Food Research 9 (2) : 316 - 322 (April 2025)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

Impact of *Xylopia aethiopica* powder on microbiological safety, biochemical characteristics, and organoleptic properties of *Kunnu gyada* produced from groundnut and rice

[1,*]Malomo, A.A., [2]Bamidele, O.P. and [1]Okedele, A.E.

[1]*Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife, Nigeria*
[2]*Department of Food Science and Technology, University of Venda, Thohoyandou, South Africa*

Article history:
Received: 19 January 2023
Received in revised form: 9 March 2023
Accepted: 12 August 2024
Available Online: 22 April 2025

Keywords:
Groundnut,
Rice,
Microorganisms,
Sugar,
Organoleptic property

DOI:
https://doi.org/10.26656/fr.2017.9(2).043

Abstract

Kunnu gyada is a nutritious beverage usually produced in small household quantities because of its poor keeping quality. This study investigated the preservative effect of *Xylopia aethiopica* powder on *Kunnu gyada* stored at refrigeration temperature (4°C) for 21 days. *Xylopia aethiopica* was added to *Kunnu gyada* at 2%, 3%, 5% and 7% concentrations to extend its shelf life. Microorganisms associated with the products were enumerated, isolated and identified, pH and sugar were evaluated, and organoleptic properties were assessed using standard methods. The results showed that total viable count (0-8.62 log CFU/mL), LAB count (0-7.47 log CFU/mL) and total fungi count (0-8.51 log CFU/mL) generally increased during storage and decreased with an increase in the concentration of *Xylopia aethiopica* added to the drink. *Pseudomonas fluorescens*, *Bacillus subtilis*, *Micrococcus luteus, Lactobacillus plantarum*, *Candida albicans*, *Aspergillus niger*, *Kluyveromyces marxianus,* and *Fusarium oxysporum* were isolated during storage. Total sugar, total reducing sugar and pH also decreased with an increase in concentration of *Xylopia aethiopica.* Results of sensory analysis of *Kunnu gyada* showed that the drink that contained 3% of *Xylopia aethiopica* powder was more accepted by the panelists than the others. Thus, *Xylopia aethiopica* could serve as a suitable bio-preservative in extending the shelf life of *Kunnu gyada* and could also encourage large-scale production for commercial purposes thereby making nutritious food available, accessible and affordable.

1. Introduction

Kunnu gyada is a thin cereal-legume beverage similar to kunu zaki. It is produced in limited daily quantities because of its short shelf life. It is different from the popular kunnu zaki which is mainly produced from cereal such as maize, sorghum and millet (Bolarinwa *et al*., 2015) because it contains both cereal and legume (rice and groundnut). It is usually consumed as weaning food or breakfast and beverages for special occasions such as weddings and naming ceremonies. It is usually produced in limited daily quantity and might spoil in a few hours if not properly refrigerated. However, it can only last for four days at refrigeration temperature (Halilu *et al.,* 2022). Legumes such as groundnut and others improve the protein content of traditional cereal-based foods because they are high in protein and essential amino acids needed for the growth and proper functioning of the body and also reduce malnutrition and nutritional-related diseases (Malomo and Abiose, 2019).

Groundnut (*Arachis hypogaea* L.) *is majorly produced for its protein and oil content* (Yadachi *et al.,* 2012). It is the second most important legume after soybeans. It is a cheap source of essential amino acids and fatty acids. The seed contains about 25-36% protein and 47-53% oil depending on the species (Prasad *et al*., 2011). Its oil is rich in essential fatty acid which is free of trans fat and cholesterol. The oil is also rich in unsaturated fatty acids “oleic acid (52%) and linoleic acid (52%)” with a low amount of saturated fatty acid (Özcan, 2010). Groundnut serves as a rich source of calcium, phosphorus, magnesium, zinc, potassium and vitamins A, B and E and also contain antioxidants and phytochemicals that are beneficial to the body (Gradawa *et al*., 2019).

*Corresponding author.
Email: *adepojuadekunbi@gmail.com*

eISSN: 2550-2166
Published by Rynnye Lyan Resources

Rice is one of the most important cereals in the world with about twenty varieties. The two important species are *Oryza sativa* and *Oryza glaberrima.* It contains carbohydrates, protein, calcium, magnesium, and phosphorus with traces of iron, copper, zinc and manganese (Oko and Ugwu, 2011). Rice flour/starch has gained attention as a stabilizer in food due to its hypoallergenic properties, gluten-free nature and bland flavour which might not interfere with the organoleptic properties of the products (Bao and Bergman, 2004). Rice will provide energy while groundnut will supply protein, fat, fat-soluble vitamins and minerals. Groundnut and rice are important in the production of a nutritious beverage known as *Kunnu gyada* which is usually produced in daily household quantity due to its short shelf life (Adbulrahman *et al*., 2014). Groundnut has high nutritional value and provides an affordable alternative to protein which has been exploited for combating malnutrition due to protein deficiencies in children. The use of locally available legumes in food processing will increase the nutritional and health status of the population, especially in those who cannot afford animal protein (Malomo *et al*., 2020). High digestibility and organoleptic acceptability have been reported in beverages produced from blends of legumes and cereal by all groups (Elsamani and Ahmed, 2014).

The addition of preservatives has improved the shelf life of many foods and beverages globally. The knowledge of the negative effects of chemical preservatives has led to an increase in the use of bio-preservatives such as spices in food (World Health Organisation (WHO), 2002). *Xylopia aethiopica* also known as Ethiopian pepper or African guinea pepper is commonly used as a flavouring agent, preservative and food seasoning because of the presence of aromatic substances (Marcel *et al*., 2010; Imo *et al*., 2018). Chemical compound found in the seed are flavonoids, alkaloids, cineol, phytosterols, tannins, saponins, glycosides, carbohydrates, terpenes, paradol, cryptone, limonene and myrtenol which give the seed antioxidative, anti-inflammatory, laxative and antimicrobial properties (Ogbonna *et al*., 2013; Anumudu *et al*., 2020). These properties also qualify it as functional food since it has many health benefits (Ogbonna *et al*., 2013).

It is important to improve the consumption of protein in developing countries with plant proteins that are available, accessible, and affordable because of the high cost of animal protein such as meat, milk, egg, and fish as this will improve the nutritional status and reduce malnutrition, especially undernutrition and micronutrient deficiencies (Malomo *et al*., 2019). This research generated information on the preservative effect of *Xylopia aethiopica* on the microbiological characteristics and physicochemical properties of *Kunnu gyada* and encouraged the production of this nutritious beverage on a large scale. Several studies have been conducted on the production, chemical properties and microbiological characteristics of Kunnu zaki which is produced from maize, millet or sorghum with low protein content (Gaffa *et al*., 2002; Essien *et al*., 2009; Ogbonna, *et al* 2011; Sosanya *et al*., 2021) but there is still a dearth of information on *Kunnu gyada*. Hence, this study determined the effect of *Xylopia aethiopica* on the microbiological characteristics, safety and shelf life of *Kunnu gyada* to increase its production on a large scale and combat micronutrient deficiencies.

2. Materials and methods

2.1 Sources of materials

Groundnut (*Arachis hypogaea* L.), rice (*Oryza glaberrima*) and *Xylopia aethiopica* were obtained from Sabo market in Ile-Ife, Nigeria. The media and chemicals used were of analytical grade.

2.2 Preparation of Xylopia aethiopica

The method of Anumudu *et al*. (2020) was used to prepare the fruit. *Xylopia aethiopica* fruits were sorted, cleaned, and dried in a hot air oven at 65°C for 24 hrs. The dried spice was cooled to room temperature, milled using a hammer mill and stored in an airtight container for further use.

2.3 Production of Kunnu gyada

Groundnut was cleaned, sorted, roasted and winnowed. It was ground in a blender (USHA mixer grinder, Model: MG:2053 N) by mixing with water at the ratio of 3:8 (w/v) and the thin slurry obtained was sieved and boiled for 10 mins. Rice was cleaned, steeped in water for 8 hrs, drained and rinsed in potable water. Water was added to rice at a ratio of 1:4 (w/v), ground in a blender (USHA mixer grinder, Model: MG:2053 N) and boiled for 10 mins to obtain thin porridge. Groundnut and rice porridge were mixed together at a ratio of 4: 1 (v/v) and boiled for 30 mins (Modified method of Abdulrahaman *et al*., 2014). The mixture was divided into five portions and *Xylopia aethiopica* powder was added to the mixture at 0%, 2%, 3%, 5% and 7%. A- *Kunnu gyada* with no preservative; B- *Kunnu gyada* with 2% *Xylopia aethiopica* powder; C- *Kunnu gyada* with 3% *Xylopia aethiopica* powder; D- *Kunnu gyada* with 5% *Xylopia aethiopica* powder; E- *Kunnu gyada* with 7% *Xylopia aethiopica* powder. The mixtures were allowed to cool, dispensed into sterile plastic bottles and stored at refrigeration temperature (4°C).

https://doi.org/10.26656/fr.2017.9(2).043

2.4 Microbiological analysis

Kunnu gyada samples treated with 0%, 2%, 3%, 5% and 7% of *Xylopia aethiopica* powder were subjected to microbiological analysis during the period of storage. Total viable count, lactic acid bacteria count, and fungi count were assessed at 7-day intervals for 21 days using the pour plate method. Each *Kunnu gyada* sample (5 mL) was dispensed into a stomacher bag and homogenized with 45 mL of diluent (peptone water). Serial dilution was carried out, and the representative dilution was dispensed into a sterile petri dish. Molten agar was poured, and the petri dish was rocked gently clockwise and anticlockwise for even distribution of growth. The total viable count was enumerated using Nutrient Agar (NA), lactic acid bacteria using de Man Rogosa and Sharpe (MRS) Agar and fungi count using Potato Dextrose Agar (PDA) (Harrigan, 1998) and plates were incubated at 35°C for 24 hrs, 35°C for 72 hrs, and 25°C for 3 to 5 days, respectively (Harrigan, 1998). The colonies formed were counted using Gallenkamp colony counter and representative colonies were streaked on the appropriate agar and kept in the refrigerator for identification. All isolates were viewed under the microscope (Leica DM500 Model 13613210) to determine their size, shape and arrangement. Bacteria isolates were identified using cultural, morphological characteristics and biochemical tests. (Harrigan and McCance, 1976; Woods and Holzapfel, 1995). Yeasts in *Kunnu gyada* samples were isolated based on cultural characteristics, cell size, shape, arrangement, reproduction, and ability to assimilate carbon and nitrate (Barnett *et al.,* 2000). Mould isolates were identified using the cultural characteristics and microscopy characteristics such as spore head, hyphae and presence of special structures (Malomo *et al*., 2018).

2.5 Determination of total sugar

Anthrone reagent Method of Morris (1948), described by Malomo *et al*. (2021), was used for the determination of the total sugar content of *Kunnu gyada.* The filtrate (1 mL) was dispensed into the test tube, and 4 ml of anthrone reagent was added. The mixture was heated in a boiling water bath (Gallenkomp, HH-S6, England) for 10 min and rapidly cooled in cold water. Absorbance was read at 620 nm against a reference blank in a spectrophotometer (Spectrumlab 752S, YM1206PHB2, China). The quantity of sugar was extrapolated from the standard curve based on known concentrations of glucose (10-100 mg/L).

2.6 Sensory analysis

Coded samples of *Kunnu gyada* were presented to 20 panelists to score for colour, taste, aroma, flavour and overall acceptability using a 9-point Hedonic scale where 1 was the lowest score and 9 was the highest (Yangilar and Yildiz, 2017).

2.7 Statistical analysis

Data were analyzed using ANOVA on SPSS (17 incorporations Chicago, USA), Principal component analyses and Agglomerative Hierarchical Clustering were conducted using XLSTAT (2014).

3. Results and discussion

3.1 Microbial count of Kunnu gyada during storage

The total viable count (TVC) of *Kunnu gyada* is shown in Figure 1. The count generally increased from week 0 (0-3.28 CFU/mL) to week 2 (3.33 to 7.44 log CFU/mL) and decreased in week 3 (2.94-6.08 log CFU/mL). The results show that the TVC decreased with an increase in addition to *Xylopia aethiopica* and the count was highest in sample A with 0% *Xylopia aethiopica*) throughout refrigeration storage. There was no TVC at week zero in Sample D and E which contain 5% and 7% *Xylopia aethiopica* respectively at the beginning of storage. Anumudun *et al*. (2020) also reported no count in orange juice preserved with *Xylopia aethiopica* at the beginning of storage. The decrease in microbial load with an increase in the concentration of *Xylopia aethiopica* could be a result of antibacterial activity exerted by the chemical compound present in *Xylopia aethiopica* (Fleisher *et al*., 2008).

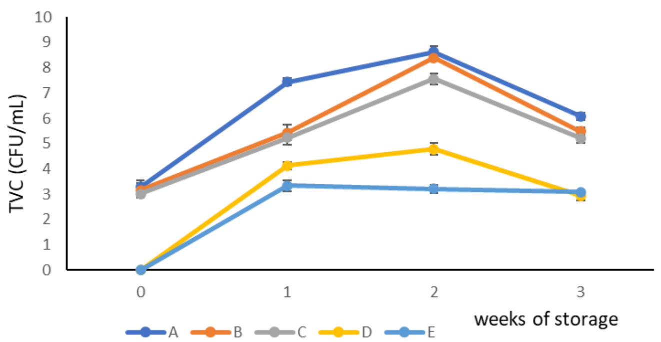

Figure 1. Changes in total viable count during storage of *Kunnu gyada*. The error bars indicate ± standard error.

Lactic acid bacteria (LAB) count decreased with an increase in the addition of *Xylopia aethiopica* powder (Figure 2). There were no viable lactic acid bacteria in Week 0 in samples B, C, D and E treated with *Xylopia aethiopica* but LAB started growing in these samples at week 1 (3.49-5.72 log CFU/mL) and progressed to week 3 (3.19-6.47 log CFU/mL). The higher the concentration of *Xylopia aethiopica* powder, the lower the LAB growth. The reduction in the growth of LAB in the samples may be due to the antibacterial activities of dried *Xylopia aethiopica* powder added to *Kunnu gyada* drink. This is in line with the report of Ogbonna *et al.* (2013) who reported the effectiveness of *Xylopia aethiopica* in inhibiting both spoilage and pathogenic bacteria. *Xylopia aethiopica* fruit has been reported to possess an anti-microbial effect against Gram-positive bacteria. *Xylopia aethiopica* seed powder has been an important ingredient in Nigerian traditional cuisines from time immemorial, especially in the preparation of Nigerian pepper soup which helps in the treatment of cough, fever and headache and also serves as an anti-inflammatory, antiplasmodial and antidiabetic agent (Jin *et al*., 2019; Onwuzuruike *et al*., 2023) It is also an essential flavour component in fermented cereal gruel and could be used as preservative in the paste because of its antimicrobial properties (Onwuzuruike *et al*., 2023).

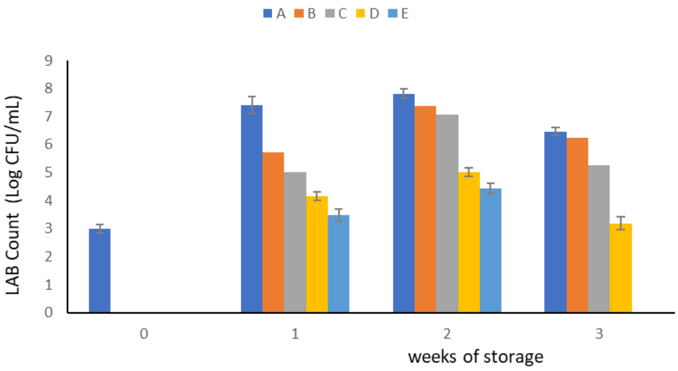

Figure 2. Changes in lactic acid bacteria count (LAB) during storage of *Kunnu gyada*. The error bars indicate ± standard error.

At the beginning of storage, the fungi count was higher in sample A which was not treated with *Xylopia aethiopica* powder (Figure 3). There was no count in Samples D and E containing 5% and 7% *Xylopia aethiopica* powder respectively at week zero. This could be due to the inhibitory action of *Xylopia aethiopica* against fungi such as *Aspergillus, Fusarium* and *Penicillium* as reported by Chinonye *et al*. (2022).

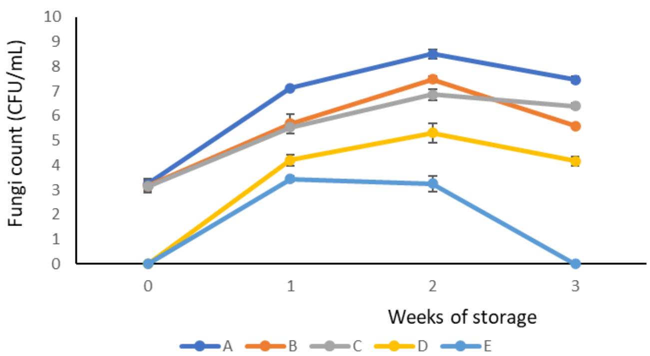

Figure 3. Changes in fungi count during storage of *Kunnu gyada.* The error bars indicate ± standard error.

3.2 Identification of microorganisms in Kunnu gyada

Microorganisms isolated from *Kunnu gyada* are *Micrococcus luteus, Lactobacillus plantarum, Pseudomonas fluorescens, Bacillus subtilis, Candida albicans*, *Kluyveromyces marxianus, Aspergillus niger* and *Fusarium oxysporus* (Figure 4). The population of these organisms decreased with an increase in the concentration of *Xylopia aethiopica* powder.

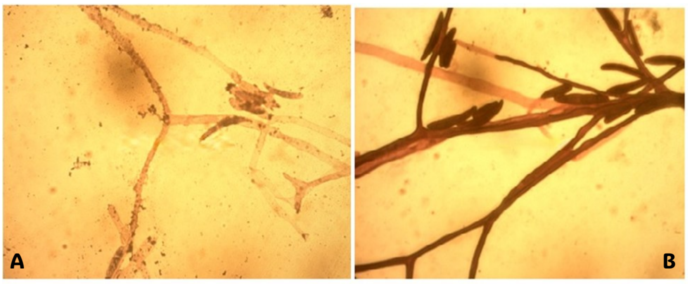

Figure 4. Pictures of *Fusarium oxysporum* isolated from *Kunnu gyada* without *Xylopia aethiopica* (Magnified 600×). A. *Fusarium oxysporum* with hyphae that has lost some cell constituent, B. *Fusarium oxysporum* with true hyphae.

Lactobacillus plantarum was present in all *Kunnu gyada* samples throughout storage and it was the most prominent bacteria. *Bacillus subtilis* was present in samples A and B and *Pseudomonas fluorescens* were only present in sample A. Inhibition of bacteria by *Xylopia aethiopica* could be due to the

action of mono- and ses-quiterpene hydrocarbons that are present in *Xylopia aethiopica* on the bacteria (Karioti *et al*., 2004). *Xylopia aethiopica* extract has been reported to have inhibitory effect on *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus faecalis*, *Pseudomonas* and *Bacillus subtilis* and some *Lactobacilli* at low concentrations (Ijeh *et al*., 2005; Ogbonna *et al*., 2011; Chinonye *et al*., 2022).

Candida albicans and *Kluyveromyces marxianus* were present in all *Kunnu gyada* samples throughout storage but their population decreased with an increase in the concentration of *X. aethiopica*. *Fusarium oxysporum* was the least as it was only isolated from sample A accounting for 8% of total microorganisms. *Aspergillus niger* was present in samples A and B throughout storage but was not detected in samples C, D and E. This shows that *Xylopia aethiopica* is effective against *Fusarium oxysporum*. The presence of *Fusarium oxysporum*; a mycotoxin-producing mould has been reported in groundnut and groundnut products such as kulikuli, donkwa, peanut butter, yaji and roasted groundnut (Odeniyi *et al*., 2019). *Aspergillus*, *Penicillium* and *Fusarium* have been reported to be the most dominant mould in rice (Nagede *et al*., 2022). It was reported that the essential oil of *Xylopia aethiopica* acts as an antifungal and it is effective against *Fusarium* and *Aspergillus* (Ogbonna *et al*., 2011).

https://doi.org/10.26656/fr.2017.9(2).043

3.3 Total sugar content of Kunnu gyada

Table 1 shows the total sugar content of *Kunnu gyada*. The range of total sugar was between 25.68 and 50.85 mg glucose/mL and generally decreased in all samples during the period of storage. *Xylopia aethiopica* did not have a significant effect ($p<0.05$) on the samples at week 0 but did from week 1 to week 3. It was highest in sample A which had no *Xylopia aethiopica* powder (44.81-50.85 mg glucose/mL) and lowest in sample E which contained 7% *Xylopia aethiopica* powder (34.88-50.57 mg glucose/mL) throughout storage. The addition of *xylopia aethiopica* generally reduced the total sugar content probably due to the dilution factor. *Xylopia aethiopica* contains high levels of phytochemicals such as tannin that are associated with astringency and bitterness (Ma *et al.,* 2014). The decrease in total sugar during storage may be due to the activities of the microorganisms that break down sugar into organic acids such as lactic acid and acetic acid (Adepoju *et al*., 2016; Malomo *et al*., 2021).

3.4 Principal component analysis of the sensory properties of Kunnu gyada

The principal component analysis (PCA) categorized the sensory parameters into four principal components with PC1 having the highest variability of 98.68% followed by PC2 with 0.88% (Figure 5). The Biplot showed that sample A had the highest score for taste (7.60), texture (7.53), thickness (7.70), Appearance (8.13), colour (8.27) and overall acceptability (8.13) followed by sample B. Samples A and B are represented on the positive axis of PC1 while C, D and E are represented on the positive axis of PC2. Sample C only had a positive correlation with appearance, and thickness but had a negative correlation with taste, colour and overall acceptability. The plot also showed that samples D and E had a negative correlation with all the sensory parameters. This showed that the addition of *Xylopia aethiopica* powder to *Kunnu gyada* reduced the scores for sensory parameters. The strong aroma which could be objectionable to some people in some food could be considered as the limitation of these spices (Ogbonna *et al*., 2013).

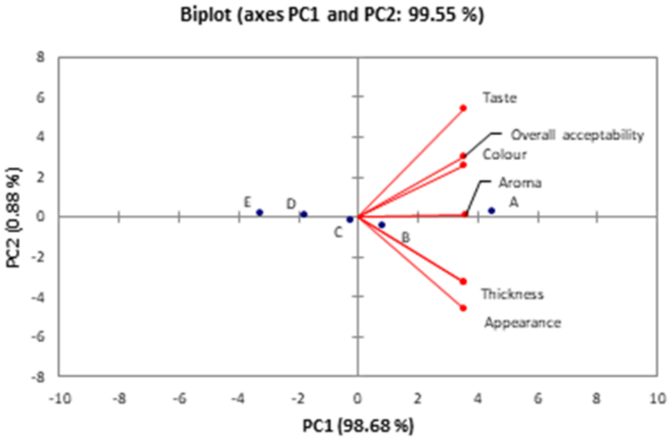

Figure 5. Principal component analysis of the sensory properties of *Kunnu gyada.*

4. Conclusion

The use of *Xylopia aethiopica* powder as a bio-preservative in *Kunnu gyada* at 2% and 3% concentration extends its shelf life with minimum effect on the sensory characteristics. It also ensures the safety of this product by inhibiting toxin-producing *Fusarium oxysporum*. This could increase the production of *Kunnu gyada* on a commercial basis and empower women who are the major producers. Production of *Kunnu gyada* in large quantities will reduce malnutrition and provide a cheap and accessible nutritious diet for both children and adults.

Conflicts of interest

The authors declare no competing interests.

Acknowledgments

We would like to thank the Food Microbiology Unit of the Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife.

References

Abdulrahaman, A.A., Olayinka, B.U., Andrauwus, Z.D., Aluko, T.A., Adebola, M.O. and Oladele, F.A. (2014). Traditional Preparations and Uses of Groundnut in Nigeria. *Annals. Food Science Technol*ogy, 15(1), 29-34.

Adepoju, A.A., Abiose, S.H. and Adeniran, H.A. (2016).

Table 1. Total sugar content of *Kunnu gyada.*

Samples	0	1	2	3
A	50.85±0.42^a	49.52±0.14^a	51.27±0.10^a	44.81±0.14^a
B	50.83±0.17^a	45.52±0.17^b	46.29±0.3\`^{b}	36.52±0.57^b
C	50.83±0.28^a	44.89±0.25^c	46.62±0.54^b	36.33±0.30^b
D	50.74±0.23^a	43.63±0.48^d	43.98±0.28^c	36.26±0.14^b
E	50.57±0.40^a	43.55±0.18^d	43.27±0.16^c	34.88±0.10^c

Values are presented as mean±standard error of triplicate. Values with different superscripts in the same column are statistically significantly different ($p<0.05$).

Effect of Pasteurisation and Selected Chemical Preservatives on Chemical Composition of *Fura de Nunu* during Storage. *African Journal of Food Science Technology,* 7(8), 178-185. https://doi.org/10.14303/ajfst.2016.102

Anumudu, C.K., Okolo, C.A., Ezembu, E.N., Anumudu, I.C., Opara, C.N., Omeje, F.I., Ikimi, C.G., Gbodo, E.E., Zige, D.V., Okpe, C.U. and Ekwueme, D.C. (2020). Biopreservative Potential of the Spices; Piper Guineense (Uziza), *Xylopia aethiopica* (Uda) and *Tetrapleura tetraptera* (Oshorisho) in Fresh Fruit Juices. *Journal of Food Technology and Nutrition Science*, 2(2), 1-6. https://doi.org/10.47363/JFTNS/2020(2)108

Bolarinwa, I.F., Olaniyan, S.A., Abdul-Hammed, M. and Oke, M. (2015). Production and quality evaluation of Kunun-zaki (A Nigerian fermented cereal beverage) from Millet and *Vigna acemosa* blends. *Journal of Chemical and Pharmaceutical Research,* 7(9), 347-352.

Barnett, J.A., Payne, R.W. and Yarrow, D. (2000). Yeasts: Characteristics and Identification. 3rd ed. Cambridge, UK: Cambridge University Press,

Bao, J. and Bergman, C.J. (2004). The functionality of rice starch. In Eliasson, A.C. (Ed.). Starch in Food. Florida, USA: CRC Press. https://doi.org/10.1201/9781439823347.ch9

Chinonye, I.R., Adanna, U.A., Christopher, A., Bilah, A., Obiagwu, I., Uchenna, O.L. and Anozie, R.C. (2022). Chemical and Medicinal Properties of *Xylopia aethiopica* Harvested from The South Eastern Nigeria. *Chemical and Pharmaceutical Research*, 4(1), 1-9. https://doi.org/10.33425/2689-1050.1027

Elsamani, M.O. and Ahmed, I.M. (2014). Physicochemical characteristics and organoleptic properties of peanuts milk-based yoghurt fortified with skimmed milk powder. *Journal of Research and Applied Science,* 1(4), 68-72.

Essien, E., Monago, C. and Edor, E. (2009). Evaluation of the nutritional and microbiological quality of *kunu* (A cereal based non-alcoholic beverage) in Rivers state, Nigeria. *The International Journal of Nutrition Wellness*, 10, 2.

Fleisher, T.C., Mensah, L.K., Mensah, A.Y., Komlagar., G.K., Gbedema, S.Y. and Skaltsa, H. (2008). Antimicrobial activity of essential oils of *Xylopia aethiopica*. *Complementary and Alternative Medicines*, 5(4), 391-393. httpss://doi.org/10.4314/ajtcam.v5i4.31295

Gaffa, T., Jideani, I.A. and Nkama, I. (2002). Traditional production, consumption and storage of *Kunnu* a non-alcoholic cereal beverage. *Plant Foods and Human Nutrition,* 57(1), 73-81. https://doi.org/10.1023/A:103129307086

Halilu, M., Yunusa, B.M. and Ghazali, H.M. (2022). Consumer Preference and Storage Stability Assessment of Drum Dried-Maltodextrin Added *Kunnu-gyada* Powder. *East African Scholar Journal of Nutrition and Food Science,* 4(1), 1-7. https://doi.org/10.36349/easjnfs.2022.v04i01.001

Harrigan, J.R. and McCance, M. (1976). Laboratory Methods in Food and Dairy Microbiology. London, UK: Academic Press.

Harrigan, W.F. (1998). Laboratory Methods in Food and Dairy Microbiology. San Diego, California: Academic Press.

Imo, C., Yakubu, O.J., Imo, N.J., Udegbunam, I.S. and Onukwugha, O.J. (2018). Chemical composition of *Xylopia aethiopica* fruits. *American Journal of Physiology, Biochemistry and Pharmacology*, 7(2), 48-53. https://doi.org/10.5455/ajpbp.20180521064020

Karioti, A., Hadjipavlou-Litnia, S.J., Mensah, M., Fleischer, T.C. and Skalltsa, H. (2004). Composition and antioxidant activity of the essential oils of *Xylopia aethiopica* (Dun) A. Rich. (Annonaceae) leaves, stem bark and fresh and dried fruits growing in Ghana. *Journal of Agriculture and Food Chemistry*, 52(26), 8094-8098. https://doi.org/10.1021/jf040150j

Ma, W., Guo, A., Zhang, Y., Wang, H., Liu, Y. and Li, H. (2014). A review on astringency and bitterness perception of tannins in wine. *Trends in Food Science and Technology,* 40(1), 6-19. https://doi.org/10.1016/j.tifs.2014.08.001

Malomo, A.A., Abiose, S.H. and Adeniran, H.A. (2018). Microbiological Changes during the Production of Maize-Acha *Masa* Fortified with Soybean. *Annals. Food Science and Technology,* 19(2), 349-357.

Malomo, A.A. and Abiose, S.H. (2019). Protein quality and functional properties of *masa* produced from maize, *acha* and soybean. *Food Research,* 3(5), 556-563. https://doi.org/10.26656/fr.2017.3(5).223

Malomo, A.A., Abiose, S.H. and Adeniran, H.A. (2019). Effects of Substitution of *Acha* and Soybean on Alpha amylase Activity, Sugars and Total Free Amino Acid during Production of Maize *Masa.* *Journal of Microbiology, Biotechnology and Food Science*, 9(3), 534-538. https://doi.org/10.15414/jmbfs.2019/20.9.3.534-538

Malomo, A.A. and Abiose, S.H. (2020). Effect of substitution of *acha* (*Digitaria exilis*) and soybean on the chemical composition and sensory properties of maize *masa. Croatian Journal of Food Science and Technology,* 11(2), 101-109. https://doi.org/10.17508/CJFST.2020.12.1.13

Malomo, A.A., Olawoye, B., Olaniran, A.F., Olaniyi, O.I., Adedoyin, A. and Adeniran, H.A., Abiose, S.H. (2021). Evaluation of sugar and free amino acid during fermentation of *ogi* from maize, *acha* and sorghum. *Food Science and Applied Biotechnology*, 4(2), 111-118. httpss://doi.org/10.30721/fsab2021.v4.i2

Marcel, K.K., Akhanovna, M.J., Yves-Alain, B., Gabin, D.B. and Jérôme, Z.B. (2010). *In vitro* antioxidant activities of total fla-vonoids extracts from leaves and stems of *Adenia lobata* (Jacq.) Engl. (Passifloraceae). *Journal of Pharmacognosis and Phytotherapy*, 3(1), 8-12.

Nagede, N.D., Alponse, S.T., Eliane, T.S., Thierry Marcel, N.B., Francky Steve, N.S., Nikaise Forestine, D.N. and Leopold, T.N. (2022). Fungi diversity and occurrence in Aflatoxin B1, citrinine and ochratoxin A in rice of Cameroon. *Journal of Food Processing and Preservation,* 46(4), e16429. https://doi.org/10.1111/jfpp.16429

Odeniyi, O., Ojo, C., Adebayo-Tayo, B. and Olasehinde, K. (2019). Mycological, Toxigenic and Nutritional Characteristics of Some Vended Groundnut and Groundnut Products from Three Northern Nigerian Ecological Zones. *African Journal of Biomedical Research,* 22(1), 65-71.

Ogbonna, I.O., Opobiyi, M.Y., Katuka, B. and Waba, J.T. (2011). Microbial Evaluation and Proximate Composition of Kunuzaki, an Indigenous Fermented Food Drink Consumed Predominantly in Northern Nigeria. *Internet Journal* of *Food Safety,* 13(1), 93-97. https://doi.org/10.5897/AJB2012.2938

Ogbonna, C.N., Nozaki, K. and Yajima, H. (2013). Antimicrobial activity of *Xylopia aethiopica*, *Aframomum melegueta* and *Piper guineense* ethanolic extracts and the potential of using *Xylopia aethiopica* to preserve fresh orange juice. *African Journal of Biotechnology*, 12(16), 1993-1998. https://doi.org/10.5897/AJB2012.2938

Oko, A.O. and Ugwu, S.I. (2011). The proximate and mineral compositions of five major rice varieties in Abakaliki, South-Eastern Nigeria. *International Journal of Plant Physiology and Biochemistry*, 3(2), 25-27.

Onwuzuruike, A.U., Chima, G.U. and OKwunolodu, F.U. (2023). Functional properties of *uda* (*Xylopia aethiopica*) and *uziza* (*Piper guineeses*) spiced *akamu* powder correlated with the paste proximate composition intended for Nigerian postnatal mothers. *Cogent Food and Agriculture*, 9(2), 2271237 . https://doi.org/10.1080/23311932.2023.2271237

Özcan, M.M. (2010). Some nutritional characteristics of kernel and oil of peanut (*Arachis hypogaea* L.). *Journal of Oleo Science*, 59(1), 1-5. https://doi.org/10.5650/jos.59.1

Prasad, P.V., Kakani, V.G. and Upadhyaya, H.D. (2010). Growth and production of peanut. In Encyclopedia of life support. Oxford, UK: EOLSS Publishers, Oxford, U.K.

Sosanya, M.E., Freeland-Graves, J.H., Gbemileke, A.O., Adeosun, F.F., Samuel, F.O. and Shokunbi, O.S. (2021). Characterization of Traditional Foods and Diets in Rural Areas of Bauchi State, Nigeria: Analysis of Nutrient Components. *European Journal of Nutrition and Food Safety*, 13(7), 1-16.

Woods, B.J.B. and Holzapfel, W.H. (1995). The Genera of Lactic Acid Bacteria*.* Vol. 2. New York, USA: Springer. https://doi.org/10.1007/978-1-4615-5817-0

World Health Organisation (WHO). (2002). World Health Report: Reducing Risks, Promoting Healthy Life. Retrieved from WHO website: https://www.who.int/publications-detail-redirect/9241562072

Yadachi, S, Nagajjanavar, K., Desai, S., Reddy, M. and Mahawa, M.K. (2012). Preparation of groundnut milk and its qualitative analysis. *Environmental Ecology,* 30(3c), 1209-1211.

Yangilar, F. and Yildiz, P.O. (2017). Effects of using combined essential oils on quality parameters of bio-yogurt*. Journal Food Processing and Preservation,* 42(1), e13332. https://doi.org/10.1111/jfpp.13332

