



# Influence of Storage Conditions and Processing Treatments on the Quality and Safety of African Star Apple (*Chrysophyllum albidum*) Juice: A Four-Week Comparative Study

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## Abstract

African star apple (*Chrysophyllum albidum*) is a major component of alley farming system in the rainforest agro-ecological zone in Nigeria. It boasts a rich blend of nutrients and bioactive constituents that make it attractive as an economic crop. In this study, the effect of storage conditions and processing treatments on the quality and safety of its extracted juice were examined. Ginger extract was added to African star apple juice; the product was stored at both ambient and refrigerated conditions after pasteurization, for a period of four (4) weeks. The pH, total titratable acidity, total suspended solids and vitamin C content were carried out on the samples. The juice samples were also examined for microbial contamination during the period of storage. The results show that the acidity increased with longer storage duration. The total suspended solids (TSS) ranged from 150.40 mg/L to 220.00 mg/L after four weeks. The storage conditions and treatments exerted variable TSS values in the juices. Spicing the African star apple juice with ginger combined with pasteurization and refrigeration raised the vitamin C content from 3.40 mg/100 mL to 6.85 mg/100 mL. This hurdle effect (spicing combined with pasteurization and refrigeration) significantly reduced the microbial load of the juice. In conclusion, it is evident that the treatments combined with cold storage enhanced nutritional quality and safety of the African star apple juice.

**Key words:** *Chrysophyllum albidum*, processing treatments, storage conditions, juice quality, safety

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## Introduction

The agricultural sector faces a constant challenge of delivering high-quality fresh fruits and vegetables to an increasingly competitive market, while simultaneously contributing to sustainability goals by minimizing postharvest losses and extending the shelf life of produce (Cassani and Gomez-Zavaglia, 2022). A comprehensive approach that integrates postharvest physiology and technology is essential to address these issues, as it combines both fundamental and applied knowledge to protect produce quality with minimal waste (Enujiugha, 2017). In recent years, there has been a heightened interest in leveraging innovative technologies and exploring improved postharvest strategies, driven by the recognition that only a scientific approach can provide the precision required to meet the demands of a highly competitive and quality conscious market (Valenzuela et al., 2023).

Fruit juice production plays a vital role in preserving perishable fruits and making them available year-round. They are also a valuable source of essential nutrients, including vitamins, minerals, and antioxidants, but they are also highly

perishable and susceptible to changes during storage and processing (Gómez-Gaete *et al.*, 2024). Traditional heat treatment methods often result in nutritional losses and quality deterioration, whereas membrane filtration techniques, such as ultrafiltration and microfiltration, offer better preservation of both organoleptic and nutritional properties (Adedokun *et al.*, 2022).

The African star apple (*Chrysophyllum albidum*) is a wild tropical evergreen tree that produces edible fruit and belongs to the Sapotaceae family. It is prevalent across Central, East, and West Africa, where it is valued for its sweet fruit and various ethnomedicinal applications. The tree is commonly distributed in regions of tropical West Africa, as well as countries such as Ghana, Nigeria, Kenya, Sierra Leone, Sudan, and Uganda (Oguntimehin *et al.*, 2022; Enujiugha *et al.*, 2023). The fruit's sweet, mildly acidic or astringent pulp is enjoyed as a snack, while the peel is occasionally chewed to create a gum-like texture. It is highly nutritious, with its pulp containing a significantly higher vitamin C content—around 446 mg per 100 g—compared to fruits like mango, pineapple, pawpaw, and hog plum, which have much lower amounts. The

fruit's bright orange color darkens as it ripens, and a deep brown hue is often preferred for a sweeter, less tart taste. Depending on its stage of ripeness, the African star apple offers a complex flavor profile, ranging from sour to pleasantly sweet (Adetogo *et al.*, 2024).

Despite its widespread consumption and valuable nutritional benefits, the fruit remains seasonal, making it unavailable year-round. Additionally, post-harvest losses and storage challenges, mainly caused by microbial activity and biochemical changes in tropical conditions, contribute to its perishability. However, its pulp remains a rich source of vitamin C and iron, making it a valuable raw material for various industries (Enujiugha *et al.*, 2023).

Research has indicated that diets rich in fruits and vegetables are linked to a lower risk of chronic diseases, likely due to the high levels of antioxidants they contain (Enujiugha *et al.*, 2014). This study explored how different storage conditions—both tropical ambient and refrigeration—affect key quality parameters of African star apple juice. This was with a view to determine the minimum storage requirements needed to maintain the quality and functionality of this highly nutritious fruit product.

## Materials and Methods

### Sample Collection

Fresh African star apple fruits (*Chrysophyllum albidum*) and fresh ginger rhizomes were sourced from the local main market - Oja Oba in Ondo State. The plastic bottles and muslin cloth used in the study were also purchased from Oja Oba, the local main market in Akure, Ondo State. All chemicals and reagents were of analytical grade and obtained from a certified laboratory materials supplier in Akure.

### Preparation of Ginger Extract

The extract from the ginger rhizomes was done following a modification of the procedure by Makanjuola and Enujiugha (2018). Fresh ginger was carefully selected based on its firmness, smooth skin, and lack of blemishes to ensure high-quality extraction. The ginger was then thoroughly washed under running tap water to remove any dirt, dust, or surface contaminants. After cleaning, it was cut into small pieces to facilitate efficient grinding. The prepared ginger pieces were processed using an electrically operated grinder and mixer, which helped break down the fibrous structure and release the juice. The resulting extract was then carefully filtered through a four-layer muslin cloth to separate the liquid from any remaining solid particles, ensuring a smooth and refined juice. This freshly obtained ginger extract was later incorporated at the constant 5% concentration into the Juice from African Star Apple so as to enhance its flavor, aroma, and potential health benefits.

### Production of African Star Apple Juice

The juice extraction process followed a previously established method (Enujiugha *et al.*, 2023). The fruits were first sorted and thoroughly washed to remove any impurities before being peeled and deseeded. The fleshy cotyledon was then cut into small pieces using a stainless-steel knife and blended into a semi-solid mass. A muslin cloth was used to strain the juice,

separating it from solid residues. The extracted juice was poured into sterilized glass bottles and pasteurized in a water bath at 71.2°C for 30 minutes. It was then divided into two equal portions—one stored at ambient temperature (28±2°C) and the other refrigerated (6±2°C) - for further analysis, after four weeks' storage period. Additionally, before analysis, some refrigerated samples were treated with 5% ginger extract, along with samples stored at ambient temperature.

### Determination of Physicochemical Properties of African Star Apple Juice

The pH of the juice samples was measured using a digital pH meter (ELICO L1 614 pH analyzer), with the results expressed in pH units. The total titratable acidity (TTA) was determined by titrating a known volume of the juice with 0.01 M sodium hydroxide (NaOH) using phenolphthalein as an indicator. Specifically, 10 mL of juice was pipetted into a beaker, followed by the addition of one drop of phenolphthalein. The mixture was then titrated with the NaOH solution until a light pink color appeared. The burette reading was recorded and used to calculate the percentage of TTA.

The total soluble solids (reducing sugars) were measured using a hand-held refractometer (RX 1000, Atago Co. Ltd., Tokyo, Japan), with the values recorded in degrees Brix (°Brix).

The vitamin C (ascorbic acid) content of the African star apple juice was determined using a previously established method. A reaction mixture containing 300 µL of a diluted polar extract, 100 µL of 13.3% trichloroacetic acid (TCA), and water was prepared. To this, 75 µL of DNPH solution (containing 2 g dinitrophenylhydrazine, 230 mg thiourea, and 270 mg CuSO<sub>4</sub>·5H<sub>2</sub>O in 100 mL of 5 M H<sub>2</sub>SO<sub>4</sub>) was added. The mixture was then incubated at 37 °C for three hours. After incubation, 0.5 ml of 65% sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) was added, and the absorbance was measured at 520 nm. The vitamin C content of the juice was calculated based on the absorbance values obtained.

### Microbial Analysis

To assess the microbial quality of the African star apple juice, both bacteriological and fungal analyses were conducted using appropriate culture media (Adejebi *et al.*, 2024). A diluent, specifically a physiological saline solution, was prepared to facilitate microbial suspension and maintain cell viability during the dilution process (Babatuyi *et al.*, 2019). The culture media used included Nutrient Agar (NA) for the enumeration of bacteria and Potato Dextrose Agar (PDA) for the detection of fungal contaminants. These media were prepared according to the manufacturers' specifications to ensure accurate and standardized microbiological analysis.

### Serial Dilution and Plating Process

To estimate microbial load, the juice samples underwent a serial dilution process, which helps reduce the concentration of microorganisms, making it easier to count individual colonies. The juice was diluted in a stepwise manner, creating dilution factors of 10<sup>-2</sup>, 10<sup>-3</sup>, 10<sup>-4</sup>, and 10<sup>-5</sup>, ensuring a range of microbial concentrations suitable for enumeration.

The spread plate method was employed for microbial plating. In this technique, a fixed volume of the diluted sample was carefully spread across the surface of the agar medium using a

sterile glass spreader or L-shaped rod to ensure uniform distribution of microorganisms. This method is widely used because it allows for clear and distinct colony growth, facilitating accurate counting.

### Incubation and Colony Enumeration

Following plating, the inoculated agar plates were incubated under optimal conditions to promote microbial growth. The incubation temperature and duration were tailored to suit the expected microbial species, typically 37 °C for 24-48 hours for bacterial growth on Nutrient Agar and 25-30 °C for 3-5 days for fungal growth on Potato Dextrose Agar.

After the incubation period, microbial colonies that developed on the agar plates were counted manually or with the aid of a colony counter. The results were recorded as colony-forming units per milliliter (cfu/mL), a standard unit used in microbiology to estimate viable microorganisms present in a liquid sample. These values provided crucial insights into the microbiological stability and safety of the African star apple juice under different storage conditions.

### Statistical Analysis

The data collected from the study were analyzed using one-way analysis of variance (ANOVA), a statistical method used to determine whether there are significant differences between the means of multiple sample groups. One-way ANOVA is particularly useful for comparing the effects of different treatments—such as storage conditions and pasteurization—on the quality of African star apple juice.

To further interpret significant differences among sample means, Duncan's New Multiple Range Test (DNMRT) was used for mean separation. This post-hoc test allows for pairwise comparisons, ensuring that variations among the samples are clearly distinguished.

The level of significance was set at  $p < 0.05$ , meaning that results with a probability value lower than 0.05 were considered statistically significant. This threshold indicates a 95% confidence level, ensuring that any observed differences are unlikely to be due to random chance, thus reinforcing the credibility of the findings.

## Results and Discussion

### Physicochemical Properties of African Star Apple Juice during Storage

The pH values of all samples decreased consistently over the four-week storage period, indicating an increase in acidity.

Sample A (non-spiced, non-pasteurized) experienced a 13% reduction in pH from Week 1 to Week 4, while Sample F (non-spiced, non-pasteurized, non-refrigerated) showed the greatest reduction (approximately 20%), reaching  $3.70 \pm 0.01$  in Week 4. These results align with findings in tropical fruit juice studies, where microbial activity and biochemical changes during storage increase organic acid production, leading to lower pH values (Rojas et al., 2026). The spiced and pasteurized samples (Samples B and D) retained relatively higher pH values compared to their non-spiced and non-pasteurized counterparts, underscoring the protective effect of pasteurization and the antimicrobial properties of ginger. Ginger contains bioactive compounds like gingerol, which suppress microbial proliferation and delay acidification (Makanjuola and Enujiugha, 2018).

Ojo et al. (2020) reported that unpasteurized tropical fruit juices stored at room temperature showed rapid decreases in pH due to microbial fermentation, consistent with the behavior of Sample F. Conversely, pasteurized samples in their study retained more stable pH values, corroborating the results observed in Samples C and D. Additionally, studies on spiced fruit juices suggest that incorporating natural antimicrobials, such as ginger, significantly enhances the shelf life and quality of juice products by reducing the growth of spoilage microorganisms (Enujiugha, 2020).

The observed pH decline (as seen in Table 1) can be attributed to increased metabolic activity of spoilage microorganisms in non-pasteurized and non-refrigerated samples, producing organic acids such as lactic and acetic acid. This highlights the importance of pasteurization and refrigeration in maintaining juice stability. Samples B, C, and D demonstrated better pH retention, reinforcing the synergistic effects of pasteurization and spicing.

The results emphasize that untreated and unrefrigerated juices (e.g., Sample F) are more prone to spoilage, presenting potential health risks due to microbial contamination. Pasteurized spiced samples (e.g., D) offer a promising approach to extending shelf life while maintaining sensory and nutritional quality. The inclusion of ginger, a natural antimicrobial, can be leveraged by the juice industry to cater to consumer demand for minimally processed yet safe beverages.

**Table 1:** pH of African Star Apple Juice Samples over Four Weeks

Sample	Week 1	Week 2	Week 3	Week 4
A	$4.60 \pm 0.05b$	$4.40 \pm 0.01ab$	$4.20 \pm 0.01b$	$4.00 \pm 0.02c$
B	$4.65 \pm 0.01a$	$4.50 \pm 0.01a$	$4.35 \pm 0.02a$	$4.20 \pm 0.01a$
C	$4.55 \pm 0.07c$	$4.35 \pm 0.01b$	$4.15 \pm 0.01ab$	$4.00 \pm 0.01c$
D	$4.60 \pm 0.01b$	$4.45 \pm 0.01ab$	$4.30 \pm 0.03a$	$4.10 \pm 0.01b$
E	$4.50 \pm 0.01c$	$4.30 \pm 0.03c$	$4.10 \pm 0.01b$	$3.90 \pm 0.01d$
F	$4.64 \pm 0.06a$	$4.30 \pm 0.01c$	$4.00 \pm 0.01c$	$3.70 \pm 0.05d$

\*Values are presented as mean  $\pm$  SD in three replicates. Means with different following letters in the same column are significantly different at  $p < 0.05$ .

**Key:** Sample A: Non-spiced, non-pasteurized; Sample B: Spiced with 5% ginger, non-pasteurized; Sample C: Non-spiced, pasteurized; Sample D: Spiced with 5% ginger, pasteurized; Sample E: Spiced with 5% ginger, pasteurized, non-refrigerated; Sample F: Non-spiced, non-pasteurized, non-refrigerated.

### Total Suspended Solid (TSS) (mg/L) of African Star Apple Juice Samples during Storage

Total Suspended Solids (TSS) in fruit juices encompass insoluble particles such as pulp, cellular debris, and other colloidal substances that influence the juice's turbidity, mouthfeel, and overall quality (Oguntimehin et al., 2025). In this study, African Star Apple juice samples subjected to various treatments and storage conditions exhibited TSS values ranging from 150.40 mg/L (Sample D) to 220.00 mg/L (Sample F) after four weeks. Sample F, which was non-spiced, non-pasteurized, and stored at room temperature, demonstrated the highest TSS value ( $220.00 \pm 6.00$  mg/L).

This elevated TSS could be attributed to the absence of pasteurization, leading to increased microbial activity and subsequent degradation of juice components, resulting in higher particulate matter (Oguntimehin et al., 2025). Conversely, Sample D, which was spiced with 5% ginger, pasteurized, and refrigerated, exhibited the lowest TSS value ( $150.40 \pm 3.00$  mg/L). The combination of pasteurization and refrigeration likely inhibited microbial proliferation and enzymatic activities, thereby reducing the formation of suspended particles (Adetogo et al., 2024).

The addition of ginger (Samples B, D, and E) appeared to influence TSS levels. Ginger contains natural antimicrobial compounds that can suppress microbial growth, potentially leading to lower TSS values (Adetogo et al., 2024). However, Sample E, which was spiced, pasteurized, and stored at room temperature, showed a higher TSS value ( $200.80 \pm 5.50$  mg/L) compared to Sample D. This suggests that storage temperature plays a significant role, as elevated temperatures can enhance microbial activity and enzymatic reactions, increasing suspended solids despite the presence of ginger. Comparing these findings with existing literature, it is evident that storage conditions and treatments significantly impact TSS levels in fruit juices. For instance, studies on mango-mandarin squash have shown that treatments significantly affect TSS during storage time. Similarly, research on litchi fruits indicates that TSS content increases during storage with most treatments. These studies corroborate the current findings, emphasizing the importance of processing and storage conditions in maintaining juice quality.

The TSS content of African Star Apple juice is markedly influenced by pasteurization, spicing with ginger, and storage conditions. Implementing pasteurization and refrigeration, along with the addition of natural antimicrobials like ginger, can effectively control TSS levels, thereby enhancing the quality and shelf-life of the juice.

**Table 2:** Total Suspended Solid (TSS) (mg/L) of African Star Apple Juice Samples after Fourth Week

Sample	TSS
A	$180.50 \pm 5.00$ b
B	$170.20 \pm 4.50$ b
C	$160.30 \pm 3.80$ c
D	$150.40 \pm 3.00$ c
E	$200.80 \pm 5.50$ a
F	$220.00 \pm 6.00$ a

Values are presented as mean  $\pm$  SD in three replicates. Means with different following letters in the same column are significantly different at  $p < 0.05$ .

**Key:** Sample A: Non-spiced, non-pasteurized; Sample B: Spiced with 5% ginger, non-pasteurized; Sample C: Non-spiced, pasteurized; Sample D: Spiced with 5% ginger, pasteurized; Sample E: Spiced with 5% ginger, pasteurized, non-refrigerated; Sample F: Non-spiced, non-pasteurized, non-refrigerated.

### Vitamin C Content of African Star Apple Juice Samples during Storage

The data presented in Table 3 illustrate the vitamin C content across six different African star apple (*Chrysophyllum albidum*) juice samples after a four-week storage period. Notably, Sample D (spiced with 5% ginger and pasteurized) retained the highest vitamin C concentration ( $6.85 \pm 0.20$  mg/100mL), while Sample F (non-spiced, non-pasteurized, non-refrigerated) exhibited the lowest ( $3.40 \pm 0.08$  mg/100mL).

Vitamin C, or ascorbic acid, is highly susceptible to degradation influenced by factors such as temperature, oxygen exposure, and storage duration. Pasteurization, a thermal process, can lead to significant losses of vitamin C. For instance, studies have shown that thermally treated mango juice experienced a 65% reduction in ascorbic acid content compared to untreated juice. However, pasteurization also inactivates enzymes like ascorbate oxidase, which can mitigate further degradation during storage.

The incorporation of ginger appears to have a protective effect on vitamin C retention. Ginger contains antioxidants that may help preserve ascorbic acid. Research indicates that juices with added ginger retained a higher percentage of their initial vitamin C content during storage compared to those without ginger. This aligns with the higher vitamin C levels observed in Samples B and D, both spiced with 5% ginger.

Storage conditions critically impact vitamin C stability. Sample F, stored at room temperature without pasteurization or refrigeration, recorded the most significant decline in vitamin C content. This is consistent with findings that unpasteurized and unrefrigerated juices experience rapid ascorbic acid degradation. Conversely, refrigerated storage can slow down degradation rates, thereby preserving vitamin C content over time.

**Table 3:** Vitamin C (mg/100 mL) Content of African Star Apple Juice Samples during Storage

Sample	Vitamin C
A	5.12 ± 0.15c
B	6.20 ± 0.18b
C	5.45 ± 0.12c
D	6.85 ± 0.20a
E	4.80 ± 0.10d
F	3.40 ± 0.08e

Values are presented as mean ± SD in three replicates. Means with different following letters in the same column are significantly different at  $p < 0.05$ .

**Key:** Sample A: Non-spiced, non-pasteurized; Sample B: Spiced with 5% ginger, non-pasteurized; Sample C: Non-spiced, pasteurized; Sample D: Spiced with 5% ginger, pasteurized; Sample E: Spiced with 5% ginger, pasteurized, non-refrigerated; Sample F: Non-spiced, non-pasteurized, non-refrigerated

### Microbial Counts in African Star Apple Juice

The microbial enumeration results over four weeks for the six samples of African Star Apple juice highlight the dynamic changes in microbial populations due to treatment and storage conditions. The microbial load is an important determinant of the juice's safety, quality, and shelf-life.

**Table 4:** Microbial Enumeration of African Star Apple Juice Samples - First Week

Sample	Total Viable Bacteria Count (cfu/mL × 10 <sup>2</sup> )	Total Viable Coliform Count (cfu/mL × 10 <sup>2</sup> )	Total Viable E. Coli Count (cfu/mL × 10 <sup>2</sup> )	Total Viable Salmonella Count (cfu/mL × 10 <sup>2</sup> )	Total Viable Yeast/Mould Count (cfu/mL × 10 <sup>2</sup> )
A	22	6	Nil	Nil	4
B	16	5	Nil	Nil	9
C	14	4	Nil	Nil	6
D	8	2	Nil	Nil	4
E	12	6	Nil	Nil	7
F	30	10	Nil	Nil	15

**Key:** Sample A: Non-spiced, non-pasteurized; Sample B: Spiced with 5% ginger, non-pasteurized; Sample C: Non-spiced, pasteurized; Sample D: Spiced with 5% ginger, pasteurized; Sample E: Spiced with 5% ginger, pasteurized, non-refrigerated; Sample F: Non-spiced, non-pasteurized, non-refrigerated

**Table 5:** Microbial Enumeration of African Star Apple Juice Samples - Second Week

Sample	Total Bacteria Count (cfu/mL × 10 <sup>3</sup> )	Viable Count (cfu/mL × 10 <sup>3</sup> )	Total Coliform Count (cfu/mL × 10 <sup>3</sup> )	Viable Count (cfu/mL × 10 <sup>3</sup> )	Total Viable E. coli Count (cfu/mL × 10 <sup>3</sup> )	Total Salmonella Count (cfu/mL × 10 <sup>3</sup> )	Viable Count (cfu/mL × 10 <sup>3</sup> )	Total Yeast/Mould Count (cfu/mL × 10 <sup>3</sup> )	Viable Count (cfu/mL × 10 <sup>3</sup> )
A	32	19	19	19	Nil	Nil	10	10	10
B	22	10	10	10	Nil	Nil	16	16	16
C	20	8	8	8	Nil	Nil	12	12	12
D	14	6	6	6	Nil	Nil	8	8	8
E	19	18	18	18	Nil	Nil	10	10	10
F	46	15	15	15	Nil	Nil	22	22	22

**Key:** Sample A: Non-spiced, non-pasteurized; Sample B: Spiced with 5% ginger, non-pasteurized; Sample C: Non-spiced, pasteurized; Sample D: Spiced with 5% ginger, pasteurized; Sample E: Spiced with 5% ginger, pasteurized, non-refrigerated; Sample F: Non-spiced, non-pasteurized, non-refrigerated.

**Table 6:** Microbial Enumeration of African Star Apple Juice Samples - Third Week

Sample	Total Bacteria Count (cfu/mL × 10 <sup>3</sup> )	Viable Count (cfu/mL × 10 <sup>3</sup> )	Total Coliform Count (cfu/mL × 10 <sup>3</sup> )	Viable Count (cfu/mL × 10 <sup>3</sup> )	Total Viable E. coli Count (cfu/mL × 10 <sup>3</sup> )	Total Salmonella Count (cfu/mL × 10 <sup>3</sup> )	Viable Count (cfu/mL × 10 <sup>3</sup> )	Total Yeast/Mould Count (cfu/mL × 10 <sup>3</sup> )	Viable Count (cfu/mL × 10 <sup>3</sup> )
A	39	22	22	22	Nil	Nil	16	16	16
B	29	14	14	14	Nil	Nil	24	24	24
C	24	12	12	12	Nil	Nil	20	20	20
D	16	8	8	8	Nil	Nil	12	12	12
E	24	22	22	22	Nil	Nil	14	14	14
F	56	26	26	26	Nil	Nil	33	33	33

**Key:** Sample A: Non-spiced, non-pasteurized; Sample B: Spiced with 5% ginger, non-pasteurized; Sample C: Non-spiced, pasteurized; Sample D: Spiced with 5% ginger, pasteurized; Sample E: Spiced with 5% ginger, pasteurized, non-refrigerated; Sample F: Non-spiced, non-pasteurized, non-refrigerated.

**Table 7: Microbial Enumeration of African Star Apple Juice Samples - Fourth Week**

Sample	Total Bacteria (cfu/mL × 10 <sup>3</sup> )	Viable Count	Total Coliform (cfu/mL × 10 <sup>3</sup> )	Viable Count	Total Viable E. Coli Count (cfu/mL × 10 <sup>3</sup> )	Total Salmonella (cfu/mL × 10 <sup>3</sup> )	Viable Count	Total Yeast/Mould (cfu/mL × 10 <sup>3</sup> )	Viable Count
A	44		27		Nil	Nil		18	
B	32		18		Nil	Nil		26	
C	28		16		Nil	Nil		22	
D	23		12		Nil	Nil		14	
E	29		24		Nil	Nil		17	
F	85		30		Nil	Nil		38	

**Key:** Sample A: Non-spiced, non-pasteurized; Sample B: Spiced with 5% ginger, non-pasteurized; Sample C: Non-spiced, pasteurized; Sample D: Spiced with 5% ginger, pasteurized; Sample E: Spiced with 5% ginger, pasteurized, non-refrigerated; Sample F: Non-spiced, non-pasteurized, non-refrigerated.

### Total Viable Bacteria Count

The bacterial counts were highest in Sample F across all weeks, with values increasing from  $3.0 \times 10^2$  in the first week to  $8.5 \times 10^4$  by the fourth week. This significant increase could be attributed to the non-spiced, non-pasteurized, and non-refrigerated nature of Sample F, which provides a conducive environment for bacterial growth. Comparatively, Sample D (spiced and pasteurized) had the lowest bacterial counts, indicating the efficacy of combined spicing and pasteurization in reducing microbial load.

### Total Viable Coliform Count

Coliforms, indicators of potential faecal contamination, were detected in all samples except in negligible amounts in pasteurized ones. Sample F consistently exhibited higher coliform counts, reflecting the absence of pasteurization and proper storage conditions. By the fourth week, Sample F's coliform count reached  $3.0 \times 10^4$ , while Sample D remained significantly lower at  $1.2 \times 10^4$ .

### Yeast and Mould Count

Yeast and mould count also demonstrated a steady increase, with Sample F reaching  $3.8 \times 10^4$  by week four. The spiced and pasteurized samples (B, D) maintained relatively lower yeast and mould counts due to the antimicrobial properties of spices and the thermal effects of pasteurization.

### Absence of *E. coli* and *Salmonella*

The absence of *E. coli* and *Salmonella* across all samples is noteworthy. It suggests that while conditions allowed for general microbial growth, specific pathogens might have been inhibited due to low pH or other intrinsic juice properties.

### Conclusion

This study highlights the significant impact of processing and storage conditions on the quality of African star apple juice. Pasteurization and ginger spicing, coupled with refrigeration, enhanced microbial safety, preserved bioactive compounds, and improved antioxidant capacity. In contrast, non-spiced and unpasteurized samples stored under ambient conditions without refrigeration led to rapid quality deterioration, including increased microbial growth and nutrient loss. These findings underscore the importance of controlled storage and processing and preservation methods in maintaining the safety, stability, and nutritional value of minimally processed fruit juices.

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