Proximate composition, minerals and anti-nutrients content of Finger Millet (*Eleusine coracana*) Conditioned at Different Temperatures

Njoku, C. C.[1], Igwe, J. F.[1] and Ogbedeagu, C. O.[2]*

[1]*Department of Food Technology, Federal Polytechnic Nekede, P.M.B 1036, Owerri, Imo State, Nigeria.*
[2]*Department of Food Science and Technology, University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria.*

KEYWORDS

Finger Millet,
Millet,
Processing.,

***CORRESPONDING AUTHOR**

ccnjoku@fpno.edu.ng
08037506042

ABSTRACT

This research evaluated the proximate, mineral and antinutrient properties of finger millet (Eleusine coracana) conditioned at different temperatures. The finger millet (Eleusine coracana) grains were obtained from a local farm in Jama's local government area of Kaduna state, Nigeria and processed to flour after conditioning at 30, 60, 70 and 80 ^{0}C. The proximate, mineral and antnutrients analyses were carried out. For proximate composition, moisture ranged from 10.05 to 10.85 %, crude fat from 4.67 to 7.10 %, crude protein from 6.63 to 9.34 %, crude fiber from 2.63 to 2.84 %, ash from 4.54 to 5.88 % and carbohydrate from 66.21 to 68.19 % with the highest protein content in sample AOB (60 0C). Mineral compositions showed that calcium ranged from 351.65 to 366.17 mg/100g, magnesium from 117.52 to 143.72 mg/100g, iron from 0.99 to 1.98 mg/100g and potassium from 120.49 to 143.86 mg/100g. For anti-nutrients showed phytates content from 0.58 to 0.90 mg/100g, oxalate from 1.13 to 1.53 mg/100g, tannin ranged from 1.60 to 1.81 mg/100g and saponin from 0.33 to 0.38 mg/100g. Conditioning finger millet at high temperature lowers moisture and fat contents, increases protein, and a slight improvement in mineral concentration. These changes can enhance the overall nutritional value of finger millet, with moderate temperature between 60 ^{0}C to 70 ^{0}C conditioning offering the best balance of improved protein content and reduced anti-nutrients.

INTRODUCTION

Millet is a minor cereal belonging to the *Poaceae grass* family that is well known in Nigeria, millet is known by various local names. In the northern part of the country, particularly in Hausa-speaking areas, millet is referred to as "gero" (Ekeke and Nwosu, 2018). Additionally, a study by Ogunbile *et al.* (2017) mentions "masa" as a local name for millet in some parts of Nigeria.. Since time immemorial, millets have been a well-known food for humans but in recent years they have been replaced by wheat and rice. Globally, annual millet production amounts to 30.73 million tons, including 11.42 million tones (37 % of the global yield) in India alone. India and Africa are the leading producers of finger millet, followed by, Nepal, and China (Dressler *et al.*, 2014).

Finger millet (*Eleusine coracana*) is an annual herbaceous plant widely grown as a cereal crop in the arid and semiarid areas in African (Njoku *et al.*, 2019). Finger millet is native to the Ethiopian and Ugandan highlands. Interesting crop characteristics of finger millet are the ability to withstand cultivation at altitudes over 2,000 metres (6,600 ft) above sea level, its high drought tolerance, and the long storage time of the grains (Husain *et al.*, 2011). It is a good source of nutrients especially of calcium, iron, phosphorus, zinc, potassium, other minerals and fibre. It is a very good source of variety of phenolic compounds which may have health benefits. The main polyphenols are phenolic acid and tannins while flavonoids are present in small quantities (Rathore *et al.*, 2016). Polyphenols have been known to impart antimicrobial, anti-diabetic, anti-mutagenic properties. Finger millet has high amount of tannin ranging from 0.04 to 3.47 % compared to other millets (Kalaisekar, 2017). Poor iron availability (low ionizable iron) in brown varieties of finger millet is due to high tannin content which adversely affect the nutritional quality. Phytate content of finger millet was found in the range of 240 to 300 mg/100g and act as anti-nutrient. Anti-nutrients like tannin, phytic acid, oxalic acid content and trypsin inhibitor cause low utilization of protein, calcium, iron and zinc in millets (Kalaisekar, 2017).

Processing finger millet (*Eleusine coracana*) at different temperatures can have various effects on its nutrient and anti-nutrient compositions. Basically, the high temperatures during processing lead to the degradation of heat-sensitive nutrients such as vitamins, minerals, and phyto-chemicals present in finger millet. Similarly, high temperatures result in the denaturation of proteins in finger millet, which may affect their digestibility and nutritional quality. This can lead to a decrease in protein functionality and bioavailability. The main aim of this study is to evaluate the nutrient and anti- nutrient composition of finger millet processed at different temperatures. The importance of the study of the proximate, anti-nutrient and mineral compositions of finger millet conditioned at different temperatures lies in its potential to improve the nutritional quality and overall health benefits of this important staple grain.

Source of raw materials

The Finger millet (*Eleusine coracana*) grains were obtained from a local farm in Jama's local government area of Kaduna state, Nigeria.

MATERIALS AND METHODS

Method of Sample Preparation

Finger millet flour was processed according to the modified method of Ubbor *et al.* (2022). Finger millet seeds were thoroughly cleaned, washed, steeped for 24 h, drained, dried at 30 ^{0}C ambient, 60 ^{0}C, 70 ^{0}C and 80 ^{0}C to ascertain the suitable drying temperature for 4 h, milled to fine flour, sieved to 0.5 µm mesh size and stored in air tight container at room temperature for analysis.

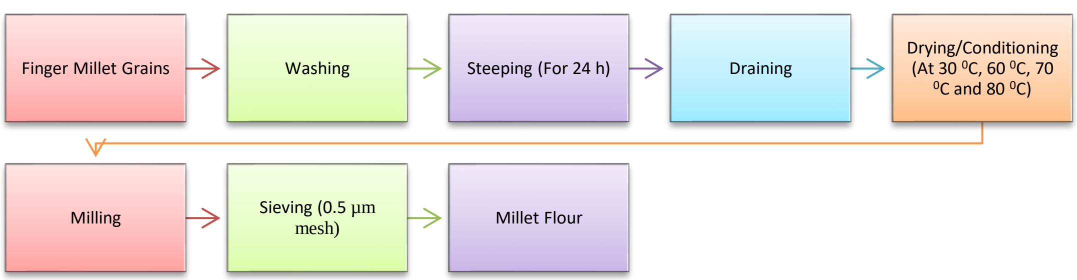

Fig 1: Flow Chart of Finger Millet Flour Production (Ubbor *et al.*, 2022).

Methods of Analysis

Proximate analysis was carried out according to the method described by AOAC (2005). The mineral content of the samples was determined by dry ash extraction method for specific mineral elements. Two grams (2 g) of the sample was ashed in a muffle furnace for 4 to 6 h at a temperature of around 550 °C to 600 °C, the resulting ash was dissolved in 100 ml of dilute hydrochloric acid and then diluted to 100 ml in a volumetric flask using distilled water. Calcium, magnesium and iron contents were determined by the method of AOAC (2005). Potassium content was determined using the modified method described by Chamba *et al*. (2021). The anti-nutrient properties such as tannin content were determined using the modified method described by Emmanuel and Deborah (2018). Saponin content was determined by the spectrophotometric method by AOAC (2000) and oxalate and phytate contents by Patel and Dutta, (2018).

Results and Discussion

Proximate Composition of Finger Millet Flour

The proximate composition of finger millet conditioned at different temperatures for samples AOA, AOB, AOC, and AOD at 30, 60, 70 and 80 ^{0}C respectively, is shown in Table 1. The moisture content of finger millet varied from 10.05 to 10.85 %, with AOA having the highest (10.85 %) and AOC had the lowest (10.05 %). Moisture content is a critical factor in the storage and shelf life of grains because high moisture can promote microbial growth and spoilage, while low moisture improves the shelf stability of the grain (Zhu *et al.,* 2015). Temperature conditioning generally reduces the moisture content of grains as heat facilitates water evaporation. This reduction is crucial for preserving the grain, as high moisture promotes enzymatic activity and microbial growth that can lead to spoilage (Bello *et al.*, 2016). Akinmoladun *et al*. (2015) found that heat treatment reduced the moisture content of millet grains, which is important for preserving the grain over time. Ash content, an indicator of the mineral content of grains, showed an increasing trend from 30 ^{0}C (4.54 %) to 70 ^{0}C (5.88 %). This suggests that conditioning at higher temperatures may concentrate or preserve mineral content. The increase in ash content could be attributed to mineral retention during drying. Heating can sometimes reduce the volume of non-volatile compounds, potentially leading to a higher concentration of minerals such as calcium, iron, and magnesium (Ravindran *et al*., 2014). Lestienne *et al*. (2005) found that the ash content of legumes increased after heat treatment, likely due to the loss of water and reduction in non-mineral components. However, it's also possible that high temperatures could cause some mineral leaching if the grain is exposed to moisture or soaking before or during heat conditioning. 70 ^{0}C, with the highest ash content, might have undergone a heat treatment that maximized mineral retention, while the lower values in AOA could reflect a less intense conditioning process. The variability suggests that temperature conditioning could be tailored to optimize mineral retention while avoiding excessive leaching of water-soluble minerals.

Table 3.1: Proximate Composition (%) of Finger Millet Conditioned at Different Temperature (30 ^{0}C, 60 ^{0}C, 70 ^{0}C and 80 ^{0}C)

Properties/Samples	AOA	AOB	AOC	AOD	LSD
Moisture	$10.85^a \pm 0.04$	$10.37^b \pm 0.06$	$10.05^c \pm 0.05$	$10.42^b \pm 0.02$	0.09
Ash	$4.54^c \pm 0.04$	$5.61^b \pm 0.04$	$5.88^a \pm 0.05$	$5.84^a \pm 0.04$	0.09
Crude Fat	$7.10^a \pm 0.03$	$4.89^c \pm 0.04$	$5.60^b \pm 0.05$	$4.67^d \pm 0.05$	0.07
Crude Protein	$6.63^c \pm 0.04$	$9.34^a \pm 0.03$	$9.26^a \pm 0.04$	$8.14^b \pm 0.02$	0.12
Crude Fibre	$2.84^a \pm 0.04$	$2.76^b \pm 0.01$	$2.63^c \pm 0.02$	$2.77^b \pm 0.02$	0.06
Carbohydrate	$68.05^a \pm 0.04$	$67.07^b \pm 0.01$	$66.21^c \pm 0.01$	$68.19^a \pm 0.04$	0.30

*Values are mean values of the duplicate samples with standard deviation and m**eans with different letters within the same row are significantly different at (p > 0.05)**. Key: AOA = Finger Millet Flour Conditioned at 30 ^{0}C (Control), AOB = Finger Millet Flour Conditioned at 60 ^{0}C, AOC = Finger Millet Flour Conditioned at 70 ^{0}C, AOD = Finger Millet Flour Conditioned at 80 ^{0}C.*

The crude fat content of the conditioned finger millet flour ranged from 4.67 % (AOD) to 7.10 % (AOA). The highest fat content was found in AOA, while the lowest was in AOD. The reduction in fat content at higher conditioning temperatures at 60 ^{0}C, 70 ^{0}C and 80 ^{0}C could be due to oxidative degradation of lipids, which is a well-documented phenomenon in heat-treated grains (Gusmão *et al.*, 2016). Heat can cause the oxidation of unsaturated fats, leading to a decrease in fat content and a potential loss of fat-soluble vitamins like vitamin E (tocopherols). This aligns with the observation by Sreenivasan and Sharma (2014), who reported that grains subjected to roasting or high-temperature conditioning often show a decrease in crude fat content due to oxidation. Conversely, millet flour dried at 30 ^{0}C, may have preserved more of its fat content. The reduction in fat content as conditioning temperature increases might also reflect a loss of volatile components such as essential fatty acids and lipid-soluble antioxidants, both of which are sensitive to high temperatures (Sanz *et al*., 2001). Crude protein content varied significantly across the samples, with the highest value in **60 ^{0}C** (9.34 %) and the lowest in 30 ^{0}C (6.63 %). The protein content generally increased with the conditioning treatment, except for the **AOD** sample, where the protein content decreased slightly (8.14 %). The increase in crude protein in the conditioned samples could be due to the reduction of anti-nutrients such as phytates, which can inhibit protein digestibility. Heat treatment has been shown to increase protein availability by breaking down these anti-nutrients (Akinmoladun *et al*., 2015). This trend is consistent with other studies showing that mild heat treatment can increase protein content in grains by enhancing the protein profile (Akinmoladun *et al*., 2015). However, the slight decrease in protein content in AOD (compared to AOB and AOC) suggests that very high temperatures may lead to protein denaturation, which can reduce protein quality and availability (Choi *et al*., 2013).

Crude fiber content showed a slight decrease from AOA (2.84 %) to AOC (2.63 %) but then increased again in AOD (2.77 %). The general decrease in fiber content with heat conditioning suggests that heat treatment might breakdown some of the cellulose and hemicelluloses structures in the grain, which are components of crude fiber (Gusmão *et al*., 2016). While heat treatments may help to reduce the fiber content, the reduction is relatively modest, suggesting that finger millet remains a good source of fiber even after conditioning. The small fluctuations in fiber content could be related to differences in temperature intensity and duration of treatment. Previous studies on cereals like sorghum and maize have shown that moderate heat treatments (such as roasting) slightly reduce fiber content but improve digestibility and nutrient absorption (Ogbonna *et al*., 2018). The fact that AOD had higher fiber content than AOC could indicate that high temperatures, while reducing some types of soluble fiber, may concentrate other forms of fiber, particularly the insoluble fraction that contributes to dietary fiber. Carbohydrate content showed minimal variation, ranging from 66.21 % at 70 0C to 68.19 % at 80 0C. This suggests that heat conditioning had little impact on the total carbohydrate content, which is primarily composed of starches in finger millet. The carbohydrate content remained relatively stable across treatments, which are consistent with the findings of Sreenivasan and Sharma (2014), who reported, that high-heat treatments like roasting and roasting did not significantly affect the total carbohydrate content in cereals. However, heat treatment can affect the digestibility of carbohydrates, as heat can alter the starch gelatinization process, making carbohydrates easier to digest (Sivakanesan *et al*., 2015). The higher carbohydrate content in AOD could be due to increased starch digestibility at higher temperatures. As noted in Sreenivasan and Sharma (2014) and Sivakanesan *et al*. (2015), the effect of temperature on total carbohydrates is minimal compared to fat or protein.

Mineral Composition and Anti-nutrient Properties of Finger Millet Flour

The results on the mineral compositions and anti-nutrient properties of finger millet conditioned at different temperatures is shown in Table 2, and provides valuable insight into how temperature conditioning affects the retention and concentration of essential minerals and anti-nutrient reduction. Calcium content showed a significant difference at ($p>0.05$) across the conditioned samples, from 366.17 mg/100g (AOA) to 351.65 mg/100g (AOD). While the decrease is modest, it suggests that temperature conditioning may lead to a slight reduction in calcium retention. This could be due to calcium leaching into water during processing or thermal degradation under high heat conditions (Ravindran *et al.,* 2014). However, the calcium content in finger millet is still relatively high even in the most heat-treated sample (AOD), indicating that finger millet remains a good source of this mineral, which is vital for bone health, muscle function, and nerve transmission. The mild reduction observed in calcium levels is consistent with the findings of Gusmão *et al.* (2016), who noted that heat processing could lead to some mineral loss, especially water-soluble minerals like calcium. However, finger millet still retains a significant amount of calcium after processing, making it an important source of this mineral. Magnesium content exhibited a more noticeable decline from 143.72 mg/100g (AOA) to 117.52 mg/100g (AOD) as the conditioning temperature increased. This suggests that higher temperatures significantly affect the retention of magnesium in the millet. Magnesium is a key mineral involved in enzyme function, protein synthesis, and muscle and nerve function, and its reduction in conditioned samples is noteworthy. Similar reductions in magnesium have been reported in grains exposed to higher temperatures or prolonged heat treatments. Lestienne *et al.* (2005) found that magnesium content in legumes decreased after roasting and heat treatment, which is in line with the results from this study. The leaching of magnesium or its degradation due to thermal stress could explain this loss. The loss of magnesium in finger millet, especially at higher temperatures, is therefore a common effect of high-heat treatments.

The iron content in the conditioned samples showed significant difference at ($p>0.05$), with AOA having the highest value (1.98 mg/100g) and AOB having the lowest (0.99 mg/100g). However, AOC (1.31 mg/100g) and AOD (1.57 mg/100g) showed values higher than AOB, suggesting that moderate temperature treatments like those in 70 ^{0}C and 80 ^{0}C might preserve or even enhance iron retention. The increase in iron content in the AOD sample (relative to AOB) could be due to the concentration effect that occurs when water-soluble components decrease due to moisture loss at higher temperatures (Choi *et al.,* 2013). Also, iron bioavailability is improved due to the reduction in anti-nutrients like phytates at higher temperatures, which can otherwise bind iron and limit its absorption (Sreenivasan and Sharma, 2014). The decrease in AOB suggests that higher temperatures might result in some loss of iron, either due to leaching or oxidative reactions. Previous studies have noted that iron can be susceptible to oxidative degradation at high temperatures (Gusmão *et al.,* 2016). The increase in iron content in AOD could be explained by improved bioavailability, while the decrease in

AOB may be due to iron losses at lower temperatures. Potassium content exhibited a gradual decrease from 143.86 mg/100g (AOA) to 120.49 mg/100g (AOD). The reduction in potassium could result from its leaching into water during processing or loss during heat treatment. Potassium is essential for fluid balance, nerve function, and muscle contractions, so this reduction may affect the nutritional quality of the millet in terms of its contribution to these functions. Similar trends have been observed in other grains subjected to high-temperature processing (Ogbonna *et al.*, 2018). Potassium being a water-soluble mineral is more likely to be lost during soaking or boiling, and the degree of loss depends on the processing method and temperature.

Table 2: Mineral (mg/100g) and Anti-nutrient (mg/100g) composition of Finger Millet Conditioned at Different Temperatures

Properties\Samples	AOA	AOB	AOC	AOD	LSD
Calcium Content	$366.17^{a}\pm5.00$	$360.85^{b}\pm5.00$	$356.79^{c}\pm5.00$	$351.65^{d}\pm5.00$	2.90
Magnesium Content	$143^{a}.72\pm4.00$	$125.56^{b}\pm1.00$	$124.10^{b}\pm5.00$	$117.52^{c}\pm6.00$	1.64
Iron Content	$1.98^{a}\pm0.50$	$0.99^{d}\pm0.01$	$1.31^{c}\pm0.06$	$1.57^{b}\pm0.70$	0.09
Potassium Content	$143.86^{a}\pm5.00$	$137.55^{b}\pm7.00$	$122.79^{c}\pm7.00$	$120.49^{c}\pm4.00$	1.93
Phytate Content	$0.90^{a}\pm0.04$	$0.66^{b}\pm0.02$	$0.58^{d}\pm0.04$	$0.62^{c}\pm0.03$	0.02
Oxalate Content	$1.53^{a}\pm0.08$	$1.52^{b}\pm0.01$	$1.30^{c}\pm0.06$	$1.13^{d}\pm0.06$	0.07
Tannin Content	$1.69^{b}\pm0.06$	$1.81^{a}\pm0.06$	$1.60^{d}\pm0.06$	$1.77^{b}\pm0.06$	0.06
Saponin Content	$0.35^{ab}\pm0.06$	$0.38^{a}\pm0.08$	$0.33^{b}\pm0.05$	$0.36^{ab}\pm0.05$	0.04

*Values are mean values of the duplicate samples with standard deviation and m**eans with different letters within the same row are significantly different at (p < 0.05)**. Key: AOA = Finger Millet Flour Conditioned at 30 ^{0}C (Control), AOB = Finger Millet Flour Conditioned at 60 ^{0}C, AOC = Finger Millet Flour Conditioned at 70 ^{0}C, AOD = Finger Millet Flour Conditioned at 80 ^{0}C.*

Phytates are considered one of the major anti-nutrients in cereals and legumes because they can bind essential minerals like iron, zinc, and calcium, thus reducing their bioavailability (Ravindran *et al.*, 2014). The data shows that phytate content decreased significantly with increasing temperature, from 0.90 mg/100g (AOA) to 0.58 mg/100g (AOC). The content increased significantly at (p<0.05) in AOD (0.62 mg/100g) but remained lower than the control (AOA). The reduction in phytate content with heat conditioning indicates that heat treatment can help break down phytates, making the minerals more available for absorption. Thermal processing has been shown to degrade phytates, particularly when subjected to roasting or boiling (Lestienne *et al.*, 2005). This process is beneficial for improving the nutrient bioavailability of finger millet and is in line with findings from other studies on cereals and legumes (Choi *et al.*, 2013). The reduction in phytate content in this study is consistent with findings from Lestienne *et al.* (2005) and Sreenivasan and Sharma (2014), who reported a decrease in phytates in legumes and cereals after thermal processing. Heat treatments such as roasting or boiling have been shown to significantly lower phytate levels, thus improving the bioavailability of minerals like iron, zinc, and calcium. Oxalates are anti-nutrients that can form insoluble salts with calcium, potentially leading to the formation of kidney stones in susceptible individuals (Tian *et al.*, 2014). The results show that oxalate content slightly decreased from 1.53 mg/100g (AOA) at 30 ^{0}C to 1.13 mg/100g (AOD) at 80 ^{0}C, with AOC (70 ^{0}C) showing a significant reduction at (p>0.0) to 1.30 mg/100g. The reduction in oxalate levels across the conditioned samples suggests that high temperatures can facilitate the degradation or leaching of oxalates, as oxalates are known to be heat-sensitive. This is consistent with studies that have shown that boiling or roasting can lower oxalate content in various grains (Ravindran *et al.*, 2014). The decreasing trend in oxalates is beneficial because it could improve the bioavailability of calcium and reduce the potential for kidney stone formation.

Tannins are polyphenolic compounds that can interfere with the absorption of iron and protein (Sreenivasan and Sharma, 2014). In the current study, tannin content slightly increased in AOB (1.81 mg/100g) compared to AOA (1.69 mg/100g), but then decreased in AOC (1.60 mg/100g) and slightly increased again in AOD (1.77 mg/100g). This indicates that temperature treatment has a complex effect on tannin content. The increase in tannins in AOB could be due to oxidation or condensation of tannins during mild heating (Choi *et al.*, 2013). However, the decrease in AOC suggests that higher temperatures (70 °C) may lead to tannin degradation or reduction, making the grain more bioavailable for iron and protein absorption. High-temperature processing, such as roasting or toasting, has been shown to reduce tannin content in other cereals and legumes (Lestienne *et al.*, 2005). Saponins are another class of anti-nutrients known for their bitter taste and their potential to interfere with nutrient absorption, particularly proteins and lipids (Sreenivasan and Sharma, 2014). The results show that saponin content remained relatively stable, with values ranging from 0.33 mg/100g (AOC) to 0.38 mg/100g (AOB). The lack of significant variation in saponin content across the conditioned samples suggests that heat treatment showed a significant difference at ($p<0.05$) on saponin degradation in finger millet. This stability could be attributed to the chemical stability of saponins under the temperature ranges tested in this study. While some studies have shown that soaking or boiling can reduce saponin levels, other studies have found that high temperatures alone might not be sufficient to significantly degrade saponins (Lestienne *et al.*, 2005).

CONCLUSION AND RECOMMENDATION

In conclusion, conditioning finger millet at higher temperatures results in a reduction of moisture and fat, an increase in protein, and a slight improvement in mineral concentration. These changes can enhance the overall nutritional value of finger millet, with moderate conditioning temperatures (60 °C - 70 °C) offering the best balance of improved protein content and reduced anti-nutrients, making it a promising method for enhancing the millet's dietary benefits. Conditioning at higher temperatures led to a slight reduction in key minerals, including calcium, magnesium, and potassium, with the highest concentrations observed at 30 °C (AOA). Iron content fluctuated across the samples, with the highest iron level at 30 °C (AOA) and lower levels at higher temperatures. These changes suggest that while temperature conditioning does not drastically affect mineral content, there is a mild loss of essential minerals at elevated temperatures, likely due to leaching or heat degradation. This suggests that temperature conditioning can be a useful technique for improving the nutritional value of finger millet by reducing harmful anti-nutrients.

Conditioning at 60 °C and 70 °C led to enhanced protein content and reduced phytates, making these temperatures ideal for improving the millet's bioavailability of essential minerals while maintaining a good nutritional profile. These conditions also offer a moderate reduction in fat and moisture, improving the millet’s shelf stability. While conditioning at 80 °C helped reduce moisture content and some anti-nutrients, the loss of important minerals (e.g., magnesium, potassium) and fat content at this temperature may result in a less favourable overall nutritional profile.

REFERENCES

Akinmoladun, A. C., Akinrinde, E. A. and Afolabi, I. S. (2015). Effect of heat treatment on the nutritional and anti-nutritional properties of millet grains. *Journal of Food Science and Technology*, 52(**4**):2111-2118.

AOAC (2000). Official Methods of Analysis (17th ed.). Gaithersburg, MD: AOAC International.

AOAC International. (2005). Official Methods of Analysis (18th ed.). Gaithersburg, MD: AOAC International.

Bello, A. B., Abdulrahaman, A. A. and Sanwo, K. A. (2016). Effects of temperature and moisture on the storage stability of millet grains. *Journal of Stored Products Research*, 69:137-144.

Chamba, J. M., Njoume, R. S. and Mimb, P. N. (2021). Determination of potassium content in plant-based foods using a modified atomic absorption spectrophotometry method. *Journal of Food Science and Technology*, 58(**2**):542-549.

Choi, S. M., Lee, S. C. and Kim, H. (2013). Effects of heat treatment on the protein denaturation and functional properties of soybean protein isolate. *Journal of Food Science*, 88(**5**):S1448-S1454.

Ekeke, C. J. and Nwosu, J. N. (2018). Traditional food systems and their significance in modern society. *Journal of Ethnic Foods*, 5(**3**):149-155.

Emmanuel, O. and Deborah, E. (2018). Determination of tannin content in plant extracts using a modified spectrophotometric method. *Journal of Pharmaceutical and Biomedical Analysis*, 161:241-246.

Gusmão, J. C., de Castro, R. J. S. and Deliza, R. (2016). Effects of heat treatment on the lipid oxidation and fatty acid composition of rice bran. *Journal of Food Science and Technology*, 53(**4**):1939-1946.

Hussain, I., Uddin, B. and Aziz, M. G. (2011). Optimization of antinutritional factors from germinated wheat and mungbean by response surface methodology. *International Food Research Journal.* 18:957–963

Kalaisekar, A. (2017). Insect pests of millets: systematics, bionomics, and management. London: Elsevier. ISBN 978-0-12-804243-4. OCLC 967265246.

Lestienne, I., Caporiccio, B., Besançon, P. and Rouanet, J. M. (2005). Effects of heat treatment on the nutritional and anti-nutritional properties of legumes. *Journal of Food Science*, 70(**4**):S155-S161.

Njoku, P. C., Nwosu, J. N. and Eke, E. G. (2019). Traditional food systems and their importance in Igbo culture. *Journal of Food Science and Technology*, 56(**2**):851-858.

Ogbonna, A. C., Okpara, D. A. and Okoro, B. C. (2018). Effects of roasting on the nutritional and anti-nutritional properties of sorghum grains. *Journal of Food Science and Technology*, 55(**2**):541-548.

Ogunbile, I. O., Akinyele, I. O. and Shittu, T. A. (2017). Indigenous knowledge of cereal-based foods in Nigeria. *Journal of Food Science and Technology,* 54(**4**):931-938.

Patel, P. and Dutta, D. (2018). Determination of oxalate and phytate contents in plant-based foods. *Journal of Food Science and Technology*, 55(**4**):1210-1216.

Ravindran, G., Ravindran, V. and Sivakanesan, R. (2014). Effects of drying methods on the retention of minerals in millet grains. *Journal of Food Engineering,* 131:101-107.

Sanchez-Mata, M. C., Camara-Hurtado, M. and Diez-Marques, C. (2001). Effects of heat treatment on the lipid and fatty acid composition of almonds. *Journal of Agricultural and Food Chemistry,* 49(**11**):5495-5501.

Sivakanesan, R. and Singh, R. P. (2015). Effects of heat treatment on the starch gelatinization and digestibility of rice. *Journal of Food Science and Technology,* 52(**2**):931-938.

Sreenivasan, S. and Sharma, S. (2014). Effects of roasting on the nutritional and anti-nutritional properties of cereals. *Journal of Food Science and Technology,* 51(**4**):857-864.

Tian, X., Fang, Y. and Chen, F. (2014). Effects of thermal processing on the oxalate content of spinach. Journal of Food Science, 89(**5**):S1448-S1453.

Ubbor, S. C., Arukwe, D. C., Ezeocha, V. C., Nwose, O. N., Iguh, B. N. and Nwibo, O. G. (2022). Production And Quality Evaluation Of Ready To Eat Extruded Snacks From Flour Blends Of Acha-Cowpea And Sweet Potato Starch. *FUDMA Journal of Sciences (FJS),* 6(**4**):245 – 253.

Zhu, F., Du, B. and Xu, B. (2015). Effects of moisture content on the storage stability of millet grains. *Journal of Cereal Science,* 65:241-246.