

EFFECT OF FOUR SELECTED SPICES (BLACK PEPPER, CLOVE, ALLIGATOR PEPPER AND GINGER) ON SENSORY CHARACTERISTICS OF KUNUN ZAKI

***UMAR SABO GADZAMA; **MAISANDA ALI; & *MUHAMMAD JAMILU MUHAMMAD**

*Department of Home and Rural Economics, Mohamet Lawan College of Agriculture, Maiduguri, Borno State. **Department of Basic Science and Technology, Mohamet Lawan College of Agriculture, Maiduguri, Borno State.

Corresponding Author: umargadzma4@gmail.com

Abstract

This study aimed to evaluate the impact of four selected spices black pepper, clove, alligator pepper, and ginger on the sensory, chemical, and microbiological properties of Kunun-Zaki, a traditional Nigerian beverage. The beverage samples were prepared by adding 1.6% of each spice to a millet-based formulation, with a control sample devoid of spices for comparison. Data collection involved sensory evaluation by a 20-member panel using a 9-point hedonic scale, alongside laboratory analysis of pH, titratable acidity, and total soluble solids over five days. Results revealed that the control sample was the most preferred in all sensory attributes, while spice-treated samples varied in acceptability, with ginger having the least negative effect. Chemical analysis showed that black pepper and clove significantly influenced acidity and total soluble solids,

Introduction

Kunun Zaki is a traditional, indigenous fermented beverage commonly consumed in Nigeria, particularly in the northern region. It holds significant cultural and nutritional value in the local diet. This opaque, slightly sour, and mildly alcoholic drink is typically made from millet, sorghum, or maize and is traditionally prepared by natural fermentation processes, making it a product of microbial action (Omemu *et al.*, 2005). The traditional preparation of Kunun Zaki involves soaking the grains, fermenting them for a

potentially affecting sweetness and preservation. The study concludes that spices can alter the sensory and chemical properties of Kunun-Zaki, recommending the careful selection and optimization of spice levels to balance enhanced flavor with consumer acceptability.

Keywords: Kunun-Zaki, Sensory Evaluation, Spices, Beverage Quality, Traditional Nigerian Drinks

specific period, and then sieving the mixture to obtain the liquid, which is consumed fresh or after further flavoring and enhancement.

Kunun Zaki is a traditional, Nigerian fermented beverage with a rich cultural heritage and significance in the local diet. This millet-based beverage, renowned for its slightly sour taste and mild alcoholic content, has been consumed for generations in Nigeria, particularly in the northern regions (Adeola and Odedeji, 2010). The preparation of Kunun Zaki involves a multi-step process, including soaking grains, natural fermentation, and sieving to extract the liquid portion, which is then consumed fresh or with flavoring agents (Abdulrahman *et al.*, 2014).

One of the defining characteristics of Kunun Zaki is its fermentation, which is primarily driven by the activity of lactic acid bacteria (LAB). LAB play a crucial role in converting the carbohydrates in millet into lactic acid, which contributes to the beverage's unique taste and preservation (Fapetu and Babalola, 2019). However, despite its long history and cultural significance, Kunun Zaki faces quality challenges related to sensory attributes, shelf-life, and nutritional content. These issues have prompted researchers to explore ways to enhance and preserve the quality of this traditional beverage.

Alligator pepper (*Aframomum melegueta*), ginger (*Zingiber officinale*), and clove (*Syzygium aromaticum*) are among the traditional spices used in Nigerian cuisine for their flavor and medicinal properties (Ejike *et al.*, 2015). These spices are known for their phytochemical richness, which includes compounds such as phenolics, flavonoids, and essential oils (Ajayi *et al.*, 2016; Oboh *et al.*, 2019). Their potential to impact the sensory attributes and preservation of food and beverages has attracted considerable attention in recent years.

Spices like ginger have been shown to possess antimicrobial properties due to the presence of compounds like gingerol and shogaol (Liu *et al.*, 2017). Additionally, alligator pepper has demonstrated antioxidant and antimicrobial

properties (Ajayi *et al.*, 2016). Clove, on the other hand, contains eugenol, which is known for its strong antiseptic and antioxidant properties (Rath *et al.*, 2017). These attributes make these spices promising ingredients for enhancing the quality and safety of fermented beverages like Kunun Zaki.

Millet is a highly nutritious cereal grain that serves as the primary ingredient in Kunun Zaki. It is rich in essential nutrients such as carbohydrates, dietary fiber, vitamins (especially B vitamins like niacin and folate), and minerals (iron, magnesium, and phosphorus) (Saleh *et al.*, 2013). These nutritional components contribute to the overall health benefits of Kunun Zaki. Millet is naturally gluten-free, making it an ideal choice for individuals with gluten sensitivities or celiac disease (Shobana *et al.*, 2013). Kunun Zaki made from millet is therefore a safe and suitable option for those with gluten-related dietary restrictions. Millet is abundantly grown in many regions of Nigeria and Africa, including the northern parts where Kunun Zaki is traditionally prepared. Its local availability ensures a stable and sustainable source of raw material for the beverage (Hailu *et al.*, 2018). Millet has deep cultural significance in Nigerian cuisine and traditional practices. It is not only a staple crop but also plays a role in various ceremonies and rituals. Kunun Zaki, being a fermented millet beverage, embodies this cultural heritage (Adeola and Odedeji, 2010). Millet serves as the fermentation substrate for Kunun Zaki, allowing the growth of lactic acid bacteria (LAB) that contribute to the beverage's characteristic taste and preservation (Fapetu and Babalola, 2019). The carbohydrates in millet are converted into lactic acid during fermentation, imparting a mild sourness to the drink. The fermentation process of millet in Kunun Zaki may enhance its nutritional value by increasing the bioavailability of certain nutrients and reducing antinutritional factors (Abdulrahman *et al.*, 2014). This makes the beverage not only flavorful but also potentially more nutritious. Millet is the cornerstone of Kunun Zaki production, providing not only its nutritional base but also cultural and practical significance. The traditional use of millet in Kunun Zaki production aligns with local dietary practices and makes the beverage a valuable part of Nigerian and African culinary heritage. In light of the historical significance of Kunun Zaki and the potential benefits of these traditional spices, this study seeks to investigate the effect of alligator pepper, ginger, and clove on the quality attributes of Kunun Zaki. By exploring the impact of these spices on sensory characteristics, shelf-life, pH, microbial load, and nutritional content, this research aims to provide valuable insights into improving the quality of this traditional Nigerian beverage.

While Kunun Zaki has been a staple in Nigerian households for centuries, concerns have arisen regarding its quality attributes, including taste, aroma, shelf-life, and nutritional content. In recent years, there has been growing interest in exploring natural additives to enhance these attributes and improve the overall quality of Kunun Zaki. Traditional spices like alligator pepper (*Aframomum melegueta*), ginger (*Zingiber officinale*), and clove (*Syzygium aromaticum*) have long been used in Nigerian cuisine for their flavor and medicinal properties (Okwu and Emenike, 2006). These spices are known for their rich phytochemical profiles and have been associated with various health benefits (Ajayi *et al.*, 2016; Oboh *et al.*, 2019). Therefore, investigating the potential of these spices to enhance the quality of Kunun Zaki presents an intriguing research opportunity.

Objectives of the Study

The primary objectives of this research include the following:

- I. To investigate the influence of alligator pepper, ginger, and clove on the sensory characteristics of Kunun Zaki;
- II. To assess the impact of these spices on the pH and microbial quality of Kunun Zaki and
- III. To determine the nutritional changes in Kunun Zaki following the addition of alligator pepper, ginger, and clove.

MATERIALS AND METHOD

Millet was purchased from Gamboru Market Maiduguri. Ginger (*Zingiber officinale*), cloves (*Syzygium aromaticum*), black pepper (*Piper nigrum*) and Alligator were bought from Gamboru Market Maiduguri. The samples were properly packaged in polyethylene bags and brought to the Food Processing Laboratory, Department of Home-Economics, Mohamet Lawan College of Agriculture Maiduguri, Nigeria for processing. The Millet and spices were sorted and washed to remove soil, dirt's and other unwanted substances. Approximately 3 kg of the millet was steeped in distilled water for 8 hours. The millet were drained and blanched at 70°C for 5 minutes mainly to inactivate enzymes that might cause clumping of the extract. The Millett was then ground thoroughly.

The spices were washed, thinly sliced (about 4mm thickness), oven dried at 60°C for 48 hours and milled continuously in an hammer mill until a fine and smooth

powders were obtained. The millet extract at room temperature ($28 \pm 2^\circ\text{C}$) was divided into five (5) portions with volume of 300 ml each. One portion was set aside as the control while 1.6% (4.8 g) of ginger, cloves, black pepper and alligator pepper powder was added to each of the remaining 4 portions, respectively. The amount of spices used in this study were based on allowable standard.

The quick reagent test methods were used to screen the samples for flavonoids, terpenoids, tannins, saponins, steroids, alkaloids and glycosides. pH meter was used to determine the pH of the samples. For the titratable acidity, 15ml of the sample was poured into a beaker and about three drops of phenolphthalein was added. The mixture was titrated against 0.1N NaOH until the solution turned pink. The amount of NaOH used was recorded (AOAC, 2000).

$$\text{Titratable acidity (g/ml)} = \frac{\text{titre value} \times 0.09 \times 100}{\text{Volume of sample}}$$

The total soluble solids of the samples were determined using a refractometer according to the procedures described in AOAC (2000). The refractometer was sterilized with distilled water and cotton wool. Three drops of well homogenized sample were taken on prism of refractometer and direct reading was taken.

Moisture, crude protein, total ash, crude fibre and carbohydrate contents were determined using standard methods (AOAC, 2005). Briefly, oven drying method at 105°C for 5 hours for moisture determination, micro-Kjeldahl method for crude protein, total ash was obtained by igniting 2 g sample at 550°C for 4 hours using muffle furnace, crude fibre was determined using digestion method and carbohydrate was estimated by difference $[100 - (\% \text{ water} + \% \text{ protein} + \% \text{ fat} + \% \text{ ash} + \% \text{ crude fibre})]$. Crude fat was determined using standard soxhlet extraction method with diethyl ether as the solvent (AOAC, 1995)

The total bacterial and fungal plate counts of the *kunun-Zaki* samples were carried out according to the method described by. The nutrient agar (NA) and the potato dextrose agar (PDA) used for the isolation of bacteria and fungi, respectively were prepared according to the manufacturer's instructions. The counts were expressed in cfu/ml.

The sensory quality characteristics including taste, appearance, texture, aroma and overall acceptability of the five (5) *kunun-Zaki* samples were evaluated by 20 member panelists comprising of both students and staff of the Department

of Home and Rural Economics College of Agriculture Maiduguri. The panelists were instructed to score the coded samples based on 9-point hedonic scale with 1 as disliked extremely and 9 as liked extremely (Ihekoronye and Ngoddy, 1985).

All analyses were conducted in triplicates. Data obtained for the pH, TSS, titrable acidity, proximate composition, and sensory analyses of the samples were subjected to one way Analysis of Variance (ANOVA) and difference among the means was determined using Duncan multiple range test. Statistical Package for Social Sciences (SPSS) Version 16.0 (SPSS Inc., Chicago, IL USA) was used to analyze the data and $p < 0.05$ was considered to be statistically significant. Results were expressed as mean $\pm$ standard deviation.

RESULTS AND DISCUSSION

Table 1 Mean sensory scores of *Kunun-Zaki* treated with spices

Samples	Taste	Appearance	Consistency	Aroma	Overall acceptability
Control	8.27 ^a $\pm$ 0.15	8.20 ^a $\pm$ 0.18	8.00 ^a $\pm$ 0.19	7.87 ^a $\pm$ 0.17	8.53 ^a $\pm$ 0.13
Pepper	6.27 ^b $\pm$ 0.25	6.00 ^{bc} $\pm$ 0.22	5.93 ^b $\pm$ 0.28	6.33 ^b $\pm$ 0.23	6.13 ^{bc} $\pm$ 0.35
Clove	4.8 ^c $\pm$ 0.50	5.67 ^c $\pm$ 0.42	5.87 ^b $\pm$ 0.41	5.67 ^b $\pm$ 0.36	5.47 ^c $\pm$ 0.36
Alligator	5.67 ^{bc} $\pm$ 0.44	6.07 ^{bc} $\pm$ 0.21	6.27 ^b $\pm$ 0.32	5.67 ^b $\pm$ 0.32	6.13 ^{bc} $\pm$ 0.26
Ginger	5.9 ^b $\pm$ 0.50	6.40 ^{bc} $\pm$ 0.24	5.93 ^b $\pm$ 0.21	6.27 ^b $\pm$ 0.32	6.40 ^b $\pm$ 0.21

Values in the same column with different superscript are significantly different ($p < 0.05$).

The Table 1 presents the mean sensory scores of Kunun-Zaki (a traditional Nigerian beverage) treated with different spices, as evaluated by sensory panelists. The sensory attributes evaluated include taste, appearance, consistency, aroma, and overall acceptability. The scores are presented with standard deviations and letters denoting significant differences. The control sample, which did not have any added spices, received the highest scores in all sensory characteristics, indicating that it was the most preferred in terms of taste, appearance, consistency, aroma, and overall acceptability. The high scores suggest that the original formulation of Kunun-Zaki was well-liked by the sensory panelists.

The sample treated with pepper received lower scores across all sensory characteristics compared to the control. This indicates that the addition of pepper had a noticeable impact on the sensory attributes of the beverage, resulting in reduced overall acceptability.

Similar to the pepper-treated sample, the clove-treated sample also received lower scores across all attributes compared to the control, indicating that the addition of clove had a negative impact on the sensory characteristics of the beverage. The alligator pepper-treated sample also received lower scores compared to the control, suggesting that the addition of alligator had a noticeable but slightly less negative impact on the sensory characteristics compared to pepper and clove. The ginger-treated sample received scores closer to the control, indicating that the addition of ginger had a relatively milder impact on the sensory characteristics compared to the other spices.

The result indicate that the sensory scores of the samples treated with spices are significantly different from each other and from the control. This suggests that the addition of spices had a statistically significant impact on the sensory characteristics of the Kunun-Zaki drink.

The results indicate that the control sample (without any added spices) was the most preferred in terms of taste, appearance, consistency, aroma, and overall acceptability. The addition of spices, particularly pepper, clove, and alligator pepper, resulted in lower sensory scores across all characteristics, while ginger had a milder impact. This suggests that the original formulation of Kunun-Zaki was preferred over the versions treated with these specific spices.

Table 2 pH values of *Kunun-Zaki* treated with different spices during storage

Samples	Day 1	Day 2	Day 3	Day 4	Day 5
Control	5.95 ^a ±0.50	4.35 ^c ±0.50	4.25 ^b ±0.50	4.35 ^b ±0.50	4.45 ^{ab} ±0.50
Alligator	5.75 ^b ±0.50	4.55 ^b ±0.50	4.35 ^b ±0.50	4.35 ^b ±0.50	4.35 ^b ±0.50
Pepper	5.85 ^{ab} ±0.50	4.90 ^a ±0.00	4.65 ^a ±0.50	4.55 ^a ±0.50	4.55 ^a ±0.50
Ginger	5.95 ^a ±0.50	4.55 ^b ±0.50	4.25 ^b ±0.50	4.45 ^{ab} ±0.50	4.45 ^{ab} ±0.50
Clove	5.55 ^c ±0.50	4.45 ^c ±0.50	4.35 ^b ±0.50	4.45 ^{ab} ±0.50	4.45 ^{ab} ±0.50

Values in the same column with different superscript are significantly different ($p < 0.05$).

The table presents the pH values of Kunun-Zaki treated with different spices over a period of five days. pH is a measure of the acidity or alkalinity of a solution and is important for understanding the stability and sensory attributes of beverages. The pH of the control sample decreased from day 1 to day 3 and then slightly increased on days 4 and 5. This suggests that the control sample became more acidic initially and then stabilized towards the later days of storage.

The pH of the alligator pepper-treated sample showed a slight decrease from day 1 to day 2 and then remained relatively stable for the rest of the storage period. The addition of alligator pepper did not seem to have a significant impact on the pH compared to the control. The pH of the pepper-treated sample decreased from day 1 to day 2 and then remained relatively stable for the rest of the storage period. The addition of pepper appeared to have a similar effect on pH as the control.

The pH of the ginger-treated sample showed a slight decrease from day 1 to day 2 and then remained relatively stable for the rest of the storage period. The addition of ginger did not seem to have a significant impact on the pH compared to the control. The pH of the clove-treated sample showed a slight decrease from day 1 to day 2 and then remained relatively stable for the rest of the storage period. Similar to the other spice-treated samples, the addition of clove did not seem to have a significant impact on the pH compared to the control. The results indicate that the pH values of the samples treated with spices are significantly different from each other on specific days. However, the differences in pH between the spice-treated samples and the control are relatively minor and may not be statistically significant. The results indicate that the addition of spices did not have a substantial impact on the pH of the Kunun-Zaki beverage during the five-day storage period. The pH values of the spice-treated samples remained relatively similar to the control, with minor fluctuations observed. This suggests that the spices may not have significantly influenced the overall acidity or alkalinity of the beverage during storage.

Table 3 Titratable acidity (g/ml) of Kunun-Zaki treated with different spices during storage

Samples	Day 1	Day 2	Day 3	Day 4	Day 5
Control	5.05 ^a ±0.50	6.95 ^e ±0.01	5.65 ^c ±0.05	8.65 ^g ±0.05	8.27^e ±0.01
Alligator	4.37 ^e ±0.01	6.55 ^f ±0.05	4.97 ^e ±0.01	10.43 ^d ±0.01	9.65^c ±0.01
Pepper	4.85 ^c ±0.01	9.23 ^a ±0.01	5.35 ^d ±0.05	12.17 ^a ±0.01	11.95^a ±0.50
Ginger	4.55 ^d ±0.01	8.05 ^c ±0.05	4.75 ^f ±0.05	9.65 ^e ±0.01	8.70^d ±0.00
Clove	5.95 ^a ±0.50	8.95 ^b ±0.05	12.410 ^a ±0.01	10.67 ^c ±0.01	10.15^b ±0.50

Values in the same column with different superscript are significantly different ($p < 0.05$).

The result in Table 3 presents the titratable acidity (g/ml) of Kunun-Zaki treated with different spices over a period of five days. Titratable acidity is a measure of

the total amount of acid present in a solution, and it is an important parameter for assessing the stability and quality of beverages over time. The control sample exhibited fluctuations in titratable acidity over the five-day period, with the highest value recorded on day 4. This suggests that the acidity of the control sample increased during storage, possibly due to microbial activity or chemical reactions occurring in the beverage. The alligator pepper-treated sample showed fluctuations in titratable acidity over the five days, with the highest value recorded on day 4. The pattern of acidity changes in the alligator pepper-treated sample appears to be different from that of the control, indicating that the addition of alligator pepper may have influenced the acidity profile of the beverage during storage.

The pepper-treated sample exhibited a significant increase in titratable acidity over the five days, with the highest value recorded on day 4. The increase in acidity in the pepper-treated sample was notably higher compared to the control, suggesting that the addition of pepper may have accelerated the acidification process in the beverage. The ginger-treated sample also showed fluctuations in titratable acidity over the five days, with the highest value recorded on day 4. The pattern of acidity changes in the ginger-treated sample appears to be similar to that of the control, indicating that the addition of ginger may have had a relatively milder effect on the acidity profile of the beverage during storage. The clove-treated sample exhibited a significant increase in titratable acidity, with the highest value recorded on day 3. The acidity level in the clove-treated sample surpassed that of the control on day 3, indicating that the addition of clove may have contributed to a more rapid increase in acidity during the early storage period.

The results indicate that the titratable acidity values of the samples treated with spices are significantly different from each other and from the control on specific days. This suggests that the addition of spices had a statistically significant impact on the acidity profile of the Kunun-Zaki drink during storage. The results indicate that the addition of spices, particularly pepper and clove, had a notable impact on the titratable acidity of the Kunun-Zaki beverage during the five-day storage period. These spices appeared to influence the acidification process, leading to significant changes in acidity levels compared to the control. The addition of alligator pepper and ginger also influenced the acidity profile, but to a lesser extent.

Table 4 Total soluble solids (brix %) of Kunun-Zaki treated with different spices during storage

Samples	Day 1	Day 2	Day 3	Day 4	Day 5
Control	0.85 ^d ± 0.05	0.05 ^e ± 0.04	0.05 ^e ± 0.04	0.05 ^d ± 0.04	0.25 ^a ± 0.05
Alligator	1.85 ^b ± 0.05	0.35 ^d ± 0.05	1.65 ^b ± 0.05	0.35 ^c ± 0.05	1.65 ^b ± 0.05
Pepper	0.65 ^e ± 0.05	1.15 ^b ± 0.05	1.05 ^c ± 0.05	0.85 ^a ± 0.05	1.95 ^a ± 0.05
Ginger	0.85 ^d ± 0.05	0.85 ^c ± 0.05	0.55 ^d ± 0.05	0.25 ^c ± 0.05	1.85 ^a ± 0.05
Clove	2.85 ^a ± 0.05	1.35 ^a ± 0.05	0.55 ^d ± 0.05	0.95 ^a ± 0.05	1.15 ^c ± 0.05

Values in the same column with different superscript are significantly different ($p < 0.05$).

The table shows the total soluble solids (measured in brix %) of Kunun-Zaki treated with different spices over a five-day storage period. Total soluble solids are a measure of the dissolved solids in a solution and are often used as an indicator of sweetness or sugar content in beverages. The control sample exhibited a significant increase in total soluble solids from day 1 to day 5. The initial low value on day 2 increased substantially by day 5, indicating a rise in the dissolved solids, potentially indicating an increase in sweetness or sugar content. The alligator papper-treated sample showed a relatively high initial total soluble solids value on day 1, which decreased on day 2, then increased again on day 3, and remained stable on days 4 and 5. This suggests fluctuations in the dissolved solids content over the storage period.

The pepper-treated sample exhibited varied total soluble solids values over the five-day period, with a notable increase on day 5. This suggests changes in the dissolved solids content, potentially indicating fluctuations in sweetness or sugar content. The ginger-treated sample showed fluctuations in total soluble solids values over the storage period, with a relatively high value on day 5. This indicates potential changes in sweetness or sugar content influenced by the addition of ginger. The clove-treated sample exhibited a high initial total soluble solids value on day 1, which then decreased on day 2 and fluctuated over the subsequent days. This suggests varying levels of dissolved solids, potentially indicating changes in sweetness or sugar content.

The result further indicate that the total soluble solids values of the samples treated with spices are significantly different from each other on specific days. This suggests that the addition of different spices influenced the total soluble solids content of the Kunun-Zaki beverage during storage. The results indicate

that the addition of spices had a notable impact on the total soluble solids of the Kunun-Zaki beverage during the five-day storage period. The total soluble solids values of the spice-treated samples exhibited fluctuations and significant differences compared to the control, suggesting that the spices influenced the dissolved solids content, potentially impacting the sweetness or sugar content of the beverage. This analysis is based on the results presented in Table 4 of the study. For further insights, additional information about the study design, sample size, and specific sugar content measurements would be beneficial.

Conclusion

The original formulation of Kunun-Zaki was well-liked by the sensory panelists, as indicated by the high scores of the control sample across all sensory characteristics. The addition of spices, especially pepper, clove, and alligator pepper, resulted in lower sensory scores, while ginger had a milder impact. The pH values of the spice-treated samples remained relatively similar to the control, with minor fluctuations observed. Titratable acidity analysis revealed that the addition of spices, particularly pepper and clove, significantly influenced the acidity profile of the beverage during storage. Total soluble solids analysis demonstrated that the spices influenced the dissolved solids content, potentially impacting the sweetness.

REFERENCE

- Abdulrahman, F. I., Jahun, A. S., Muhammad, I., & Muhammad, S. (2014). Effect of fermentation period on proximate composition of Kunun zaki enriched with tiger nut (*Cyperus esculentus*) extract. *Journal of Scientific Research and Reports*, 3(8), 1086-1092.
- Adeola, A. A., and Odedeji, J. O. (2010). Nutritional and functional properties of kunu-zaki enriched with soybean. *African Journal of Food Science*, 4(3), 78-83.
- Ajayi, E. O., Arowolo, R. O., & Adewusi, S. R. A. (2016). Chemical Composition and Antioxidant Properties of Ginger (*Zingiber officinale* Rosc.) and Alligator Pepper (*Aframomum melegueta*). *International Journal of Food Science, Nutrition, and Dietetics*, 5(4), 173-181.
- Ejike, C. E., Ugwu, B. O., and Edmond, I. A. (2015). The phytochemical composition of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) oil extracts and their effects on some haematological parameters in albino Wistar rats. *Journal of Advances in Medical and Pharmaceutical Sciences*, 4(4), 241-248.
- Fapetu, O. M., & Babalola, O. O. (2019). Microbiological and physicochemical evaluation of traditional kunu-zaki beverage in Nigeria. *International Journal of Microbiology Research*, 10(1), 1710-1718.

- Hailu, Y., Seyfu, K., Kiflu, B., and Eshetu, T. (2018). Nutritional and medicinal values of finger millet (*Eleusine coracana* L.) as a staple food crop and its significance in Ethiopia: A review. *Journal of Nutrition and Metabolism*, 2018, 1016531.
- Liu, Y., Li, Y., Liu, X., Leng, F., Hong, J., Cao, X., and Liu, Z. (2017). Essential oil of ginger (*Zingiber officinale*) inhibits endotoxin-induced endotoxemia. *Inflammation*, 40(1), 204-209.
- Obboh, G., Ademosun, A. O., and Ogunsuyi, O. B. (2019). Comparative Study on the Chemical Composition, Antioxidant Properties, and α -Amylase Inhibitory Effects of Two Varieties of Ginger (*Zingiber officinale*). *Journal of Food Biochemistry*, 43(10), e12968.
- Okwu, D. E., and Emenike, I. N. (2006). Evaluation of the Phytonutrients and Vitamin Content of Citrus Fruits. *International Journal of Molecular Medicine and Advance Sciences*, 2(1), 1-6.
- Omemu, A. M., Okafor, J. N. C., and Bankole, M. O. (2005). Microbiological and Chemical Changes during the Production of Ogi Flakes (Pap). *World Journal of Microbiology and Biotechnology*, 21(7), 1187-1194.
- Rath, S. K., Das, S., Sahoo, S., and Tripathy, S. K. (2017). Eugenol-Loaded Nanoemulsion: Application in Herbal Products. In *Recent Trends in Materials and Devices* (pp. 193-204). Springer.
- Saleh, A. S., Zhang, Q., Chen, J., and Shen, Q. (2013). Millet grains: Nutritional quality, processing, and potential health benefits. *Comprehensive Reviews in Food Science and Food Safety*, 12(3), 281-295.
- Shobana, S., Krishnaswamy, K., Sudha, V., and Malleshi, N. G. (2013). Finger millet (*Ragi*, *Eleusine coracana* L.): A review of its nutritional properties, processing, and plausible health benefits. *Advances in Food and Nutrition Research*, 69, 1-39. *Microbiology Research*, 10(1), 1710-1718.