aminu Maidala[1], Iliya B. Amaza[1], Lawan Adamu[1], Sudik S. David[1], Akeem B. Sikiru[2], Musa Ahmad Rufai[1] and Ajide S. Olusoji[3]

Accepted 11 June 2025

[1]Department of Animal Science, Federal University, Gashua, Nigeria.
[2]Department of Animal Science, Federal University of Agriculture, Zuru 872101, Kebbi, Nigeria.
[3]Department of Animal Science, Landmark University, Omu-Aran, Nigeria.

ABSTRACT

The rising and unpredictable costs of conventional livestock feed ingredients, despite the vast untapped potential of most non-conventional alternatives such as pearl millet, remain a serious concern. This study evaluated the effects of two processing methods on the nutrient and anti-nutrient compositions of pearl millet grains, using maize as the standard energy source. Two different processing methods -boiling and fermentation- were employed out. All raw and processed pearl millet grains were milled and taken to the laboratory for proximate, mineral, and antinutrient analyses. All the nutrient parameters measured showed significant differences (P<0.05). Maize had significantly (P<0.05) higher values of dry matter, ether extract, crude fibre, ash, nitrogen-free extract, metabolizable energy, and total carbohydrates compared to both raw and processed pearl millet grains. The percentage of organic matter (98.11–98.68%) and crude protein (8.84–10.58%) was significantly higher (P < 0.05) in the processed pearl millet grains. The ash content (1.32–1.89%) was significantly lower (P < 0.05) in both raw and processed pearl millet compared to maize. Crude fibre content (4.74%) was highest in the raw pearl millet relative to the other grains. All minerals analyzed-except magnesium (Mg)—were significantly higher (P < 0.05) in maize grains than in both raw and processed pearl millet grains. Furthermore, all the antinutritional factors measured were significantly higher (P < 0.05) in raw pearl millet grains compared to the processed millet and maize. Fermentation resulted in a significantly greater reduction (P<0.05) in saponin (37.65%) and tannin (19.32%) compared to boiling, which achieved reductions of 35.56% and 15.04%, respectively. In contrast, boiling was more effective (P<0.05) in reducing oxalate and phytate contents, with reductions of 32.14% and 20.11%, respectively, compared to 25.00% and 16.96% in the fermented samples. It was concluded that pearl millet should be processed before inclusion in feed formulations. Further studies are recommended to evaluate its effects on animal growth, health, and productivity.

Keywords: Antinutritional factors, boiling, fermentation, maize, pearl millet

*Corresponding author.Email: johyinmak@yahoo.com

INTRODUCTION

Pearl millet (*Pennisetum glaucum*) is a versatile cereal cultivated for both human consumption and livestock feed (Arora et al., 2003), particularly in African and Asian countries (Nambiar et al., 2011). Pearl millet has the ability to thrive under drought and high temperature conditions, making it a viable crop in regions where wheat, maize and other cereal crops struggle to survive. Among all millet varieties, Pearl millet occupies more than 29 million hectares globally. However, its cultivation is largely concentrated in Africa (15 million hectares) and Asia (11 million hectares), which are the leading producers (Rathore et al., 2016). More than 95 per cent of pearl millet production comes from developing countries, with India being the largest producer (Basavaraj et al., 2010). India cultivate the crop on approximately 9.8million hectares of land (Rathore et al., 2016). Beyond its agronomic adaptability, pearl millet also offers distinct nutritional advantages. It contains higher levels of protein (14.0%), fat (5.7%), fiber (2.0%), and ash (2.1%) compared to major cultivated cereal crops such as wheat (Kavitha and Parimalavalli, 2014), rice (Ahmed et al., 2014), and sorghum (Awadelkareem et al., 2015) (Sade, 2009). Its superior protein quality—particularly in terms of tryptophan and threonine content (Singh et al., 2024)—along with higher levels of calcium, iron, and zinc (Yadav et al., 2012; Singhal et al., 2022; Kumar et al., 2022), makes it highly beneficial for human nutrition. Additionally, the energy content of pearl millet is greater than that of sorghum and comparable to that of brown rice, owing to its rich composition of unsaturated fatty acids (75%) and linoleic acid (46.3%). (Jaybhaye et al. 2014).

Despite its nutritional benefits, pearl millet also contains certain anti-nutritional factors such as phytates, tannins, and polyphenols (Meena et al., 2024). These compounds can chelate dietary minerals in the gastrointestinal tract, thereby

Table 1: Nutrient Compositions of maize, raw and processed millet grains.

Items (%)	Maize (white)[1]	RPMM	BPMM	FPMM	SEM	P-val.
Dry Matter	95.28^a	93.67^b	92.88^c	94.67^a	0.14	0.0076
Organic matter	98.11^c	98.39^b	98.74^a	98.68^a	0.03	0.0023
Crude Protein	8.84^c	9.68^b	10.22^a	10.58^a	0.09	0.0003
Ether Extract	3.89^a	3.35^b	3.26^b	2.99^c	0.03	0.0023
Crude Fibre	3.39^c	4.74^a	3.77^b	3.62^b	0.08	0.0010
Ash	1.89^a	1.61^b	1.26^c	1.32^c	0.02	0.0023
NFE[2]	77.27^a	70.30^d	74.37^c	76.16^b	0.13	0.0002
ME(Kcal/kg)[3]	3388.77^a	3238.62^d	3284.76^c	3339.73^b	2.35	<.0001
Total Carbohydrates	83.88^a	78.24^c	82.75^b	82.81^b	0.17	0.0004

Maize[1] = used a standard grain to compare the nutrient in raw and processed pearl millet grains. NFE[2]: Nitrogen Free Extract =100-(%CP+%CF+%EE+%Ash). ME[3] = Metabolizable Energy, RPMM= Raw pearl millet meal. BPMM= Boiled pearl millet meal. FPMM= Fermented pearl millet meal.

reducing their bioaccessibility and bioavailability (Nour et al., 2014). Additionally, the presence of polyphenolic pigments in the pericarp, aleurone, and endosperm regions may impart an undesirable gray color and taste to finished products (Rathi et al., 2004). The development of off-odors and flavors in pearl millet flour and its products is primarily attributed to lipase activity in the pericarp, aleurone layer, and germ of the grains (Yadav et al., 2012; Singh et al., 2024). Reducing these anti-nutritional factors is crucial for enhancing both the shelf life and nutritional quality of pearl millet and its processed products. Various processing techniques such as dehulling, milling, malting, parboiling, and acid or heat treatments have been reported to effectively reduce these compounds. (Legesse, 2013; Makinde et al. 2019; Ajibade et al. 2021).

To evaluate the nutritional modifications induced by processing, maize—a commonly used cereal grain—was employed as a nutritional reference. Maize is rich in carbohydrates and minerals, including potassium and magnesium. However, it contains trace amounts of lysine and tryptophan, contributing to its relatively low content of protein, as well as trace amounts of B-vitamins (Singh et al. 2024). Therefore, maize grain was used here as a standard to compare the nutrients in raw and processed pearl millet grains. This study aimed to determine the effect of two processing methods on the nutrient and antinutrient compositions of pearl millet grains in comparison with the chemical composition of maize.

MATERIALS AND METHODS

Study Location

This study was conducted at the Teaching and Research Farms of the Department of Animal Science, Federal University, Gashua, Yobe State, Nigeria. Gashua is located at latitude 12°, 52.547/12.8758°N and 11.0120°/11°00.719E; and it is situated in the Sahel savanna zone of Nigeria (Ovimaps, 2024).

Sample collection and preparation

The maize and pearl millet grains used in this study were purchased from the local market in Gashua, Yobe State. The grains were divided into 3 batches as follows:

Raw

One kilogram of pearl millet grain was air-dried at 25 °C for 3 days, milled using a hammer mill with a 2 mm sieve, and labeled as Raw Pearl Millet Meal (RPMM).

Fermentation

One kilogram of pearlmillet grain was fermented in water for 48 h at a ratio of 1 kg of grain to 5 litres of water, as described by Makinde et al.(2019). The grains were poured into a jute bag, immersed in water, and covered for 48 h. After fermentation, the jute bag was removed, and the fermented grains were air-dried at 25 °C for three days. The dried grains were then milled using a hammer mill with a 2mm sieve and labeled as Fermented Pearl Millet Meal (FPMM).

Boiling

One kilogram of pearl millet grain was boiled at 100 °C for 15 minutes at a ratio of 1 kg of grain to 5 litres of water, as described by Makinde et al.(2019; 2023). After boiling, the water was drained using 2 mm sieve and the grains were air-dried at 25 °C for three days. The dried grains were milled using a 2 mm hammer mill and labeled as Boiled Pearl Millet Meal (BPMM).

The samples were subjected to laboratory analysis to determine their nutrient compositions using the procedures of AOAC (2006), while the anti-nutrient contents were analysed using the indirect colorimetric method of Azim et al. (2007), as earlier reported by George et al. (2023). Gross energy was determined using a Gallenkamp Ballistic Bomb Calorimeter (Model 1266, Parr Instrument Co., Moline, IL.) with benzoic acid as the internal standard. Metabolizable energy was estimated using the method outlined by Panzenga (1985).

Metabolizable Energy ME (Kcal/kg) = 37 x % CP + 81.8 x % EE + 35.5 x %NFE.

CP = Crude protein, EE = Ether extract, NFE = Nitrogen free extract

Data Analysis

Data were subjected to one-way analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of SAS software (version 9.3, SAS Institute Inc., Cary, NC, USA). Means were compared and considered significantly different at P < 0.05.

RESULTS AND DISCUSSION

The results of the proximate compositions of maize, raw, and processed millet grains are presented in Table 1. All the parameters determined were significantly (P<0.05) different.

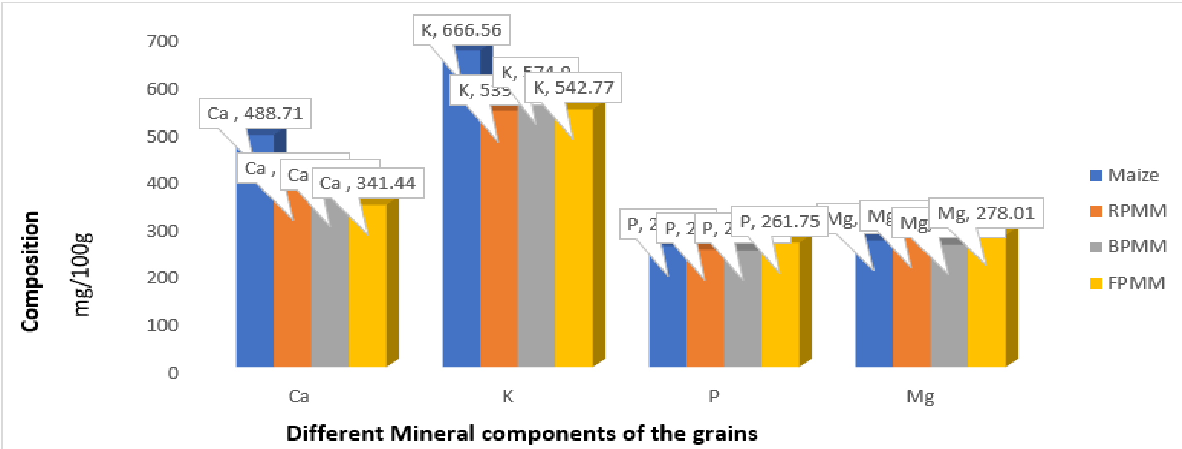

Figure 1: Mineral Compositions of maize, raw and processed millet grains.
RPMM= Raw pearl millet meal. **BPMM**= Boiled pearl millet meal. **FPMM**= Fermented pearl millet meal. *Maize was used a standard grain to compare the nutrient in raw and processed pearl millet grains.

Maize had significantly (P<0.05) higher values of dry matter, ether extract, crude fiber, ash, NFE, ME and total carbohydrate compared to both the raw and processed pearl millet grains. However, the percent organic matter and crude protein were significantly higher (P<0.05) in the processed millets. The percent ash was lower in the raw and processed pearl millet compared to maize. Crude fiber was higher in the raw pearl millet compared to other grains.

Maize is rich in carbohydrates and minerals, including potassium and magnesium. It contains trace amounts of lysine and tryptophan, contributing to its relatively low content of protein, as well as trace amounts of B vitamins (Singh et al. 2024). There, maize grain was used as a standard to compare the nutrients in raw and processed pearl millet grains in this study. All the values observed for maize grains in this study were similar to those of previous reports (Bulus et al., 2014; Ohini et al., 2019). The crude protein contents of both raw and processed pearl millet grains (9.68 – 10.58%) observed in this study were lower than the values of 12.02% (Bulus et al., 2014) and 12.99% (Laminu et al., 2014) for raw pearl millet grains. The increase observed in the crude protein content during the fermentation of pearl millet may be attributed to the activities of microorganisms during the fermentation processes (Kumari et al. 2022). All the samples had above 90% dry matter, which is a good indicator of their potential to have a longer shelf life (Valverde-Miranda et al. 2021). The higher dry matter content of grains inhibits the biochemical activities of invading microorganisms, preventing food spoilage during storage (Srivastava and Mishra, 2021; Alegbeleye et al., 2022).

The reduction in ether extract (fat) content observed in the processed pearl millet grains may be due to the enhanced activity of lipolytic enzymes during processing. These enzymes hydrolyze fats into free fatty acids and glycerol, thereby lowering the fat content. This finding aligns with the results of Inyang and Zakari (2008), who reported similar trends in pearl millet following processing. Specifically, fermentation reduced the ether extract from 3.35% in raw millet to 2.99% in the fermented samples, likely due to the solubilization and leaching of fats during water-based treatments, as also noted by Nabayi et al. (2021). In contrast, the ether extract content in the boiled millet remained relatively unchanged.

Regarding crude fiber, the processed millet samples had lower fiber content compared to the raw samples. This is likely due to the partial loss of seed coats during processing, which are a major source of fiber. The raw pearl millet had a crude fiber content of 4.74%, which is notably higher than the 2.83% reported by Laminu et al. (2014) for raw millet in a separate study.

An increase in nitrogen-free extract (NFE), total carbohydrate, and metabolizable energy contents was observed in the processed pearl millet compared to the raw form; however, none of the values were comparable to those of maize. This indicates that the processing methods effectively enhanced the energy content of the grains. Bulus et al. (2014) reported NFE and metabolizable energy values of 72.20% and 3280.94 kcal/kg, respectively, for raw pearl millet, while George et al. (2023) reported a carbohydrate range of 79.73–86.05% for different varieties of raw finger millet grains..

Figure 1 shows the results of the mineral composition in maize, raw and processed pearl millet grains. All the minerals analysed in this study, except Mg were higher (P<0.05) in maize grains than in the raw and processed pearl millet grains. This suggests that maize is very rich in minerals compared to pearl millet. The reduction observed in the content of Ca among the processed pearl millet grains could be attributed to the loss in the ash content during boiling and fermentation. Previous studies (Okpalanma et al.2021; Zubair et al.2023) have reported that more than 50% of the ash in sorghum was leached into the steeping and washing water.

In this study, the most abundant minerals in the maize grain were potassium (666.56mg/100 g) and calcium (488.71mg/100 g), while the least concentrated mineral was manganese (255.11 mg/100 g). Both the raw and processed millet grains were also rich in the following valuable minerals:
K (539.38 – 574.90 mg/100 g), Ca (373.28 - 359.30 mg/100 g), P (245.69 - 261.75 mg/100 g), and Mg (257.33 – 278.01 mg/100 g). These minerals are suitable for bone formation in livestock. The value observed for phosphorus in the raw pearl millet grains (246.85 mg/100 g) is lower than the value of 399.23 mg/100 g reported by Laminu et al. (2014) for raw pearl millet. The value observed for potassium in the raw pearl millet grains (539.38 mg/100 g) falls within the range of 279.0 - 688.52 mg/100 g reported by George et al. (2023) for different varieties of raw finger millet.

The results of the anti-nutritional factors in maize, raw and processed pearl millet grains are shown in Figure 2. All the

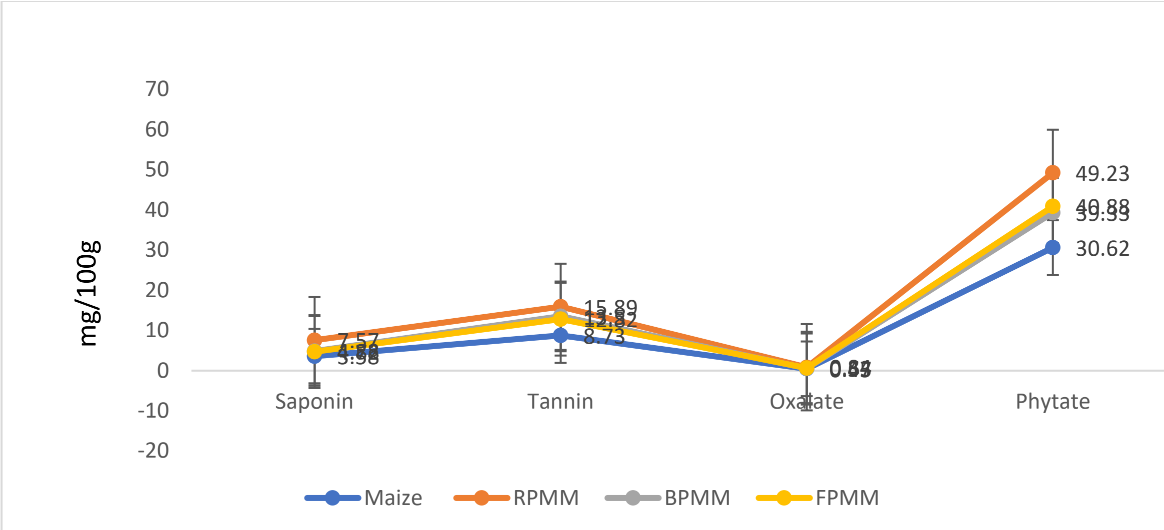

Figure 2: Anti-nutritional factors in **maize, raw and processed finger millet grains.**
RPMM= Raw pearl millet meal. BPMM= Boiled pearl millet meal. FPMM= Fermented pearl millet meal. Maize was used a standard grain to compare the nutrient in raw and processed pearl millet grains.

Table 2: Percentage reduction of Anti-nutritional factors in raw and processed pearl millet grains.

Items (mg/100g)	RPMM	BPMM	FPMM	SEM	P-val.
Saponin	7.57^{a}	4.88^{b}	4.72^{b}	0.08	0.0002
% reduction		35.56	37.65		
Tannin	15.89^{a}	13.50^{b}	12.82^{b}	0.03	<.0001
% reduction		15.04	19.32		
Oxalate	0.84	0.57	0.63	0.08	0.2597
% reduction		32.14	25.00		
Phytate	49.23^{a}	39.33^{c}	40.88^{b}	0.20	<.0001
% reduction		20.11	16.96		

RPMM= Raw pearl millet meal. BPMM= Boiled pearl millet meal. FPMM= Fermented pearl millet meal.

antinutritional factors determined were significantly higher ($P<0.05$) in raw pearl millet grains compared to the fermented and boiled pearl millet, as well as maize. The tannin (15.89 mg/100g) and phytate (49.23 mg/100g) contents of raw pearl millet grains observed in this study were slightly higher than the values reported for finger millet grains-12.77 mg/100g and 48.15 mg/100g, respectively (George et al., 2023). This variation could be attributed to factors highlighted by Mohamed et al. (2011), who noted that different species may vary not only in their nutrient composition but also in the type and quantity of antinutritional factors. Therefore, results obtained from one species may not necessarily apply to another. Even the length of storage time can also affect certain characteristics. In India, Pandarinathan and Geethanjali (2023) reported tannin levels ranging from 0.15 to 1.30 mg/100g and phytate levels between 23 and 45 mg/100g for selected millet varieties. Similarly, Sharma et al. (2021) documented phytic acid contents ranging from 5.54 to 5.58 mg/g and tannin levels of 3.5 mg/g in finger millet. In comparison, the same study reported that pearl millet contains 9.2 mg/g of phytic acid and 2.2 mg/g of tannins.
Table 2 presents the percentage reduction in anti-nutritional factors observed across the processing methods. Fermentation led to a significantly higher reduction in saponin (37.65%) and tannin (19.32%) contents compared to boiling, which achieved reductions of 35.56% and 15.04%, respectively. In contrast, boiling was more effective in reducing oxalate and phytate levels, achieving reductions of 32.14% and 20.11%, respectively, as opposed to 25.00% and 16.96% observed in the fermented samples. The apparent decrease in the content of phytates during boiling may be due to leaching into the boiling medium, thermal degradation, or the formation of insoluble complexes between phytates and other components such as phytate-proteins and phytate-protein-mineral complexes (Sarkhel and Roy, 2022). Reduction of phytate is expected to enhance the bioavailability of proteins and dietary minerals of the boiled grains. The reduction in the tannin content of fermented pearl millet may be due to microbial activity, which hydrolyzed the condensed tannins to lower molecular weight phenols (Srivastava et al., 2024). The reduction of tannins in the fermented pearl millet could also be attributed to soaking. Tannins are polyphenolic compounds that are water-soluble in nature (Basak et al.,2021). Therefore, a reduction in tannin content may be attributed to the leaching of phenols into the medium, which can be eliminated with the discarded water. Since polyphenolic compounds are present on the outer periphery of the grain, they can leach out into the

soaking medium during processing (Adhikari, 2024).

CONCLUSION

This study demonstrated that processing significantly (P<0.05) altered the nutrient and antinutrient composition of pearl millet grains. Both boiling and fermentation improved crude protein content and reduced anti-nutritional factors such as saponins, tannins, phytates, and oxalates. Processed pearl millet grains exhibited higher protein levels compared to maize and unprocessed millet. They also offered improved nitrogen-free extract and total carbohydrate contents, although their metabolizable energy remained lower compared to that of maize. These findings suggest that properly processed pearl millet may serve as a promising alternative ingredient in animal diets due to its balanced nutritional profile. However, *in vivo* animal feeding trials are essential to validate these chemical composition findings and assess actual animal performance. Therefore, it is recommended that pearl millet be processed before being included in feed formulations. Further studies should evaluate its effects on animal growth, health, and productivity.

ACKNOWLEDGEMENTS

The study was sponsored by the Tertiary Education Trust Fund (TetFund) through the Federal University, Gashua, Nigeria. The authors gratefully acknowledge the technical support provided by the staff of the Department of Animal Science, Federal University, Gashua.

REFERENCES

Azim MA, Rashid MM, Rahman MM, Alam MM, Begum J (2007). A Study on Nutritional and Socio-Economic Level of the Rural Household in a Village Jugitola under Gazipur District. Pakistan Journal of Nutrition, 6: 138-142. https://doi.org/10.3923/pjn.2007.138.142

Adhikari S (2024). Effects of Soaking, Germination and Popping on Nutritional and Anti-Nutritional Factors in Sorghum *(Sorghum bicolor L. Moench) SEEDS* (Doctoral dissertation, Department of Nutrition & Dietetics Central Campus of Technology Institute of Science and Technology Tribhuvan University, Nepal. 2021).

Ahmed K, Shoaib M, Akhtar MN, Iqbal Z (2014).Chemical analysis of different cereals to access nutritional components vital for human health. International Journal of Chemical and Biochemical Sciences, 6:61-67.

Ajibade AJ, Makinde OJ, Adedeji AS, Adeniji OA, Sulyman A,Irunokhai EA,Adetona A (2021).Processing effects on nutritive value and anti-nutrient compositions of E*tandaafricana*guill. &perr. Seed. Journal of Forestry Research and Management,18(4):106-115.

Alegbeleye O, Odeyemi OA, Strateva M, Stratev D (2022). Microbial spoilage of vegetables, fruits and cereals. Applied Food Research, 2(1): 100122.

AOAC (Association of Official Analytical Chemists), (2006). Official method of analysis of the AOAC (W. Horwitz Editor) 8th Edition.Washington D.C, AOAC.

Arora P, Sehgal S, Kawatra A(2003). Content and HCl-extractability of minerals as affected by acid treatment of pearl millet. Food Chemistry, 80(1):141-144.

Awadelkareem AM, Hassan EG, Fageer ASM, Sulieman, AME, Mustafa AMI (2015).Nutritive value of two sorghum cultivars. International Journal of Food and Nutritional Sciences, 4(1):1-7.

Basaket S, Raja ASM, Saxena S, Patil PG (2021). Tannin-based polyphenolic bio-macromolecules: creating a new era towards sustainable flame retardancy of polymers. Polymer Degradation and Stability, 189, 109603.

Basavaraj G, Rao PP, Bhagavatula S, Ahmed W(2010).Availability and utilization of pearl millet in India.SAT e Journal. 8:1-6.

Bulus ED, Ibe EA, Dodo ST, Samuel I, Makinde OJ (2014). Performance of Broiler Chickens Fed Two Varieties of Guinea Corn and Millets as Replacement for Maize. Iranian Journal of Applied Animal Science,4(3): 541-547.

George N, Mildred N, Wanzala E, Munga J, Oduori C, Kinyuru J, Hudson N (2023). Nutritional Composition and Anti-Nutrient Levels in Raw and Processed Varieties of Finger Millet Promoted for Nutritional Security. Food and Nutrition Sciences, 14: 1183-1205. https://doi.org/10.4236/fns.2023.1412074

Inyang CV,Zakari VM (2008). Effect of germination and fermentation of pearl millet on proximate, chemical and sensory properties of instant “fura” – A Nigerian cereal. Pak. J. Nutr., 7(1): 9-12.

Jaybhaye RV, Pardeshi IL, Vengaiah PC, Srivastav PP (2014). Processing and Technology for millet-based food products: a review. Journal of Ready-to-Eat Food. 1(2):32-48.

Kavitha S, Parimalavalli R (2014). Effect of processing methods on proximate composition of cereal and legume flours.Foodsci*:* Indian Journal of Research in Food Science and Nutrition, 1(4):1-5.

Kumar RR, Singh SP, Rai GK, Krishnan V, Berwal MK, Goswami S, Mishra GP, Satyavathi CT, Praveen S (2022). Iron and zinc at a cross-road: a trade-off between micronutrients and anti-nutritional factors in pearl millet flour for enhancing the bioavailability. Journal of Food Composition and Analysis, 111, 104591.

Kumari R, Bhatt S, Agrawal H, Dadwal V, Gupta M (2022). Effect of fermentation conditions on nutritional and phytochemical constituents of pearl millet flour (*Pennisetum glaucum*) using response surface methodology. Applied Food Research, 2(1): 100055.

Laminu HH, Modu S, Muhammad AA (2014). Evaluation of the chemical composition, anti-nutrients and mineral element level of a composite meal from pearl millet, wheat, cowpea and groundnut. Sky Journal of Food Science, 3(8):034- 040.

Legesse E(2013).Effect of processing on qualtiy characteristics of pearl millet (*Pennisetum glaucum*) based value added products, MSc thesis, 2013.

Makinde OJ, Aremu A, Alabi OJ, Jiya EZ,AjideSO(2019). Effects of Different Processing Methods on Nutrient and Anti-Nutrient Compositions of African Star Apple *(Chrysophyllum albidum)* Kernels. African Journal of Food, Agriculture, Nutrition and Development, 19(4):14848-14862. https://doi.org/10.18697/ajfand.87.16980

Makinde OJ,Ayo A, Alabi OJ, Jiya EZ, Sikiru AB, Opoola E,Okunade SA (2023). Growth performance and haemato-biochemical indices of growing rabbits fed African Star Apple (*Chrysophyllum albidum*) kernel meal. Archivos de Zootecnia, 72(279):194-201.

Meena K K, Meena S, Joshi M, Dhotre AV (2024). Nutritional and functional exploration of pearl millet and its processing and utilization: An overview. Food and Humanity, 100334.

Mohamed KR, Abou-Arab EA, Gibriel AY, Rasmy NM and Abu-salem, FM(2011).Effect of legume processing treatments individually or in combination of theirphytic acid content. African Journal Food Science and Technology, 2:36-46.

Nabayi A, Sung CTB, Zuan ATK, Paing TN, Akhir NIM (2021). Chemical and microbial characterization of washed rice water waste to assess its potential as plant fertilizer and for increasing soil health. Agronomy, 11(12): 2391.

Nambiar VS, Dhaduk JJ, Neha S, Tosha S, Rujuta D (2011). Potential functional implications of pearl millet (*Pennisetum glaucum*) in health and disease.Journal of Applied Pharmaceutical Science, 1(10): 62-67.

Nour AAM, Sokrab AM, Ahmed IAM, Babiker E(2014). Supplementation and cooking of pearl millet: changes in anti-nutrients, and total mineral content and extractability. Innovative Romanian Food Biotechnology, 15:9-22.

Ohini OP, Ferdinand OM,Betsy OO (2019).Chemical, Anti-Nutritional Factors and Sensory Properties ofMaize-Kidney Bean Flours. Food Sci Nutr Technol, 4(6): 000203.

Okpalanma EF, Ukpong ES, Chude CO, Abah RC (2021). Determination of malting conditions, proximate and biochemical properties of sorghum/millet grains and malts. International Journal of Food Science and Nutrition, 6(2): 51-58.

Pandarinathan S, Geethanjali S (2023). Profiling of nutritional and anti-nutritional factors in selected minor millets. Biological Forum-

An Inter. J., 15: 524-529.
Panzenga U (1985). Feeding parent-stock. Zootechical International.
Rathi A, Kawatra A, Sehgal S(2004). Influence of depigmentation of pearl millet (*Pennisetum glaucum* L.) on sensory attributes, nutrient composition, in vitro protein and starch digestibility of pasta. Food Chemistry, 85(2):275-280.
Rathore S, Singh K, Kumar V(2016). Millet grain processing, utilization and its role in health promotion: a review.International Journal of Nutrition and Food Sciences. 5(5):318-329.
Sade FO (2009). Proximate, antinutritional factors and functional properties of processed pearl millet (*Pennisetum glaucum*). Journal of Food Technology. 7(3):92-97.
Sarkhel S, Roy A (2022). Phytic acid and its reduction in pulse matrix: Structure–function relationship owing to bioavailability enhancement of micronutrients. Journal of Food Process Engineering, 45(5), e14030.
SAS (2015). Statistical Analysis System Institute. User's guide. Version 9.3, SAS Institute Inc. Cary, N. C.
Sharma R, Sharma S, Dar BN, Singh B (2021). Millets as potential nutri-cereals: a review of nutrient composition, phytochemical profile and techno-functionality. Inter. J. Food Sci. Technol., 56: 3703-3718.
Singhal T, Tara Satyavathi C, Singh SP, Mallik M, Anuradha N, Sankar SM, Bharadwaj C, Singh N (2022). Achieving nutritional security in India through iron and zinc biofortification in pearl millet (Pennisetum glaucum (L.) R. Br.). Physiology and Molecular Biology of Plants, 28(4): 849-869.
Singh S, Yadav D, Beckmann M, Naveen A, Gangashetty PI, Mur LA, Yadav RS (2024). Variation in protein and amino acids in global collection of pearl millet (Pennisetum glaucum) germplasm. Journal of Food Composition and Analysis, 134: 106557.
Srivastava S, Mishra HN (2021). Ecofriendly nonchemical/nonthermal methods for disinfestation and control of pest/fungal infestation during storage of major important cereal grains: A review. Food Frontiers, 2(1): 93-105.
Srivastava U, Saini P, Ahmed M, Singh A(2024). Optimizing antioxidant potential and mitigating antinutritional factors in pearl millet (Pennisetum glaucum) via fermentation with Lactobacillus reuteri. Vegetos, 1-12.
Valverde-Miranda D, Díaz-Pérez M, Gómez-Galán M, Callejón-Ferre ÁJ (2021). Total soluble solids and dry matter of cucumber as indicators of shelf life. Postharvest Biology and Technology, 180: 111603.
Yadav DN, Anand T, Kaur J, Singh AK(2012). Improved storage stability of pearl millet flour through microwave treatment. Agricultural Research. 2012; 1(4):399-404.
Zubair AB, Femi FA, Maxwel YMO, Jiya MJ, Isah LR, Owheruo JO (2023). Anti-Nutrient Composition of Starch Isolated from Red and White Sorghum Cultivars Subjected to Different Steeping Times. Journal of Food Nutrition, 2(2): 1-5.