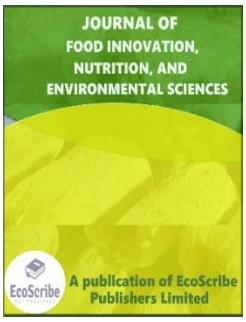
Journal of Food Innovation, Nutrition, and Environmental Sciences
May, 2026, Volume 3; Issue 2:191-199
ISSN No:3078-5537




ORIGINAL RESEARCH ARTICLE

# A Study on Preservative Effect of Ginger (Zingiber Officinale) Extract on the Nutritional Quality and Shelf Life of Tigernut-Acha Non-Dairy Drink

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**DOI:** https://doi.org/10.70851/jfines.2026.3(2).191.199

## ABSTRACT

This study focused on the preservative effect of aqueous ginger extract on the nutritional quality and shelf life of tigernut-*acha* non-dairy drink. Tigernut and *acha* are underutilized tuber and cereal respectively. These agricultural products are known for their nutritional content such as fiber, minerals, vitamins and natural sugar and potential health benefits. Incorporating aqueous ginger extract into this non-dairy beverage serves as a natural preservative and also helps maintain its nutritional content during storage. Non-dairy beverage was produced from tigernut and *acha*. aqueous ginger extract (1 - 3%) was added to the drinks. All the samples were stored for 3 weeks at 4 °C. During the storage period, the total viable count (TVC), lactic acid bacteria count, and fungal count ranged from an initial value of 0.70 to 2.00 log CFU/mL and final value of 2.06 to 2.90 log CFU/mL, 1.90 to 3.14 log CFU/mL and 1.00 to 3.10 log CFU/mL respectively. Also, the percentage titratable acidity (TTA) and pH values of the drinks varied from 0.29 to 0.75 % and 3.27 to 5.56. *Staphylococcus aureus*, *Bacillus subtilis, Escherichia coli* and *Pseudomonas aeruginosa* were probable organisms identified with the spoilage of tigernut-*acha* drinks during storage. The result of this study showed that aqueous ginger extract inhibited microbial growth in the tigernut-*acha* drink. This is an indication that aqueous ginger extract can serve as a preservative for tigernut and *acha* drink.

**Article history**
*Received;*
*28 January, 2026*
*Revised;*
*07 May, 2026*
*Accepted;*
*01 June, 2026*

**Keywords**
Aqueous ginger extract,
Acha,
Tigernut,
Preservation,
Shelf-life

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Peer review under responsibility of Journal of Food Innovations, Nutrition, and Environmental Sciences.

A Publication of EcoScribe Publishers company Limited, Uganda.

## 1. INTRODUCTION

Preservation of food is crucial in order to ensure food security and safety. Today, consumers are more aware of what they eat, where what they eat comes from and how it impacts their health and well-being (Chauhan and Rao, 2024). However, food products such as beverages are highly perishable due to their rich nutrient composition and high moisture content, which create favourable conditions for microbial spoilage and chemical degradation (Shankar *et al*., 2021).

Over the years, synthetic preservatives have been used in various food industries in combatting the challenge of spoilage, but with growing health concerns, consumers are shifting towards natural preservatives rather than chemical additives (Shi *et al*., 2024). Plant based preservatives have been increasingly exploited because they are natural, generally regarded as safe, contain bioactive compounds and rich in antimicrobial and antioxidant properties. Ginger (*Zingiber officinale*) is an example of plant-based preservatives, which is rich in bioactive compounds like shogaol, gingerol and zingerone. Asides its preservative effect, it helps in treating gastrointestinal disorders such as nausea, constipation and indigestion (Yusuf *et al*., 2024). Although numerous studies have confirmed the antimicrobial and antioxidant effects of ginger in fruit juices and some plant-based beverages, its ability to extend the shelf-life of cereal-tuber based drinks such as tigernut- *acha* has not been fully explored.

Tigernut is an underutilized tuber which is known for its nutritional content such as carbohydrates, fiber, minerals, vitamins and natural sugar (Haoua *et al*., 2023). It does not contain lactose sugar which makes it suitable for lactose intolerant people. However, the drink is deficient of sodium, casein protein, gluten and cholesterol (Ogbonna *et al*., 2013). Drink from *acha*, which is also known as "hungry rice" or "fonio", has been gaining attention due to its nutritional value and potential health benefits.

*Acha* is a nutritious grain that is a good source of essential amino acids, vitamins, and minerals. Traditionally consumed as a food staple in West Africa, particularly in countries like Nigeria, Togo, and Mali, *acha* has also been used to produce a refreshing and nutritious beverage (Dansi *et al*., 2010; Ballougou *et al*., 2013). The combination of tigernut and *acha* in the production of non-dairy beverage gives a drink that is both functional and nutritional. However, tigernut-*acha* drink has high moisture content and it is rich in nutrient. It is highly susceptible to microbial spoilage, thereby reducing its shelf life. Incorporating aqueous ginger extract into this non-dairy beverage serves as a natural preservative and also helps maintain its nutritional content during storage. Therefore, this study focuses on the preservative effects of aqueous ginger extract on the nutritional quality and shelf-life of tigernut-*acha* drink.

## 2. MATERIALS AND METHODS

### 2.1 Sample collection

Different varieties of tigernut tubers, *acha* grains, and ginger were purchased from the central market, Ile-Ife in Nigeria. The chemicals and equipment that were used for the analyses are of analytical grade and was obtained from the Food Microbiology, Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife Osun state Nigeria.

### 2.2 Sample preparation

The tigernut was prepared by first sorting the tuber and the *acha* grain. The ginger was also sorted and the skin was peeled. Foreign materials and bad/rotten seeds which may affect the taste and quality of the drink were removed. Samples were washed with potable water and then used to produce the milk analogue.

#### 2.2.1 Tigernut milk extraction

For the tigernut milk extraction, 800 g of oven-dried tigernut were soaked in covered vessel with 550 mL of water for 12 hours. The nuts were milled in a blender with fresh water (twice the new weight of tubers after soaking) at high speed for 5 minutes. The milk was extracted manually by pressing it with hand through a cheesecloth (Belewu and Abodunrin, 2008).

#### 2.2.2 Processing of *acha* starch

The starch from *acha* grains was processed using the method outlined by Kunle *et al.* (2003). The chaff, stones and other unnecessary debris were manually removed from the *acha* grains to obtain clean grains. After this, the *acha* grains were soaked in water at 28 ºC for 24 h. The enlarged grains were then washed with water and milled. After milling, the obtained slurry was filtered through muslin cloth and dried at ambient temperature (28 ºC). A blender was used to ground the dry starch cake into a fine powder.

#### 2.2.3 Processing of aqueous ginger extract

Aqueous ginger extract was produced using the method described by Gbodi *et al.* (2002). The procured raw gingers were graded and washed. Cleaned ginger was peeled and oven-dried at 60 °C for 4 hours (with moisture content < 5%) and ground in a Philip Grinder (HL 1631/00, Voltage 230 V ~50 Hz, China). The powder obtained was sieved through mesh size of 600 µm to remove the chaff and residues. Then 1.5 L of distilled water was mixed with 100 g of the powder and stirred using the magnetic stirrer. The slurry was sieved using a muslin cloth to obtain aqueous ginger extract.

### 2.2.4 Tigernut and *acha* drink production

Tigernut-*acha* drink was produced using 85 g of tiger nut milk and 15 g of *acha* starch. aqueous ginger extract (1%, 3% and 5%) was added to the drink. The resultant mixture was homogenized for 10 minutes. One hundred percent (100%) tigernut milk served as the negative control while tigernut-*acha* drink with no preservative served as the positive control. The products were pasteurized at 75 °C for 15 minutes and then cooled.
Samples of the tigernut-*ach*a drink (labelled as sample M, L, N, P and T) were portioned into twelve 750 mL PET bottles each and stored at 4 °C. Each independent portion (3 bottles for each sample) was brought out and opened weekly for microbial and physicochemical analyses. The samples were kept for 3 weeks. Analyses of the samples were carried out in triplicates

### 2.3 Microbial analysis

Five grams (5 g) of each sample was homogenized in a stomacher and serial dilution of the samples were carried out. One millilitre (1 mL) of the mixture was diluted approximately. The representative dilution of 1 mL was dispensed into the petri dish and 20 mL of molten agar at 45 °C was poured and swirled in clockwise and anticlockwise direction to ensure even mixing. The plates were incubated at 35 °C for the total viable count for 24 h using nutrient agar and lactic acid bacteria count for 72 h using MRS agar respectively. For yeast and mould count, 1 mL of the diluent was cultured on potato dextrose agar (PDA) and incubated at 28 °C for 3 – 5 days. The colonies that were formed were reported in colony forming unit per millilitre (CFU/mL) and distinct colonies were streaked to obtain pure isolates. The pure isolates obtained were identified using cultural, morphological and biochemical characteristics (Harrigan, 1998).

### 2.4 Physicochemical Properties

The pH and titratable acidity of the milk samples were determined on weekly basis.

### 2.4.1 pH

Each sample (20 mL) was poured into beaker and pH was determined using pH meter after standardization with buffer solutions having pH 4 and 7 according to the AOAC (2000). The pH values were recorded.

### 2.4.2 Titratable acidity (TTA)

Each sample (10 mL) was dispensed into a conical flask and then diluted with 10 mL of distilled water and stirred to homogenize the sample. Two drops of phenolphthalein indicator was added to the solutions and then titrated against 0.1 N NaOH until the solution colour changes to pink (AOAC, 2000). Titratable acidity value was calculated as:

$$\%\ Lactic\ Acid = \frac{(\text{Volume of NaOH}) \times 0.1 \times 0.09 \times 100}{Volume\ of\ sample}$$

### 2.5 Proximate Analysis

### 2.5.1 Moisture Analysis

According to AOAC (2012), two grams (2 g) of each sample was dried in a conventional oven at 105 °C for 4 h until a constant weight was achieved. After drying, the samples were allowed to cool in a desiccator, and the dry weight of each sample plus the dish was measured. The percentage loss in weight was calculated and reported as the moisture content. The percentage moisture content of the sample was calculated using the formula in Equation 1

$$\textbf{MC}\ (\%) = \frac{M_1 - M_2}{M_1 - M_0} \times 100$$

(*Equation 1*)

Where: $M_0$ = weight of dish (g), $M_1$= weight of dish and sample before drying (g)
$M_2$ = weight of dish, and sample after drying (g), M C = Moisture content, %

### 2.5.2 Determination of ash content

Three grams (3 g) of the sample was weighed and placed into an empty, cleaned and dried porcelain crucible. The crucible with the sample was placed in the muffle furnace and heated at 600 °C for 4 h until the sample turned into ash. Afterward, the crucible containing the ash residue was allowed to cool in a desiccator for a few minutes and weighed (according to AOAC, 2012). The ash content was calculated as follows (Equation 2):

$$\textbf{Ash}\ (\%) = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

(Equation 2)

Where $W_1$= weight of empty crucible (g), $W_2$ = weight of crucible + sample before drying ashing $W_3$= weight of crucible + ash

### 2.5.3 Crude fiber determination

Three grams (3 g) of the sample was placed in a 250 mL conical flask as $W_1$. Next, 200 mL of 1.25% $H_2SO_4$ was added, and the solution was brought to the boiling point within one minute. The mixture was gently boiled for 30 min while rotating the flask every minute to ensure proper mixing and removal of particles from the sides. After boiling, the mixture was allowed to cool for 1 minute before being filtered through muslin cloth stretched over a 9 cm burner funnel. The filtered mixture was rinsed with distilled water multiple times to remove acidity. The residue was scraped back with a spatula, and 200 mL of 1.25% sodium hydroxide was added. The resulting solution was boiled for 30 min, and the solution obtained was filtered and

thoroughly washed with hot distilled water, rinsed once with 10% HCl, four times with hot distilled water, and twice with petroleum ether. The drained residue was scraped into a crucible, dried in an oven at 105 °C, cooled in a desiccator, and weighed as $W_2$. The dried sample was later transferred into a muffle furnace and ashed at 450 °C for 5 h. After ashing, the sample was cooled in a desiccator and weighed as $W_3$ (AOAC, 2012).
The calculation for crude fiber is as follows (Equation 3)

$$\textbf{Crude fibre } (\%) = \frac{W_2 - W_3}{W_1} \times 100$$

(Equation 3)

Where; $W_2$ = weight of the oven dried residue, g; $W_3$ = weight of the residue after ashing, g; $W_1$ = weight of the sample, g

### 2.5.4 Determination of fat

Fat content was determined according to the method described by AOAC (2012). Three grams (3 g) of the sample was weighed and placed into a thimble, which was fixed onto the soxhlet extractor. N-hexane was used as the solvent and poured into a round-bottom flask, which was fitted and positioned on a heating mantle. The extraction of fat commenced as the solvent refluxed. The extraction process continued for approximately 6 h, after which the flask was allowed to cool and disconnected from the apparatus. The weight of the extracted content was subtracted from the initial weight of the sample. The percentage fat was calculated on a wet basis, as illustrated in Equation 4.

$$\textbf{Fat } (\%) = \frac{\textit{Weight of oil}}{\textit{Weight of sample}} \times 100$$

(Equation 4)

### 2.5.5 Determination of protein

Protein content was determined according to the method described by AOAC (2012). The Kjeldahl method wasused to determine the quantity of nitrogen in the sample. Two grams (2 g) of the sample was placed into the flask, 10 mL concentrated $H_2SO_4$ was added followed by 1 g each of $K_2SO_4$ and $CuSO_4$ to decompose the organic substances through oxidation, liberating reduced nitrogen as ammonium sulfate. The sample was digested inside a fume cupboard for 45 minutes until the mixture turned colourless. After cooling the digested sample, it was diluted with a small quantity of ammonia-free distilled water and transferred to the distillation apparatus into which 10 mL of NaOH solution will be added. The digested sample was steam-distilled for five minutes and the liberated ammonia was collected into 25 mL of 4% boric acid solution containing 4 drops of bromocresol green/methyl red indicator. The liberated ammonia (which represented total nitrogen) was latere titrated immediately against standard $H_2SO_4$ (1 mL of 0.1N $H_2SO_4$ acid, which was equivalent to 1.401 mg N). The average value obtained from the titration represented the nitrogen content in the sample. The protein content was calculated by multiplying the percentage of nitrogen by 6.25 according to AOAC (2012)

$$\textbf{Nitrogen } (\%) = \frac{\textit{Volume of acid} \times \textit{Molarity of acid} \times \textit{Atomic mass of Nitrogen}}{\textit{Weight of sample}}$$

(Equation 5)

$$\textbf{Protein } (\%) = N \times 6.25$$

(Equation 6)

### 3.2.6 Determination of carbohydrate

The carbohydrate (CHO) content in each sample was determined by difference.

**Carbohydrate** (%) = 100 - (% Protein + % Fat + % Crude fibre + % Moisture content)

(Equation 7)

### 2.6 Sensory evaluation

Freshly prepared tigernut-acha drink samples were coded and presented randomly to 20 semi trained panelists in the sensory laboratory of the Department of Food Science and Technology, Obafemi Awolowo University to evaluate each sample for appearance, aroma, colour, flavour, mouthfeel, taste, thickness and overall acceptability. The panelists were asked to rate the samples using 9-point Hedonic Scale. Scale 1 means 'dislike extremely' and 9 means 'like extremely' (Alebiosu, 2024). A consent form was given to each panelist to give detailed information about the products and acceptance to participate was obtained before proceeding with the analysis.

### 2.7 Statistical Analysis

All data collected were subjected to analysis of variance (ANOVA), and when significant difference was found, comparisons among mean difference were computed using Duncan's Multiple Comparison Range Test. Probability level was maintained at 0.05 (confidence limit). Least significant difference tests (LSD) were used to determine significance within the mean of the samples.

## 3. RESULTS AND DISCUSSION

### 3.1 Microbial count

The total viable count and fungal count of tigernut samples with or without *acha* starch during refrigerated storage is presented as follows:

### 3.1.1. Total viable count of the Tigernut – *acha* drink

**Figure 1** shows the total viable count (TVC) of tigernut – *acha* drink stored at refrigeration conditions. The microbial load of all samples generally increased during the storage period. The initial TVC ranged from 0.70 to 2.00 log CFU/mL. Tigenut milk (sampe L) and tigernut-*acha* drink with 1% aqueous ginger extract (sample N) had the lowest initial TVC (0.70 log CFU/mL) while tigernut-*acha* drink

without preservative (sample M) had the highest initial TVC (2.00 log CFU/mL). At the end of storage, the TVC ranged from 2.06 to 2.90 log CFU/mL. Tigernut-*acha* drink that had 1% aqueous ginger extract had the lowest TVC (2.06 log CFU/mL) after storage for three weeks. Addition of 1% aqueous ginger extract had a positive effect in reducing the microbial load. This could be due to the presence of bioactive compounds such as gingerol and shogaols (Brum *et al.,* 2020).

The microbial load of Samples M and T showed a progressive increase from week 0 to week 3. This trend indicates ongoing starch degradation, whereby starch acts as a readily available nutrient substrate that supports microbial proliferation, thereby accounting for the rise in total viable counts during the early storage period (Miao & Hamaker, 2021).

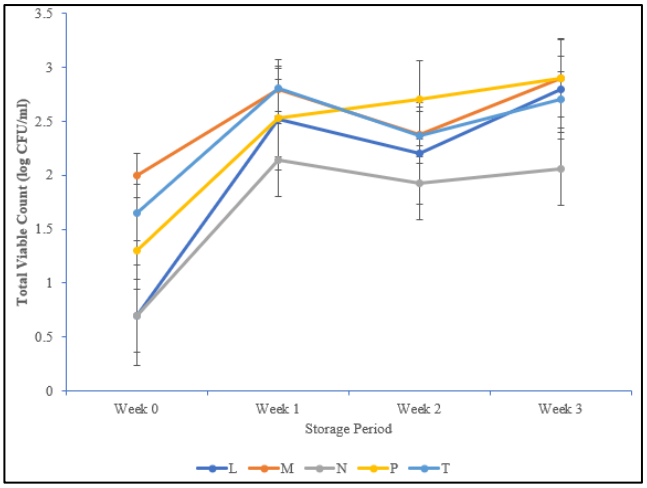


**Fig. 1.** The total viable count (TVC) of tigernut – acha drink stored at refrigeration conditions. L - Tigernut milk; M - Tigernut-acha drink; N – Tigernut-acha drink with 1% aqueous ginger extract; P – Tigernut-acha drink with 3% aqueous ginger extract; T – Tigernut-acha drink with 5% aqueous ginger extract

### 3.1.2 Lactic acid bacteria count of the tigernut – *acha* drink

**Figure 2** shows the lactic acid bacteria count obtained from the tigernut – *acha* drink samples stored at refrigerated temperatures (4 ± 2°C) over a period of 21 days. The initial lactic acid bacteria count ranged from 1.77 to 2.18 log CFU/ml with the drink with 1% aqueous ginger extract (Sample N) having the lowest initial lactic acid bacteria count. Athe end of the storage, sample N had the lowest LAB count and tigernut milk (Sample L) had the highest LAB count (3.14 log CFU/mL). Throughout the storage period, all samples exhibited an increase in lactic acid bacteria. The minimal changes in LAB count observed in the drink with 1% aqueous ginger extract could be an indication of the anti-microbial activities of some compounds in ginger (such as zingerone) (Malomo and Abiose, 2020).

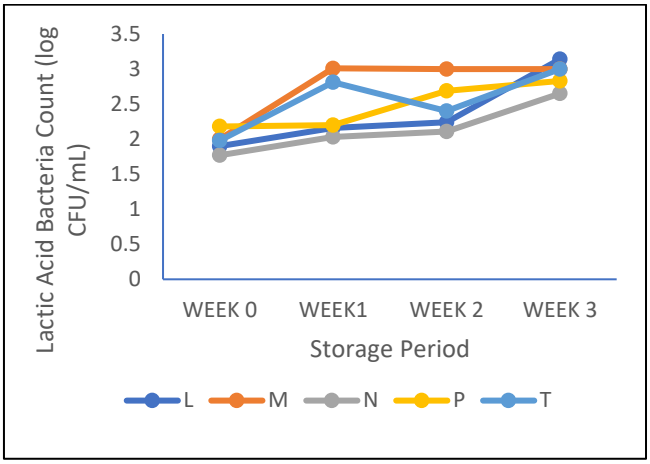


**Fig. 2.** Lactic acid bacteria count of tigernut – *acha* drinks
Keys: L - Tigernut milk; M - Tigernut-*acha* drink; N – Tigernut-*acha* drink with 1% aqueous ginger extract; P – Tigernut-*acha* drink with 3% aqueous ginger extract; T – Tigernut-*acha* drink with 5% aqueous ginger extract

### 3.1.3 Total fungal count of the tigernut – *acha* drinks

**Figure 3** shows the fungal count of tigernut – *acha* samples stored at refrigeration temperature (4 ± 2°C) over a period of three weeks. The fungal count of all tigernut - *acha* samples increased with increase in storage period. It ranged from 1.00 to 3.10 log CFU/mL during the period of storage. Fungal count was highest in sample containing 100% tigernut milk at the beginning of storage (2.92 log CFU/mL). Sample T (addition of 5% aqueous ginger extract) had the lowest fungal count of 2.38 log CFU/mL, followed by Sample P (addition of 3% aqueous ginger extract) with a fungal count of 2.46 log CFU/mL at week 0. On the other hand, Sample M had the highest fungal count of 3.10 log CFU/mL at the end of the storage period. These findings agree with the claims of Malomo and Abiose, 2020 where aqueous ginger extract was reported to minimize the growth of fungi in dairy and soy yoghurt. Lower fungal count was observed in sample with 3% aqueous ginger extract during the period of storage.

### 3.1.4 Probable identity of microorganisms isolated from the tigernut – *acha* drinks

During the storage of tigernut based drinks (with or without *acha* starch), a variety of microorganisms were isolated from the samples and then identified using morphological and biochemical tests. The microorganisms identified presumptively are: *Pseudomonas aeruginosa, Escherichia coli, Staphylococcus aureus, Bacillus subtilis and Corynebacterium spp.*

*Bacillus species* are known for their ability to form endospores, making them resilient and commonly found in soil, water (often due to soil-water contamination), and vegetables (Vasques *et al*., 2004). *Staphylococcus spp.* has been reported to contribute to the spoilage of tigernut milk by producing enzymes that break down proteins and fats, resulting in souring, curdling, and the development of

unpleasant odours and flavours (Argudín *et al.,* 2010). It is said to produce enterotoxins that are heat-resistant and can cause food poisoning. If contaminates tigernut milk, it can lead to serious health risks, including nausea, vomiting, and diarrhea (Le Loir *et al*., 2003).

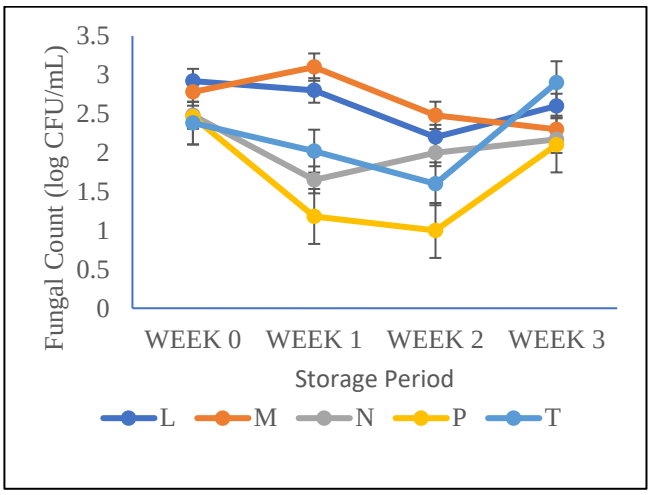


**Fig. 3.** Fungal Count (log CFU/mL) of the tigernut – *acha* drinks. L - Tigernut milk; M - Tigernut-*acha* drink; N – Tigernut-*acha* drink with 1% aqueous ginger extract; P – Tigernut-*acha* drink with 3% aqueous ginger extract; T – Tigernut-*acha* drink with 5% aqueous ginger extract

### 3.2. Proximate Composition

The proximate composition of the tigernut-*acha* drink blend is presented in **Table 1**. The moisture content significantly increased with increased amount of *acha* and ginger from 82.57% in 100 % tigernut to 85.54% in the sample with tigernut, *acha* starch and 5% aqueous ginger extract. The high moisture content reflects a characteristic quality of a typical beverage for thirst quenching which is higher in previously reported range of moisture content of tigernut by Obadesagbo *et al*. (2023). This high moisture content also indicates a decline in storage stability and a high risk of microbial contamination thereby compromising the product's safety (Ariyo *et al.,* 2021).

A significant increase in the protein content of tigernut acha drink was observed. Samples having 5% aqueous ginger extract drink having the highest protein content of 2.52%. The protein content of tigernut milk was 2.60 % while tigernut-based drinks had lower protein content with drink without aqueous ginger extract having protein content of 2.15%. The protein content of the tigernut milk-based drink in this sample was low compared with the protein content range of tigernut milk (3.7 - 4.2 %) reported by Ajayi and Bankole, (2020). The lower protein content in this study could be a result of the addition of *acha* starch to the tigernut drinks. Reduction in the protein content of the sample treated with ginger could be as a result of binding and screening effects of the anti-nutritional factors such as tannis present in the spices (Akeem *et al*., 2016).

Fat contributes substantially to the energy value of a food (Ghobadi *et al*., 2006). An insignificant decrease in fat content was observed with addition of aqueous ginger extract to the tigernut-acha drink with samples from 100 % tigernut milk having the highest value (4.95 %) and samples with 5 % aqueous ginger extract having the lowest value (4.87 %). The values recorded in this research is within the range reported by Ariyo *et al,* (2021).

Fibre composition of the samples ranged from 0.11- 0.95 % with samples from 100 % tigernut having the lowest value and samples from tigernut-acha drink and 5 % aqueous ginger extract having the highest value. These values are within the values reported by Ariyo *et a1*. (2021) but lower than the values reported by Obadesagbo *et al*., (2023). The increase observed in the values of the fibre content of the samples could be as a result of addition of *acha* and aqueous ginger extract. The elevated fibre content of the blend indicates its potential role in supporting weight management, prevention of diverticulosis and glycemic control.

There was no significant difference in the ash content of the samples and the positive control. Ash content of the sampe falls within the range of 0.55 to 0.82% with sample M having the lowest value and sample L having the highest value. The ash content of the tigernut-*acha* drink falls within the standard limit of < 5 % (SON) as reported by Adedokun & Barizaa (2014) though lower than 15 % reported by Ajayi and Bankole, (2020). This increase is a reflection of the improvement in the rheological properties and nutritional quality of the blends in terms of composition of the minerals (Schuck *et al.,* 2012).

**Table 1.** Proximate composition of tigernut-*acha* drinks

| Sample | Moisture | Protein | Ash | CHO | Fat | Fibre |
|---|---|---|---|---|---|---|
| L | 82.57 ± 0.14$^{e}$ | 2.60±0.14$^{a}$ | 1.23±0.02$^{a}$ | 8.52±0.01$^{b}$ | 4.95±0.06$^{a}$ | 0.11±0.01$^{e}$ |
| M | 82.80±0.03$^{d}$ | 2.15±0.02$^{e}$ | 0.55±0.03$^{ab}$ | 9.35±0.01$^{a}$ | 4.93±0.07$^{ab}$ | 0.21±0.02$^{d}$ |
| N | 84.45±0.01$^{c}$ | 2.37±0.01$^{d}$ | 0.61±0.06$^{ab}$ | 7.36±0.02$^{c}$ | 4.91±0.02$^{bc}$ | 0.32±0.03$^{c}$ |
| P | 84.84±0.02$^{b}$ | 2.41±0.01$^{c}$ | 0.52±0.16$^{b}$ | 6.79±0.01$^{d}$ | 4.89±0.01$^{cd}$ | 0.45±0.02$^{b}$ |
| T | 85.54±0.03$^{a}$ | 2.52±0.02$^{b}$ | 0.82±0.55$^{ab}$ | 5.73±0.06$^{e}$ | 4.87±0.01$^{d}$ | 0.95±0.05$^{a}$ |

Key: L - Tigernut milk; M - Tigernut-*acha* drink; N – Tigernut-*acha* drink with 1% aqueous ginger extract; P – Tigernut-*acha* drink with 3% aqueous ginger extract; T – Tigernut-*acha* drink with 5% aqueous ginger extract

### 3.3 Physicochemical properties

#### 3.3.1 Titratable acidity

The percentage titratable acidity (TTA) of the samples as shown in **Figure 4** can be attributed to the production of lactic acid by some species of lactic acid bacteria (*Lactobacillus leichmanm* and *Lactobacillus fermentum*) during the fermentation process (Akoma *et al.,* 2006). The values ranged from 0.29 - 0.63 % during the storage period from which sample L had the lowest titratable acidity and sample T had the highest value. Addition of acha starch to the tigernut milk caused an increase in the titratable acidity of the drink upon storage while the addition of ginger as a preservative caused a slight reduction in the TTA of the sample.

Over the storage period, the pH values of all the samples exhibited a gradual decrease as shown in **Figure 5**. This decline in pH can be attributed to the enzymatic conversion of sugars by lactic acid bacteria, as reported in previous studies by Lahtinen *et al*. (2004). At the end of the storage period, Sample T displayed the highest acidic activity, with a pH of 3.27. This enhanced the production of lactic acid, which is responsible for the observed decrease in pH (Rashid and Thakur, 2012).

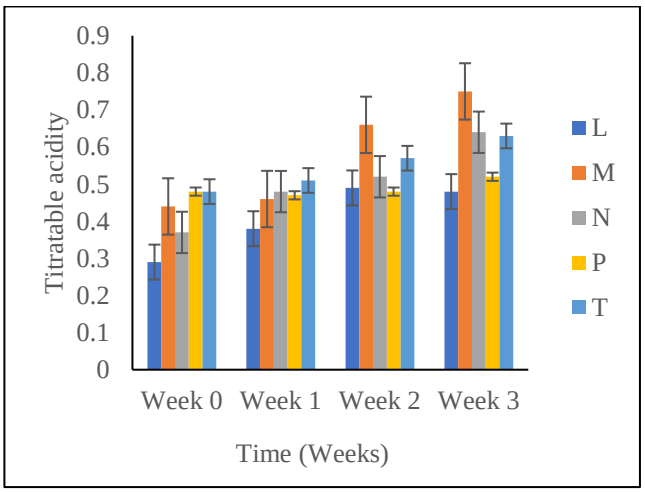


**Fig. 4.** Titratable acidity (TTA) of the Tigernut-acha drinks**.** L - Tigernut milk; M - Tigernut-*acha* drink; N – Tigernut-*acha* drink with 1% aqueous ginger extract; P – Tigernut-*acha* drink with 3% aqueous ginger extract; T – Tigernut-*acha* drink with 5% aqueous ginger extract.

### 3.4 Sensory scores of Tigernut-*acha* Drinks

The mean sensory scores for tigernut-*acha* drinks are shown in **Table 2**. The sensory attributes assessed were colour, aroma, taste, sweetness, and overall acceptability. The mean scores for colour of the samples ranged from 4.95 - 6.10 (**Table 2**). Sample L had the highest mean score for colour (6.10) while sample T had the lowest mean score (4.95). The result showed all the samples were not significantly ($p > 0.05$) different from one another. The mean scores for mouthfeel of the samples ranged from 4.20 - 5.75 (Table 3.3). Sample P had the highest mean score (5.75) while sample T had the lowest mean score (4.20). The result showed all the samples were not significantly ($p > 0.05$) different from one another in terms of mouthfeel. The mean scores for aroma ranged from 4.45 - 6.05 (Table 3.3). The result showed that there was significant ($p < 0.05$) difference in the aroma of all the samples.

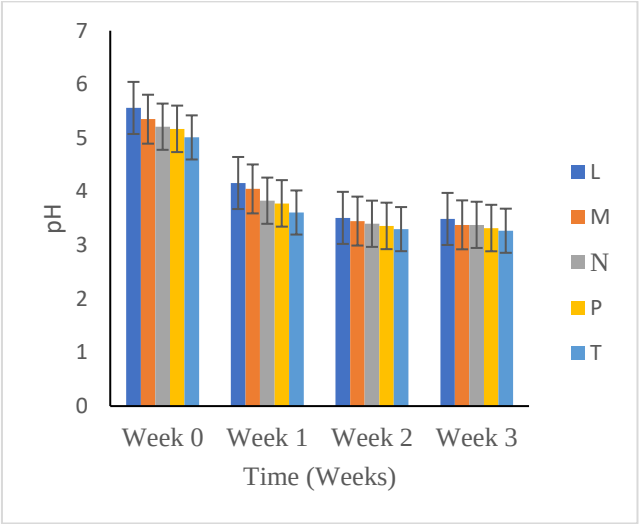


**Fig. 5.** pH of the tigernut-acha drink. L - Tigernut milk; M - Tigernut-*acha* drink; N – Tigernut-*acha* drink with 1% aqueous ginger extract; P – Tigernut-*acha* drink with 3% aqueous ginger extract; T – Tigernut-*acha* drink with 5% aqueous ginger extract

The mean scores for flavour of the drinks ranged from 4.40 - 5.70 (**Table 2**) with sample M having the highest mean score (5.70) while sample T had the lowest mean score (4.40). The result showed all the samples were not significantly ($p > 0.05$) different in flavour from one another.

The mean scores for overall acceptability ranged from 4.35 – 5.85 (**Table 2**) with sample M having the highest mean score (5.85), which agrees with Ajayi and Bankole (2020), while sample T had the lowest mean score (4.35). The result showed all the samples were not significantly ($p > 0.05$) different in terms of acceptability from one another.

**Table 2.** Sensory scores of Tigernut-acha drinks

| Sample | Appearance | Aroma | Flavour | Mouthfeel | Colour | Thickness | Overall acceptability |
|---|---|---|---|---|---|---|---|
| L | 6.70±1.42$^{b}$ | 5.10±1.74$^{ab}$ | 5.40±1.79$^{a}$ | 5.40±1.85$^{a}$ | 6.10±1.59$^{a}$ | 5.55±1.96$^{a}$ | 5.55±1.73$^{a}$ |
| M | 6.65±1.04$^{b}$ | 6.05±1.36$^{b}$ | 5.70±1.84$^{a}$ | 5.45±1.61$^{a}$ | 5.90±1.12$^{a}$ | 5.65±1.35$^{a}$ | 5.85±1.53$^{a}$ |
| N | 5.95±1.40$^{ab}$ | 5.00±1.78$^{ab}$ | 5.05±1.50$^{a}$ | 5.45±1.73$^{a}$ | 5.45±1.76$^{a}$ | 5.80±1.24$^{a}$ | 5.55±1.64$^{a}$ |
| P | 4.90±1.48$^{a}$ | 4.75±1.80$^{ab}$ | 4.50±2.09$^{a}$ | 5.75±1.89$^{a}$ | 5.10±1.77$^{a}$ | 5.30±1.78$^{a}$ | 4.60±1.70$^{a}$ |
| T | 4.90±1.42$^{a}$ | 4.45±1.67$^{a}$ | 4.40±2.09$^{a}$ | 4.20 ±2.33$^{a}$ | 4.95±1.93$^{a}$ | 5.10±2.20$^{a}$ | 4.35±2.23$^{a}$ |

L - Tigernut milk; M - Tigernut-*acha* drink; N – Tigernut-*acha* drink with 1% aqueous ginger extract; P – Tigernut-*acha* drink with 3% aqueous ginger extract; T – Tigernut-*acha* drink with 5% aqueous ginger extract

## CONCLUSION

The inclusion of 1% aqueous ginger extract had a preservative effect on tigernut-*acha* drink with a minimal change in the total viable and lactic acid bacteria count over storage period. Aqueous ginger extract stabilized the physicochemical properties of tigernut-*acha* drink for a period of three weeks. Likewise, the addition of upto 5% aqueous ginger extract did not alter the sensory properties of tigernut-acha drink. This study showed that the use of 1% aqueous ginger extract in tigernut-*acha* drink extended the shelf-stability of the product.

## CONFLICT OF INTEREST

All authors declare that they do not have any conflicts of interest that could have appeared to influence the work reported in this paper.

## DATA AVAILABILITY

The data used to support the findings of this study are available upon reasonable request from the corresponding author.

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