# Synergistic Impacts of Gum Arabic and Bio-Based Preservatives on the Physicochemical and Microbiological Quality of Stored Plantain

**Eunice I. Bamishaiye[1], Oluwakemi E. Otenaike[2], Janet O. Alimi[1], Ayanfe P. Olorunfemi[1], Kehinde M. Atilola[1], and Blessing I. Adediran [1]**

[1]Perishable Crops Research Department, Nigerian Stored Products Research Institute, Ilorin, Kwara State.
[2]Department of Biochemistry, Faculty of Life Sciences, Federal University Oye-Ekiti, Ekiti State

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**CORRESPONDING AUTHOR**
**Janet O. Alimi**
Perishable Crops Research Department, NSPRI, Ilorin, Nigeria
alimijo@nspri.gov.ng
+234-803-4809835

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## Abstract

*Postharvest losses significantly constrain the steady market supply of plantain; thus, bio-based preservatives are increasingly employed as sustainable alternatives to chemical agents for extending its shelf life. This study evaluated the effects of bio-based coatings on plantain quality during a 15-day storage period. Mature green plantains were treated with gum arabic cinnamon extract coating (A), gum arabic clove extract coating (B), gum arabic bay leaf extract coating (C), gum arabic alone (D), untreated (E) and gum arabic shea butter coating(F). Treatment B recorded the highest weight loss of 28%. Although there was a decline in the moisture content of all treatments, treatment D showed optimal retention (65.660%). Treatments A (6.24) and F (6.153) maintained pH stability, while C and D exhibited acidification (4.87 and 5.25, respectively). Vitamin C levels increased across treatments (12.5–18.7 mg/100 g), although β-carotene degraded substantially. Treatment F demonstrated the highest starch content (58.228±0.002 mg/100 g) and potassium (8.54 mg/100 g). Treatments A, B, and C resulted in reduced bacterial populations, while treatments A and B achieved complete fungal inhibition. Treatment C recorded 33.33% decay incidence despite antimicrobial activity. Panelists rated F highest in colour (7.45), appearance (7.30), odour (6.90), texture (7.60), and general acceptability (7.75). Results demonstrate that gum arabic-shea butter coatings optimized overall quality and consumer acceptability, while cinnamon and clove formulations provided superior antimicrobial protection. These composite coatings offer sustainable alternatives for extending plantain shelf life under tropical conditions.*

**Keywords:**
Edible Coatings, Natural Preservatives, Plantain, Post-harvest Preservation, Shelf Life

## Introduction

Plantain (*Musa paradisiaca* L.) ranks among the most economically significant staple crops in tropical and subtropical regions, serving as a primary carbohydrate source for over 400 million people globally (FAO, 2020). Despite its nutritional importance and commercial value, the plantain value chain suffers from severe post-harvest losses estimated at 25-40% in sub-Saharan Africa, with spoilage rates reaching 30% within the first week post-harvest under ambient storage conditions (FAO, 1999; Pokhrel, 2021). These losses, driven by the fruit's climacteric nature, high respiration rate, mechanical damage, and susceptibility to microbial invasion, impose substantial economic burdens on smallholder farmers and threaten food security in producing regions. Traditional postharvest management strategies have relied predominantly on synthetic fungicides and chemical waxes to suppress microbial proliferation and retard ripening (Tchango et al., 1999). While effective, mounting evidence of pesticide residue accumulation in food products, the emergence of fungicide-resistant pathogen strains, and documented adverse environmental and human health impacts have catalyzed a paradigm shift toward natural, sustainable preservation alternatives (Tajkarimi et al., 2010; Orisakwe et al., 2012). This transition aligns with contemporary consumer preferences for minimally processed,

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chemical-free produce and supports the United Nations Sustainable Development Goals targeting food waste reduction and sustainable agriculture.

Edible coating technology has emerged as a promising bio-based intervention, functioning through multiple mechanisms including formation of semi-permeable barriers that modulate gas exchange ($O_2$, $CO_2$, ethylene), reduction of transpirational water loss, provision of structural integrity, and serving as carriers for functional bioactive compounds (Maringgal et al., 2020; Han et al., 2023; Krishna et al., 2023). Among polysaccharide-based coating materials, gum arabic, a natural exudate from *Acacia senegal* and *Acacia seyal*, exhibits exceptional film-forming properties, biocompatibility, and Generally Recognized As Safe (GRAS) status, making it particularly suitable for food applications (Patel & Goyal, 2015). Its hydroxyl-rich molecular structure facilitates moisture retention while maintaining adequate gas permeability for normal fruit respiration.

Recent advances in coating formulation have demonstrated that incorporating antimicrobial agents, particularly essential oils and plant-derived bioactive compounds,into polysaccharide matrices generates synergistic effects that enhance both physical and microbiological preservation (Dutta et al., 2021). Essential oils from cinnamon (*Cinnamomum zeylanicum*), clove (*Syzygium aromaticum*), and bay leaf (*Laurus nobilis*) contain phenolic compounds (eugenol, cinnamaldehyde, cineole) with documented broad-spectrum antimicrobial activity against common post-harvest pathogens (Gamal et al., 2021; Kumar et al., 2022). Similarly, shea butter (*Vitellaria paradoxa*), abundant in West Africa and rich in triterpenes and phytosterols, exhibits natural antimicrobial properties alongside its lipid barrier function (Abubakar et al., 2022).

Despite growing research interest in natural preservatives, critical knowledge gaps remain regarding: the comparative efficacy of different antimicrobial agents when integrated with gum arabic coatings, the extent to which these composite systems maintain nutritional quality parameters beyond physical preservation and their practical applicability under tropical ambient conditions where refrigeration infrastructure is limited. Furthermore, few studies have employed comprehensive analytical frameworks simultaneously assessing physicochemical, nutritional, microbiological, and sensory dimensions, all critical for commercial viability and consumer acceptance.

Although interest in natural preservatives has increased in recent years, several important questions remain unanswered. There is still limited understanding of how different antimicrobial agents perform when incorporated into gum arabic coatings, how effectively these composite systems preserve the nutritional quality of fruits beyond their physical appearance, and how well they function under tropical ambient conditions where refrigeration is scarce. This study was designed to bridge these gaps by examining the combined effects of gum arabic-based coatings enriched with four natural antimicrobial agents, cinnamon, clove, bay leaf extracts, and shea butter on the postharvest quality of plantain stored under simulated tropical environments. The results generated evidence-based insights that can guide the development of sustainable, low-cost postharvest management practices suited to resource-limited tropical agricultural systems.

## Materials and Methods

### Samples collection

Cinnamon bark, cloves, bay leaves, and shea butter were purchased from Mandate Market in Ilorin, Kwara State, Nigeria. While freshly harvested, mature green plantains were procured from Ipata Market, having been delivered directly from a local farm in Ilorin, Kwara State, Nigeria. The plantain bunch was de-fingered, sorted, and cleaned to remove field dirt. The cleaned plantains were surface-sterilized in 0.1% hypochlorite solution, allowed to air-dry before use.

### Preparation and application of coatings

Coatings were prepared following the protocol of Lin & Zhao (2007). A portion of 35 g of each spice was blended separately in 350 mL of warm water and conditioned at 60 °C for 1 hour. The resulting solutions were filtered separately using muslin cloth, and 15% w/v gum arabic was dissolved in each extract on a hot plate with constant stirring at 60 °C using a magnetic stirrer. Exactly 1.5% v/v glycerol was added to the solution, and agitated continuously to obtain a fine solution. A solution of gum arabic alone was prepared using distilled water and glycerol, following the above protocol, to serve as a control.

The matured green plantains were divided into six lots, and the coatings were applied to each lot as follows:

A (gum arabic + cinnamon extract),
B (gum arabic + clove extract),
C (gum arabic + bay leaf extract),
D (gum arabic alone),
E (Untreated)
F (gum arabic + Shea butter)

The coatings were applied by dipping plantains in the respective coatings for 2 minutes, after which they were air-dried and stored in uniformly sized paper cartons (30×18×18 cm) at ambient temperature (28±2 °C), with 83% relative humidity monitored using Temlog 20H data loggers. The experimental setup was maintained for 15 days, with physicochemical analyses carried out every 5 days. Nutritional analyses, mineral content, and microbial load were determined at days 0 and 15, while sensory evaluation was done at day 15.

**Estimation of weight loss (%)**

Weight loss was estimated as described by Radi et al. (2017), where the difference in the initial and final (after storage) weights of the banana fruits was determined against the initial weight and expressed as a percentage.

**Determination of moisture content**

Moisture content was determined following the oven drying technique described by AOAC (2019). Exactly 2 g of each well's homogenized sample was weighed in clean, moisture-proof cans ($W_1$). The cans containing the samples were placed in an oven at 130 °C for 1 hour until a constant weight was achieved. After which the cans were cooled in a desiccator and reweighed ($W_2$). The percent moisture content was then calculated using the formula:

$$\% \text{ Moisture} = \frac{W_2\text{-}W1}{\text{Wt.of sample}} \times 100$$

Where:

$W_1$ = Initial weight of crucible + sample

$W_2$ = Final weight of crucible + sample

**Determination of ash content**

To determine the ash content, clean, empty crucibles were first placed in a muffle furnace at 600 °C for one hour. After cooling in a desiccator, the weights were recorded ($W_1$). Each sample (2 g) was then placed in the crucible and ignited over a burner using a blowpipe until it began to char. The crucible was subsequently heated in a muffle furnace at 550 °C for four hours, and the formation of a gray-white ash signified the complete oxidation of organic material in the sample. Finally, the crucible was removed, cooled in a desiccator, and weighed ($W_3$). The percentage of ash was calculated using the following formula:

$$\% \text{ Ash} = \frac{\text{Wt. of Ash}}{\text{Wt. of sample}} \times 100$$

Weight of Ash $W_3$-$W_1$

**Colour determination**

Colour attributes of the stored samples were determined using a colorimeter to estimate lightness (L*), redness-greenness (a*), and Yellow-blueness (b*) following the method outlined by AbdelGawad et al. (2016). The samples were exposed to the sensor of the colorimeter, which had been previously standardized using black and white calibration tiles. The displayed values were recorded for their respective colour attributes.

**Pulp/peel ratio**

The banana peel was removed, and the weights of both the peel and pulp were recorded. The pulp-to-peel ratio was then determined by dividing the weight of the pulp by the weight of the peel (Dadzie & Orchard, 1997).

**Decay incidence (%)**

Decay incidence (%) was evaluated by recording the number of decayed fruits on the 15th day of storage for all the treatments and dividing by the total number of fruits initially packaged according to the formulae below;

$$\text{Decay incidence } \% = \frac{\text{Number of decayed fruits}}{\text{Total number of fruits}} \text{x } 100$$

**Determination of physicochemical properties**

The pH, titratable acidity, and total soluble solids were determined using the method described by Sharoba (2009), with minor modifications, as follows: 10 g of each sample homogenate was taken and diluted to 100 mL with distilled water. The solution was filtered, and the pH was measured at 20 °C with a pH meter (SEARCHTECH PHS-3C). Titratable acidity was determined by titrating with 0.1 N NaOH, using phenolphthalein as an indicator, until a pH of 8.1 was reached (rose pink colour) and reported as grams of citric acid/100 g of fresh weight. The total Soluble solids content of the homogenates was determined at 20 °C with a refractometer (ABBE MARK II 10481; Cambridge Instrument Inc., NY) and reported as °Brix.

**Determination of vitamin C content (mg/100 g)**

The 2,6-dichlorophenol indophenol titration method, as modified by Ndawula et al. (2004), was used to determine the vitamin C (ascorbic acid) content of the banana samples. Two (2) g of the sample was homogenized in a mortar with 10 mL of 0.5% oxalic acid (the extraction solution) and then transferred into a 100 mL volumetric flask. An additional extraction solution was added to reach the calibrated mark, thoroughly mixed, and immediately filtered using

Whatman No. 4 filter paper. Aliquots (10 mL) of the extract were then titrated against a standardized 2,6-dichlorophenol indophenol solution. Simultaneously, an equivalent volume of the extraction solution was titrated against the standard 2,6-dichlorophenol indophenol solution as a blank.

**Determination of carotenoids**

The samples were homogenized using a mortar and pestle in the presence of a water bath containing squash ice, following the method described by Fashanu et al. (2019). To extract carotenoids, 16 mL of acetone-hexane (4:6) solvent was added to 1.0 g of the homogenized sample and mixed in a test tube. An aliquot was taken from the upper phase of the resulting solution, and its optical density (OD) was measured at 663, 645, 505, and 453 nm using a UV-VIS spectrophotometer (SEARCHTECH INSTRUMENTS; UV1902PC, England). Lycopene and β-carotene contents were then calculated using the equations provided by Lawal & Olapade (2024).

Lycopene (mg per 100 mL) = -0.0458 × OD 663 + 0.204 × OD 645 + 0.372 × OD 505 - 0.0806× OD453

Beta-Carotene (mg per 100 mL) = 0.216 × OD 663 - 1.22 × OD 645 - 0.304 × OD 505 + 0.452 × OD 453

Where OD represents optical density.

**Mineral analysis**

The dry digestion method, as outlined by AOAC (2019), was applied in this study. One (1) g of homogenized sample was weighed into a crucible and placed in a muffle furnace at 450 °C for 8 hours to produce ash, which was then cooled in a desiccator. The ash was digested using 2 mL of 6 M HCl, evaporated to dryness, then dissolved and diluted to 100 mL with 0.1 M nitric acid. The resulting digest was analyzed for specific elements: sodium (Na) and potassium (K) were quantified using a Jenway digital flame photometer. At the same time, magnesium (Mg) and iron (Fe) were measured using an atomic absorption spectrophotometer.

**Determination of starch**

The starch content was determined using the method described by Hodge and Hofreiter (1962). First, 0.5 g of the sample was weighed and treated with hot 80% ethanol to remove sugars, followed by centrifugation to retain the residue. The residue was repeatedly washed with hot 80% ethanol until the washings showed no color with Anthrone reagent. It was then thoroughly dried over a water bath before being mixed with 5.0 mL of water and 6.5 mL of 52% perchloric acid. Extraction was conducted at 0°C for 20 minutes, followed by centrifugation to collect the supernatant.

A second extraction using fresh perchloric acid was performed, and after centrifugation, the supernatants were pooled and diluted to 100 mL. To prepare standards, 0.1 or 0.2 mL of the supernatant was pipetted and brought to 1 mL with water. Additional standards were prepared by diluting 0.2, 0.4, 0.6, 0.8, and 1 mL of the working standard to 1 mL with water. Subsequently, 4 mL of Anthrone reagent was added to each tube, and the tubes were heated in a boiling water bath for eight minutes. The samples were then rapidly cooled, and the intensity of the green to dark green color was measured at 630 nm.

**Microbiological analyses**

The plantain samples were properly labeled, washed with sterile water, and placed in well-marked 225 mL beakers. One milliliter of the homogenate was added to 9 mL of distilled water in a test tube labeled 1:10 ($10^{-1}$) dilution. Then, the solution was serially diluted across five additional test tubes labeled $10^{-2}$, $10^{-3}$, $10^{-4}$, and $10^{-5}$ using sterile pipettes. This procedure was repeated for each group.

Next, 1 mL of the $10^{-5}$ and $10^{-3}$ dilutions was aseptically transferred into sterile petri dishes. Nutrient agar and potato dextrose agar media were prepared according to the manufacturer's instructions. The plates were incubated in an inverted position at 37 °C for 24 hours to promote bacterial growth and for 2–5 days to promote fungal growth. After incubation, colony enumeration was performed. Results are reported as log CFU/g sample, following the method described by Fawole & Oso (2007).

**Sensory evaluation**

The sensory evaluation of the stored samples was conducted. The samples were presented to a trained panel of 20 members. The panelists assessed the samples based on color, appearance, odor, texture, and overall acceptability using a 9-point hedonic scale, where one represented "dislike extremely" and nine represented "like extremely," following the method described by Lawal et al. (2019).

**Statistical analysis**

All collected data were analyzed using a one-way Analysis of Variance (ANOVA) in the SPSS Software Package Version 20.0.0 (IBM Statistics Inc.). Mean values were separated using the New Duncan Multiple

Range Test (DMRT) at a 95% confidence level ($p < 0.05$).

## Results and Discussion

### Percentage weight loss of stored plantain

Figure 1 presents the percentage weight loss of stored plantains, which ranged from 28% to 60%. The differential weight loss observed across treatments (28-60%) provides critical insights into the preservation mechanisms of composite coatings. Treatment B (gum arabic + clove extract) achieved the lowest weight loss (28%), while treatment D (gum arabic alone) recorded the highest (60%), demonstrating that antimicrobial fortification significantly enhances the physical barrier properties of polysaccharide coatings. This finding aligns with Nxumalo et al. (2022), who demonstrated that gum arabic forms semi-permeable barriers that restrict water vapor transmission through stem-end scars and lenticels, the primary routes of transpirational moisture loss in plantain fruits. The superior performance of clove-fortified coatings can be attributed to eugenol's dual functionality. Eugenol comprises 70–85% of clove oil composition, and its hydrophobic nature enhances the coating's moisture barrier properties, while its phenolic hydroxyl groups provide antioxidant activity that stabilizes membrane lipids, thereby maintaining cellular integrity and reducing senescence-associated water loss (Kumar et al., 2022).

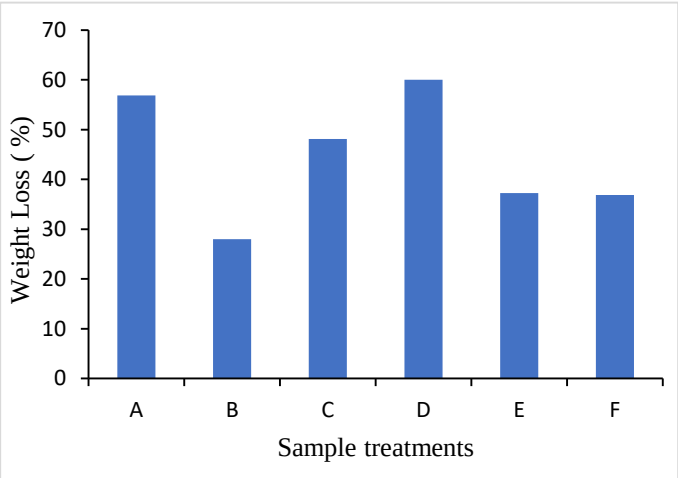


Figure 1: Effect of natural preservatives on the average weight loss of plantain. A=gum arabic + Cinnamon extract, B= gum arabic + Clove extract, C = gum arabic + Bay leaf extract, D=gum arabic, E= Control, F= gum arabic + Shea butter.

### Moisture and ash content

The moisture and ash contents of the coated plantains are detailed in Table 1. A general decrease in the moisture content of the stored plantains was observed, from an initial value of 67.880%, which aligns with the observed result for weight loss. This decrease may be attributed to variations in water vapor pressure between the produce and its storage environment, resulting in vapor-phase diffusion. Additionally, cellular membrane disintegration, which leads to the leakage of cellular contents and subsequently accelerates senescence (Hailu et al., 2013). At day 15, the lowest moisture content was observed in treatments B and F, while the bay leaf extract treatment in sample D must have contributed to its reduced moisture loss
Regarding ash content, the coated plantain exhibited an increase as the storage period progressed, starting from an initial value of 0.457. The highest ash content observed was 2.387 in Treatment C, whereas the lowest increase was 0.974 in Treatment F, both at day 15. Where ash content gives an estimate of the amount of minerals present in a food sample, further analyses provide detailed information on the individual mineral constituents that make up the ash content. According to Lawal et al. (2019), surface applications have a minimal impact on the mineral content in stored produce. Since edible coatings effectively influence surface-related processes (such as moisture loss and gas exchange), they have a limited impact on internal mineral metabolism. This indicates that the observed trend in ash content can be attributed to the reduced moisture content and weight loss previously observed, which increased the dry matter available in the fruits.

### Colour of stored plantain

The colour changes in stored plantains coated with various treatments over different days are summarized in Table 2. The color variations were evaluated using the L, a*, b* colour space parameters, where L indicates lightness, a* represents the green-to-red axis, and b* corresponds to the blue-to-yellow axis. On day 3, Treatment A showed an increased L value, reaching 17.06, indicating a lighter color compared to the initial measurement. Treatment B exhibited a similar pattern. Meanwhile, Treatments C, D, and E displayed varying changes in their L, a*, and b* values. Treatment F also displayed a small increment in L value. By day 6, Treatment A experienced a decrease in L value, indicating a shift toward a darker colour. Treatment B showed a notable reduction in its L value. Similar trends were observed in Treatments C, D, and E, with changes in their colour parameters. Treatment F exhibited a decline in L value during this period. On day 15, Treatment A showed a significant decrease in L value, while Treatment B also recorded a decrease. Treatments C and D reflected alterations in their colour parameters, with Treatment E experiencing a

substantial reduction in L value. Treatment F displayed a slight decrease in L value as well.

The findings revealed that the coated samples displayed varied colour changes over time, unlike the uncoated sample. These colour variations, observed in plantains treated with different coatings, underscore the potential role of substances like Shea butter and gum arabic in maintaining colour stability and quality during storage. The unique attributes of these coatings, such as their phytochemical compounds, fatty acid profiles, and mineral content, may have contributed to the observed differences in colour.

Treatment F, which involved Shea butter, exhibited distinctive colour changes throughout the storage period. The application of Shea butter likely led to unique colour variations due to its phytochemical composition (Abubakar et al., 2022). Shea butter has long been recognized for its traditional, medicinal, and industrial applications (Kolawole, 2024). Additionally, the physicochemical properties of Shea butter, including its fatty acid makeup and triglyceride content, as reported by Musa et al. (2016) and Lykke et al. (2021), may have influenced the colour changes in treatment F. The presence of essential minerals in Shea butter, as highlighted by Musa et al. (2016) and Megnanou & Niamké (2021), could also contribute to its impact on the plantains' colour.

**Table 1: Moisture and Ash Content of Stored Plantain**

| Treatments | Storage days | Moisture content | Ash content |
|---|---|---|---|
| **A** | 0 | 67.880±0.111$^{a}$ | 0.457±0.017$^{a}$ |
| **B** | | 67.880±0.111$^{a}$ | 0.457±0.017$^{a}$ |
| **C** | | 67.880±0.111$^{a}$ | 0.457±0.017$^{a}$ |
| **D** | | 67.880±0.111$^{a}$ | 0.457±0.017$^{a}$ |
| **E** | | 67.880±0.111$^{a}$ | 0.457±0.017$^{a}$ |
| **F** | | 67.880±0.111$^{a}$ | 0.457±0.017$^{a}$ |
| **A** | 5 | 64.174±0.262$^{c}$ | 1.131±0.050$^{a}$ |
| **B** | | 65.080±0.603$^{d}$ | 1.297±0.212$^{a}$ |
| **C** | | 63.396±0.233$^{bc}$ | 1.313±0.014$^{a}$ |
| **D** | | 66.458±0.341$^{e}$ | 1.228±0.044$^{a}$ |
| **E** | | 62.301±0.408$^{b}$ | 1.123±0.102$^{a}$ |
| **F** | | 61.040±0.178$^{a}$ | 1.191±0.011$^{a}$ |
| **A** | 10 | 59.083±0.153$^{a}$ | 1.894±0.092$^{d}$ |
| **B** | | 67.690±0.392$^{f}$ | 1.305±0.237$^{b}$ |
| **C** | | 65.911±0.250$^{e}$ | 1.270±0.015$^{ab}$ |
| **D** | | 62.450±0.400$^{c}$ | 1.028±0.055$^{a}$ |
| **E** | | 63.799±0.183$^{d}$ | 1.209±0.084$^{ab}$ |
| **F** | | 60.291±0.436$^{b}$ | 1.402±0.069$^{c}$ |
| **A** | 15 | 62.434±0.247$^{bc}$ | 1.860±0.259$^{c}$ |
| **B** | | 60.999±0.479$^{a}$ | 1.974±0.097$^{c}$ |
| **C** | | 62.952±0.880$^{c}$ | 2.387±0.059$^{d}$ |
| **D** | | 65.660±0.788$^{d}$ | 1.610±0.035$^{b}$ |
| **E** | | 61.669±0.470$^{ab}$ | 1.191±0.007$^{ab}$ |
| **F** | | 60.768±0.301$^{a}$ | 0.974±0.119$^{a}$ |

The results are presented as mean ± standard error (SE) based on triplicate readings. Means within the same column that have unshared superscripts are significantly different at a 95% confidence level ($p < 0.05$). A=gum arabic + Cinnamon extract, B= gum arabic + Clove extract, C = gum arabic + Bay leaf extract, D=gum arabic, E= Control, F= gum arabic + Shea butter

## Colour of stored plantain

The colour changes in stored plantains coated with various treatments over different days are summarized in Table 2. The color variations were evaluated using the L, a*, b* colour space parameters, where L indicates lightness, a* represents the green-to-red axis, and b* corresponds to the blue-to-yellow axis. On day 3, Treatment A showed an increased L value, reaching 17.06, indicating a lighter color compared to the initial measurement. Treatment B exhibited a similar pattern. Meanwhile, Treatments C, D, and E displayed varying changes in their L, a*, and b* values. Treatment F also displayed a small increment in L value. By day 6, Treatment A experienced a decrease in L value, indicating a shift toward a darker colour. Treatment B showed a notable reduction in its L value. Similar trends were observed in Treatments C, D, and E, with changes in their colour parameters. Treatment F

exhibited a decline in L value during this period. On day 15, Treatment A showed a significant decrease in L value, while Treatment B also recorded a decrease. Treatments C and D reflected alterations in their colour parameters, with Treatment E experiencing a substantial reduction in L value. Treatment F displayed a slight decrease in L value as well.

The findings revealed that the coated samples displayed varied colour changes over time, unlike the uncoated sample. These colour variations, observed in plantains treated with different coatings, underscore the potential role of substances like Shea butter and gum arabic in maintaining colour stability and quality during storage. The unique attributes of these coatings, such as their phytochemical compounds, fatty acid profiles, and mineral content, may have contributed to the observed differences in colour.

Treatment F, which involved Shea butter, exhibited distinctive colour changes throughout the storage period. The application of Shea butter likely led to unique colour variations due to its phytochemical composition (Abubakar et al., 2022). Shea butter has long been recognized for its traditional, medicinal, and industrial applications (Kolawole, 2024). Additionally, the physicochemical properties of Shea butter, including its fatty acid makeup and triglyceride content, as reported by Musa et al. (2016) and Lykke et al. (2021), may have influenced the colour changes in treatment F. The presence of essential minerals in Shea butter, as highlighted by Musa et al. (2016) and Megnanou & Niamké (2021), could also contribute to its impact on the plantains' colour.

**Table 2: Colour of Stored Plantain**

| Days | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | | | **Day 0** | | | |
| **L** | 16.14±0.02$^{a}$ | 16.14±0.02$^{a}$ | 16.14±0.02$^{a}$ | 16.14±0.02$^{a}$ | 16.14±0.02$^{a}$ | 16.14±0.02$^{a}$ |
| **a*** | -1.92±0.04$^{a}$ | -1.92±0.04$^{a}$ | -1.92±0.04$^{a}$ | -1.92±0.04$^{fg}$ | -1.92±0.04$^{a}$ | -1.92±0.04$^{a}$ |
| **b*** | 13.83±0.14$^{a}$ | 13.83±0.14$^{a}$ | 13.83±0.14$^{a}$ | 13.83±0.14$^{a}$ | 13.83±0.14$^{a}$ | 13.83±0.14$^{a}$ |
| | | | **Day 3** | | | |
| **L** | 17.06±0.31$^{bc}$ | 17.68±0.71$^{c}$ | 18.49±0.23$^{d}$ | 16.57±0.13$^{b}$ | 16.15±0.07$^{a}$ | 17.56±0.12$^{c}$ |
| **a*** | -3.68±0.07$^{bc}$ | -3.54±0.17$^{bc}$ | -3.15±0.10$^{b}$ | -3.58±0.14$^{bc}$ | -3.37±0.16$^{bc}$ | -2.67±0.08$^{a}$ |
| **b*** | 14.25±0.20$^{c}$ | 15.31±0.33$^{de}$ | 13.72±0.04$^{b}$ | 13.05±0.67$^{a}$ | 15.51±0.16$^{e}$ | 13.16±0.44$^{a}$ |
| | | | **Day 6** | | | |
| **L** | 19.66±0.15$^{m}$ | 17.64±0.04$^{jkl}$ | 16.68±0.90$^{hij}$ | 15.66±0.57$^{gh}$ | 14.19±1.03$^{f}$ | 18.08±0.34$^{kl}$ |
| **a*** | -3.43±0.07$^{ab}$ | -2.89±0.08$^{cde}$ | -1.78±0.11$^{g}$ | -3.42±0.22$^{ab}$ | -2.42±0.11$^{ef}$ | -1.79±0.01$^{g}$ |
| **b*** | 16.35±0.10$^{m}$ | 12.77±0.28$^{ghij}$ | 12.85±0.38$^{ghij}$ | 16.50±0.14$^{m}$ | 14.05±01.10$^{ijk}$ | 13.92±01.96$^{ijk}$ |
| | | | **Day 9** | | | |
| **L** | 16.06±0.11$^{ghi}$ | 12.45±0.20$^{de}$ | 11.39±0.25$^{cd}$ | 11.53±0.06$^{cd}$ | 10.94±0.13$^{c}$ | 11.54±0.15$^{cd}$ |
| **a*** | -1.68±0.16$^{g}$ | 0.51±0.10$^{k}$ | -0.18±0.03$^{i}$ | -0.89±0.15$^{h}$ | 0.33±0.07$^{jk}$ | -0.28±0.10$^{i}$ |
| **b*** | 9.20±0.37$^{ef}$ | 9.65±0.09$^{f}$ | 8.27±0.29$^{def}$ | 7.94±0.17$^{cde}$ | 9.11±0.01$^{ef}$ | 9.74±0.06$^{f}$ |
| | | | **Day 12** | | | |
| **L** | 13.62±1.06$^{f}$ | 13.41±0.73$^{ef}$ | 16.62±0.06$^{hij}$ | 15.97±0.25$^{ghi}$ | 15.30±0.62$^{g}$ | 17.57±0.08$^{jkl}$ |
| **a*** | 2.07±0.43$^{lm}$ | 3.36±0.37$^{n}$ | 0.45±0.22$^{k}$ | -0.06±0.02$^{i}$ | 3.82±0.45$^{n}$ | 1.75±0.04lm |
| **b*** | 9.24±0.46$^{ef}$ | 7.06±0.63$^{bcd}$ | 13.01±0.19$^{hij}$ | 11.47±0.20$^{g}$ | 12.61±0.62$^{ghi}$ | 11.85±0.10$^{gh}$ |
| | | | **Day 15** | | | |
| **L** | 8.88±0.02$^{b}$ | 10.51±0.14$^{c}$ | 7.47±0.21$^{a}$ | 12.40±0.10$^{de}$ | 16.71±0.14$^{hij}$ | 11.53±0.29$^{cd}$ |
| **a*** | 1.78±0.11$^{lm}$ | 0.45±0.02$^{k}$ | 1.59±0.09$^{l}$ | 2.23±0.07$^{m}$ | 4.55±0.19$^{o}$ | 2.20±0.27$^{m}$ |
| **b*** | 8.62±0.18$^{ef}$ | 6.64±0.12$^{bc}$ | 2.70±0.11$^{a}$ | 6.00±0.07$^{b}$ | 13.37±0.22$^{ij}$ | 9.73±0.14$^{f}$ |

Results are expressed as mean ± standard error (SE) based on triplicate readings. Means within the same row that have unshared superscripts indicate a significant difference at a 95% confidence level ($p < 0.05$). A=gum arabic + Cinnamon extract, B= gum arabic + Clove extract, C = gum arabic + Bay leaf extract, D=gum arabic, E= Control, F= gum arabic + Shea butter

**Pulp/Peel Ratio of Stored Plantain**

The Pulp/Peel ratio of stored plantains is an essential indicator of changes in composition and quality during storage. As shown in Table 3, the initial ratio of 1.259 provides a baseline for assessing the final ratios of the coating treatments (A to F), which ranged between 2.462 and 2.931. This noticeable increase in the Pulp/Peel ratio indicates significant alterations in the fruit's composition, potentially driven by factors such as ripening, water loss, and the efficacy of the applied coatings (Martirosyan et al., 2023).

**Table 3: Pulp/Peel ratio of stored plantain**

| Treatment | Day 0 | Day 15 |
|---|---|---|
| **A** | 1.259 | 2.624 |
| **B** | 1.259 | 2.931 |
| **C** | 1.259 | 2.746 |
| **D** | 1.259 | 2.691 |
| **E** | 1.259 | 2.648 |
| **F** | 1.259 | 2.462 |

A=gum arabic + Cinnamon extract, B= gum arabic + Clove extract, C = gum arabic + Bay leaf extract, D=gum arabic, E= Control, F= gum arabic + Shea butter

**Decay incidence of stored plantain**

The decay incidence findings, as highlighted in Table 4, reveal that only the plantains coated with gum arabic + bay leaf extract recorded decay incidence during storage, with 33.33% of fruits affected. In contrast, all other treatments (gum arabic alone, gum arabic combined with cinnamon, clove, or shea butter, as well as the control) showed no decay incidence. Gum arabic has been reported to possess a natural film-forming ability, capable of reducing respiration rate, delaying senescence, and creating a semi-permeable barrier that restricts oxygen diffusion and microbial invasion (Embuscado & Huber, 2009; Ali et al., 2010). Its effectiveness is further enhanced when combined with antimicrobials such as essential oils and extracts rich in phenolic compounds, which exhibit broad-spectrum activity against food spoilage microorganisms (Dutta et al., 2021). However, the decay incidence recorded for plantains coated with gum arabic combined with bay leaf extract suggests that bay leaf extract may be less effective in suppressing microbial growth under the given storage conditions. Although bay leaf contains bioactive compounds such as cineole, eugenol, and linalool, which possess antimicrobial properties (Gamal et al., 2021), the concentration of the extract used in this study may not have been sufficient to confer significant antifungal protection. It was also observed that the control samples (E) showed no decay incidence during the storage period, which suggests that the storage environment itself may have been generally unfavorable to rapid fungal proliferation.

**pH of stored plantain**

The pH levels of stored plantain ranged from 4.87 to 6.45, signifying mild acidity. All samples had a consistent pH of 6.227, which is consistent with Adi et al. (2019), who observed values between 6.2 and 6.5 for mature green plantains under normal conditions. Over time, some samples experienced a decrease in pH, while others remained relatively stable. By day 5, Treatments C and D showed noticeable increases in acidity, with pH values dropping to 4.87 and 5.25. This decline aligns with findings by Mogaji & Mogaji (2020), who identified peak microbial and enzymatic activity, particularly lipase and pectinase, around the fifth day, resulting in greater acid production. Umeh et al. (2017) also linked microbial growth to accelerated spoilage and acidification in unrefrigerated settings. Conversely, Treatments A, B, E, and F maintained higher pH levels; treatments A and F reached 6.25 and 6.23, respectively, by day 10. This deviates from usual ripening trends where acid accumulation typically reduces pH. Interestingly, Treatments E and F showed a pH rise on day 5, possibly due to acid breakdown and biochemical changes during the later stages of ripening, as explained by Campos et al. (2022). By day 15, Treatments A and F retained relatively high pH levels (6.24 and 6.153), suggesting reduced acid formation or stronger buffering systems.

**Table 4: Post-Storage Decay Rate (%) in Plantain Fruits**

| Treatment | % Decay Incidence |
|---|---|
| A | 0 |
| B | 0 |
| C | 33.33 |
| D | 0 |
| E | 0 |
| F | 0 |

A=gum arabic + Cinnamon extract, B= gum arabic + Clove extract, C = gum arabic + Bay leaf extract, D=gum arabic, E= Control, F= gum arabic + Shea butter

**Total Titratable Acidity (TTA) of stored plantains**

During the storage period, total titratable acidity (TTA) values ranged from 0.06 to 0.30 (Figure 3). TTA was found to increase over time, with no significant difference ($p < 0.05$) between the untreated and treated samples on day 0, which was expected since all samples originated from the same source. This pattern aligns with established ripening physiology and microbial dynamics in plantain storage. The rise in TTA values in Samples C and D by day 5 (0.21 and 0.18) is consistent with findings by Tortoe et al. (2019)**,** who reported that organic acid accumulation during early ripening stages contributes to increased acidity, peaking around mid-storage. Similarly**,** Sugri & Johnson (2009) observed that plantains stored under modified atmosphere conditions showed elevated TTA levels during the first 10 days, attributed to metabolic activity and starch conversion. By day 10, Treatment E (control) reached the highest TTA value of 0.30**,** which aligns with the results of Adi et al. (2019), who

recorded a peak acidity of 0.29 in untreated plantains nearing senescence. This suggests that untreated samples may undergo faster biochemical changes, leading to higher acid buildup compared to coated or treated samples. The observed decline in Treatments A, B, C, and E may be due to acid catabolism or microbial degradation of organic acids, as noted by Hagan et al. (2022) in their study on 1-MCP-treated plantains. In contrast**,** Treatments D and F showed a continued increase, possibly due to delayed ripening or enhanced preservation effects, similar to the findings of Sugri et al. (2010), who reported that shea butter coatings extended shelf life and maintained acidity for longer.

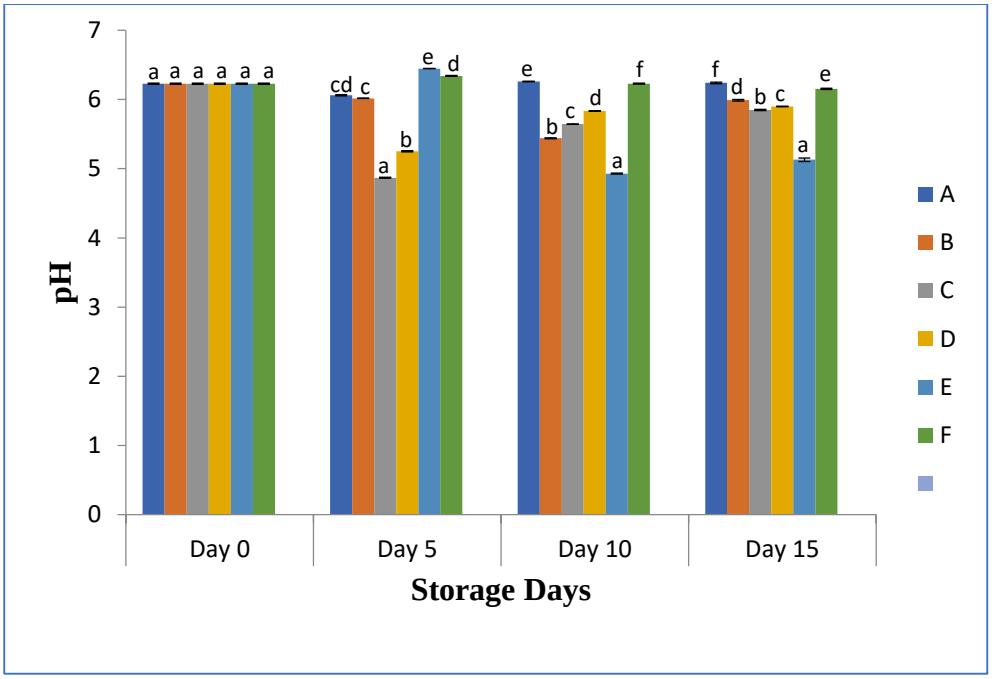


Figure 2: Effect of natural preservatives on the pH of plantain. Each bar represents the mean of triplicate readings (n=3)**.** A= gum arabic + Cinnamon, B= gum arabic + Clove, C= gum arabic + Bay leaf, D=gum arabic, E= Control, F= gum arabic + Shea butter

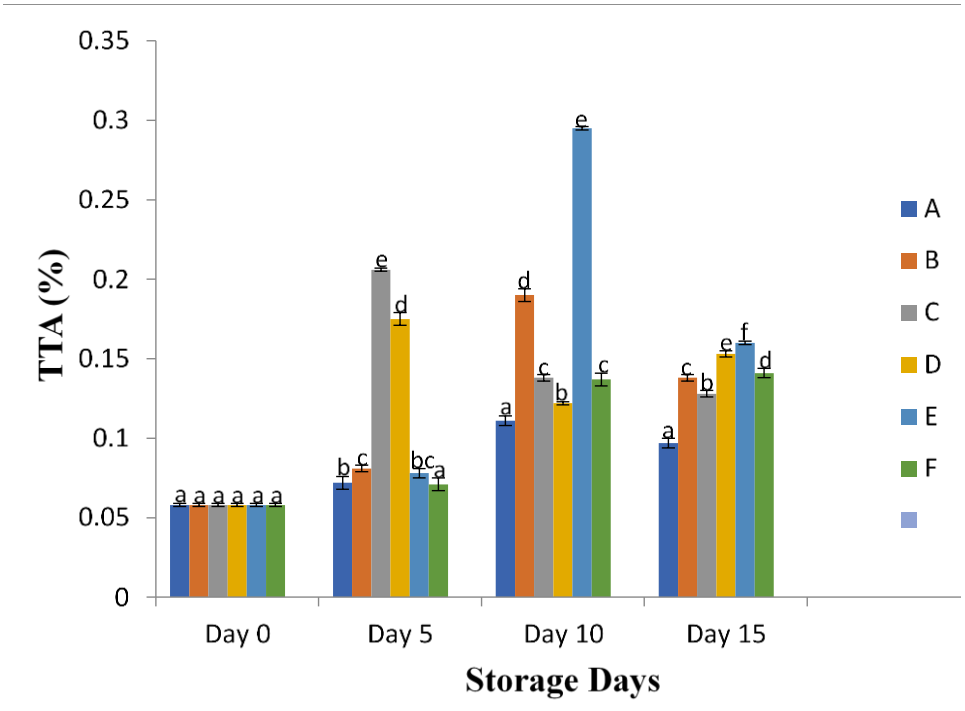


Figure 3: Effect of natural preservatives on the TTA (%) of plantain. Each bar represents the mean of triplicate readings (n=3)**.** A= gum arabic + cinnamon, B= gum arabic + clove, C= gum arabic + Bay leaf, D=gum arabic, E= Control, F= gum arabic + shea butter

**Total Soluble Solids (TSS) of stored plantains**

As the stored plantains ripened, the total soluble solids (TSS) content increased progressively. In the control group, TSS values increased from 0.867 to 2.3, as illustrated in Figure 4. Over the 15-day storage duration, the TSS of the control plantains exhibited a continuous increase. Notably, a sharp rise in TSS was reported on day 10, which was likely attributed to water loss from the fruits and the ripening process, facilitating enzymatic digestion of carbohydrates and thereby increasing TSS levels (Jain & Mukherjee, 2011). Treatment C was found to exhibit the highest TSS value of 2.267 on day 5, while the control group reportedly reached its peak TSS value of 2.167 on day 15. The results observed for the coated fruits at day 15 of storage suggest that the applied coatings were able to reduce metabolic reactions and processes within the fruits, thereby slowing down the ripening process.

**Vitamin C, carotenoids, and starch contents of stored plantains**

The results of the Vitamin C and provitamin analyses were illustrated in Figures 5, 6, and **7**. At day 15 of storage, evident variations in these parameters were observed, influenced by the specific treatments applied to the plantain fruits. The vitamin C levels showed a significant increase ($p < 0.05$) across both the control and the treated groups (A, B, C, D, and F) as storage days progressed. This increase in vitamin C content can be attributed to the ripening of the fruits over the storage period, and corroborates the findings of Emmanuel et al. (2018), who observed a similar pattern in the vitamin C content of stored tomato varieties during shelf-life studies.

Regarding β-carotene, its degradation occurred consistently across both treated and untreated groups, with no notable statistical difference. Among the groups, the untreated control E experienced the highest level of degradation (0.022 mg/100 g), while treatment D showed the greatest retention (0.028 mg/100 g). Similar results were observed for Lycopene degradation, with the most substantial losses recorded in treatments D and E (0.013 mg/100 g) and the least degradation in treatment A (0.017 mg/100 g). Although the coating treatments were unable to preserve the carotenoid content of the fruits fully, a significant difference ($p < 0.05$) was observed in the carotenoid content of the treated fruits compared to the control, which was significantly lower. These observations align with those of Onyegbula et al. (2023), who reported carotenoid degradation during post-harvest quality studies on red-ripe tomato fruits coated with Aloe gel.

Conversely, starch content displayed a marked increase (Figure 8) across the treatments, with treatment F showing the most pronounced rise (58.228 ± 0.002). This aligns with Adetuyi & Lola (2010), who found an increase in starch content in stored plantains treated with wax coatings. The rise in starch can be attributed to the conversion of acids into sugars, which are typically stored as starch during the ripening of plantains.

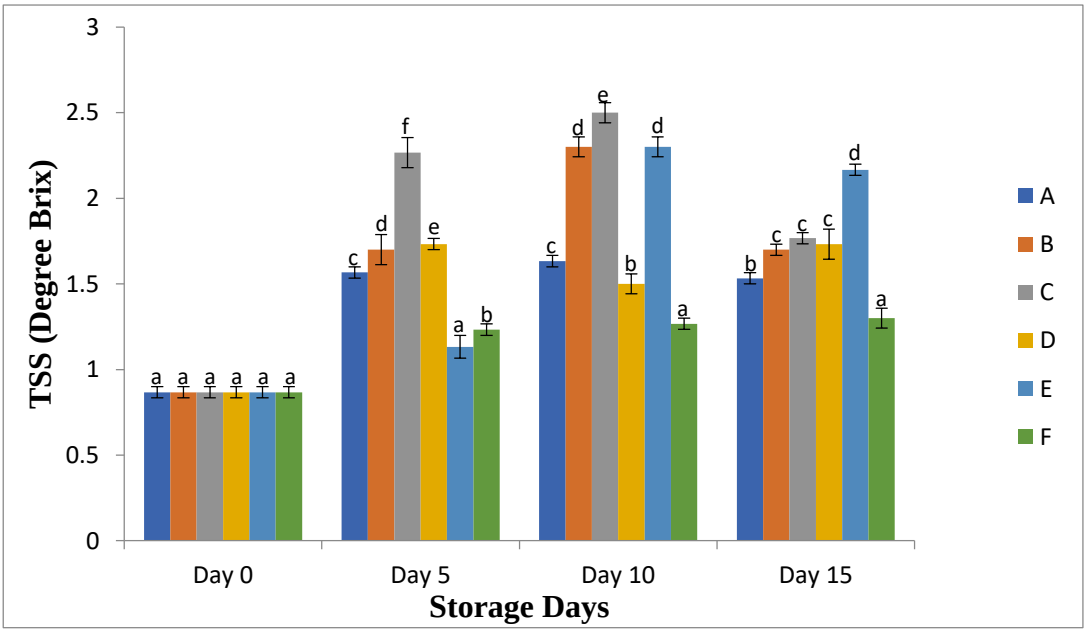


Figure 4: Effect of natural preservatives on the TTS (Degree Brix) of plantain. Each bar represents the mean of triplicate readings (n=3)**.** A= gum arabic + Cinnamon, B= gum arabic + Clove, C= gum arabic + bay eaf, D=gum arabic, E= Control, F= gum arabic + shea butter

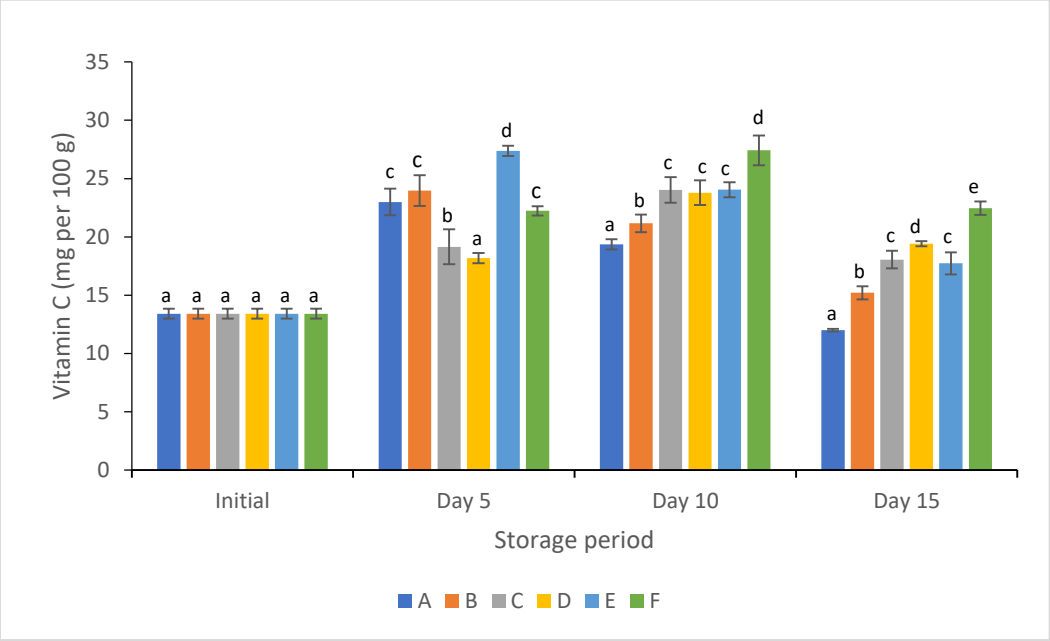


Figure 5: Vitamin C content in both treated and untreated plantains during storage.The results are presented as mean ± standard error (SE) based on triplicate readings. Means with unshared superscripts indicate statistically significant differences at a 95% confidence level. A= gum arabic + Cinnamon, B= gum arabic + Clove, C= gum arabic + bay eaf, D=gum arabic, E= Control, F= gum arabic + shea butter

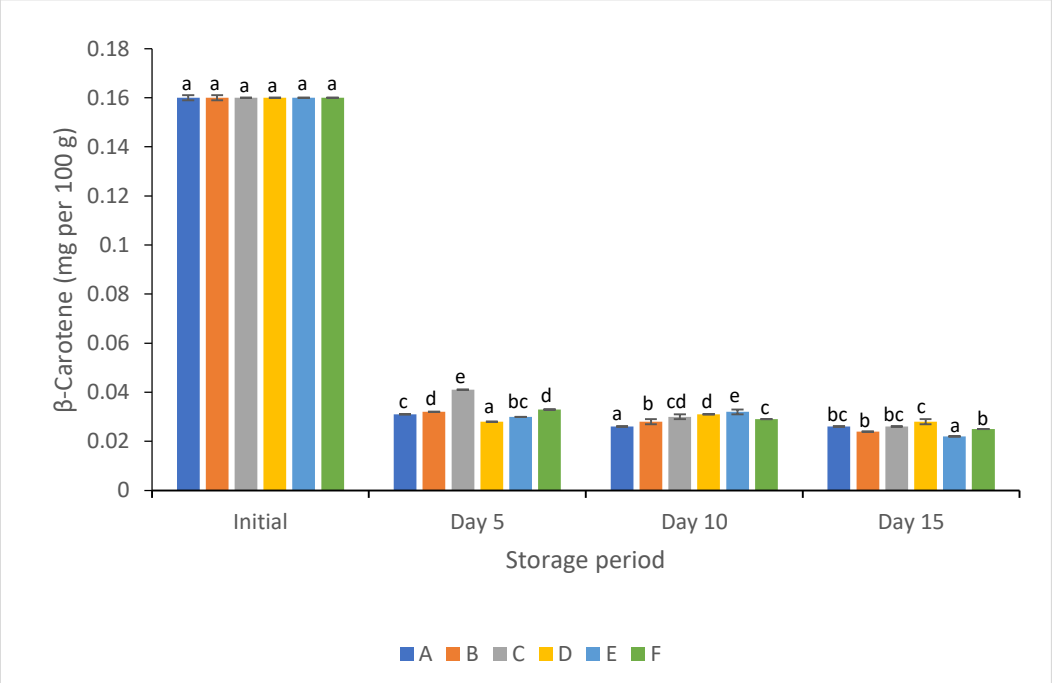


Figure 6: β-Carotene content of the treated and untreated plantain during storage. The results are presented as mean ± standard error (SE) based on triplicate readings. Means with unshared superscripts indicate statistically significant differences at a 95% confidence level. A= gum arabic + Cinnamon, B= gum arabic + Clove, C= gum arabic + bay eaf, D=gum arabic, E= Control, F= gum arabic + shea butter

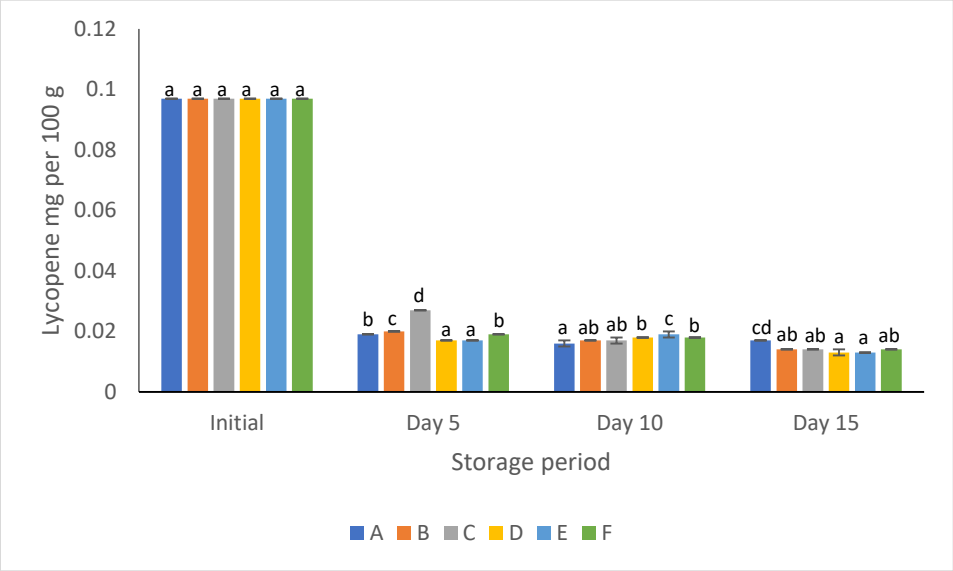


Figure 7: Lycopene content of the treated and untreated plantain during storage. The results are presented as mean ± standard error (SE) based on triplicate readings. Means with unshared superscripts indicate statistically significant differences at a 95% confidence level. A= gum arabic + Cinnamon, B= gum arabic + Clove, C= gum arabic + bay eaf, D=gum arabic, E= Control, F= gum arabic + shea butter

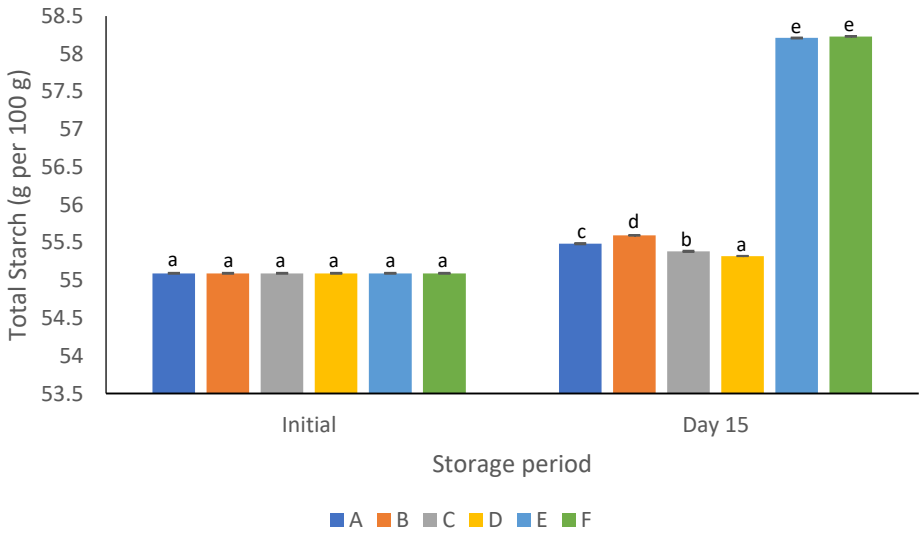


Figure 8: Total Starch Content of the treated and untreated plantain during storage. The results are presented as mean ± standard error (SE) based on triplicate readings. Means with unshared superscripts indicate statistically significant differences at a 95% confidence level. A= gum arabic + Cinnamon, B= gum arabic + Clove, C= gum arabic + bay eaf, D=gum arabic, E= Control, F= gum arabic + shea butter

## Mineral Composition

Mineral elements are essential chemical compounds that plants absorb from the soil for growth and development, forming vital nutrients. Their roles span biological functions, bodily mechanisms, or systemic processes in the body (FAO, 2011; Omorodion & Chinwo, 2022). This study focused on four mineral elements (potassium, magnesium, sodium, and iron) in plantains (Table 5). Among the tested samples, plantain coated with shea butter exhibited the highest potassium content (8.54 mg/100 g). However, it showed no significant difference compared to those coated with gum arabic combined with cinnamon and bay leaf extract. Considering the slight differences in the individual mineral contents analyzed, this could be a result of the reduced moisture content reported earlier in this study, which makes additional dry matter available in the fruits, causing the notable changes in the mineral content of the fruits. Potassium emerged as the predominant mineral element in the plantain samples, followed by magnesium. Iron, on the other hand, was consistently present in low quantities, which aligns with the findings of Barnabas & Anthony (2019).

**Table 5: Mineral Composition (mg/100g) of Plantain Before and After Storage**

| Sample | Potassium | Magnesium | Sodium | Iron |
|---|---|---|---|---|
| Initial | 7.76±0.09$^{a}$ | 6.04±0.00$^{a}$ | 2.27±0.01$^{ab}$ | 0.34±0.01$^{b}$ |
| A | 8.12±0.06$^{ab}$ | 6.14±0.00$^{bc}$ | 2.38±0.01$^{ab}$ | 0.32±0.01$^{a}$ |
| B | 7.69±0.12$^{a}$ | 6.15±0.00$^{cd}$ | 2.37±0.12$^{ab}$ | 0.36±0.00$^{c}$ |
| C | 8.27±0.32$^{ab}$ | 6.66±0.00$^{f}$ | 2.48±0.11$^{ab}$ | 0.57±0.00$^{f}$ |
| D | 7.55±0.14$^{a}$ | 6.17±0.00$^{e}$ | 2.51±0.00$^{b}$ | 0.41±0.00$^{d}$ |
| E | 7.64±0.27$^{a}$ | 6.16±0.00$^{de}$ | 2.20±0.03$^{a}$ | 0.34±0.00$^{b}$ |
| F | 8.54±0.32$^{b}$ | 6.13±0.01$^{b}$ | 2.43±0.14$^{ab}$ | 0.47±0.00$^{e}$ |

The results are expressed as mean ± standard error based on duplicate readings. Means with unshared superscripts in the same row indicate significant differences ($p < 0.05$). A= gum arabic + Cinnamon, B= gum arabic + Clove, C= gum arabic + bay eaf, D=gum arabic, E= Control, F= gum arabic + shea butter

**Microbiological Analysis**

The enumeration of total heterotrophic bacteria across the experimental lots declined from an average of 6.4 log CFU on the initial day of storage to 5.1 log CFU (Table 6). Also, the total fungal count reduces from 5.08 log CFU/g to zero. Treatments A, B, and C exhibit retarded bacterial proliferation on coated samples compared to treatments D and F, with indicated proliferations compared to the control lot E; this highlights the delivered antimicrobial efficacies of cinnamon, clove, and bay-leaf extract over the consideration of gum arabic as a primary coating constituent in this study. In the acceptance of 5.0 log 10 CFU/g permissible bacteria population on fresh fruits (Omorodion & Chinwo, 2022), treatments A, B, and C are considered the most effective in post-harvest management of plantain under tropical conditions in Nigeria. Gum arabic-cinnamon-coated plantains had the highest antimicrobial effect, reducing the total heterotrophic bacteria count from 6.15 to 4.79 log CFU/g. Pandey et al. (2022) reported that cinnamon oils, along with eugenol and cinnamaldehyde, exhibit antimicrobial activity against both Gram-negative and Gram-positive bacteria.

**Table 6: Microbial Count of Plantain fruits before coating (day 0) and after storage (day 15)**

| Sample | Total Heterotrophic Bacteria Count (log CFU/g) | | Total Fungal Count (log CFU/g) | |
|---|---|---|---|---|
| | **Day 0** | **Day 15** | **Day 0** | **Day 15** |
| **A** | 6.15 | 4.79 | 5.08 | 0 |
| **B** | 6.2 | 4.7 | 5.26 | 0 |
| **C** | 5.61 | 4.72 | 5.2 | 2.7 |
| **D** | 6.81 | 5.3 | 4.95 | 2.7 |
| **E** | 6.73 | 5.18 | 5.28 | 4.7 |
| **F** | 6.8 | 5.76 | 6.77 | 5.62 |

Key: A- (treated with gum arabic + cinnamon), B (gum arabic + clove), C (gum arabic + bay leaf), D (gum arabic), E (Untreated), and F (gum arabic + shea butter). CFU- Colony Forming Unit

Consequently, cinnamon and clove demonstrate fungicidal properties, likely due to alterations in fungal cell wall permeability that disrupt essential cellular functions (do Nascimento et al., 2023). Similarly, Ranasinghe et al. (2002) found that cinnamon and clove oils effectively inhibited the growth of fungal pathogens such as *Colletotrichum musae*, *Lasiodiplodia theobromae*, and *F. proliferatum* in vitro. Furthermore, Mohd Israfi et al. (2022) reported that incorporating 4 mg/mL cinnamon oil into 100 mg/mL gum arabic reduced anthracnose incidence in post-harvest bananas by 80% and minimized weight loss by 89% after 28 days of cold storage, compared to untreated bananas. Additionally, cinnamon oil inhibited 88% of *Colletotrichum musae* growth in vitro, and at concentrations up to 0.3%, it presents a promising and safe method for post-harvest anthracnose control in bananas (Maqbool et al., 2011)

The observation on fungal counts presents the interrelationship between the effectiveness of bio-preservative agents, the innate plant's defense, and microbial dynamics under storage conditions. The initially high fungal contaminants, which exceeded the recommended limits of 4.0 log 10 CFU/g, were significantly inhibited by the cinnamon and clove constituents of the applied coatings in this study, as evidenced by sustained potencies at the 15th-day evaluations for treatments A and B. The complexities of microbial succession hinder the appraisal of efficacies exhibited as fungicidal or fungistatic; a longer study duration could have allowed for such an assertion. The functional property of gum arabic as a primary coating base and the antimicrobial potency of bay-leaf extract were also deduced from the presented result (Figure 6), with a lesser fungal populace than the uncoated plantain fruits. Microorganisms, including yeasts, molds, and bacteria, primarily drive microbiological spoilage in fruits. The total bacterial population reflects both the natural microflora and

potential contamination from farming practices and transportation. Meanwhile, the favorable pH conditions enable fungi, particularly yeasts and molds, to serve as the dominant agents of fruit spoilage (Chavan et al., 2023).

**Sensory evaluation**

The sensory evaluation results (Table 7) revealed significant differences ($p < 0.05$) among treatments for all the sensory attributes assessed (colour, appearance, odour, texture, and general acceptability). The gum arabic + shea butter coating received the highest ratings across all parameters, followed by the control and gum arabic alone. In contrast, plantains coated with gum arabic + bay leaf extract recorded the lowest scores. The impressive rating garnered for the sensory qualities of fruits coated with gum arabic and shea butter can be attributed to the film-forming and moisture-retaining abilities of both components. Shea butter acts as a natural lipid barrier, minimizing transpiration and oxidative browning, which helps maintain firmness and surface gloss (Akinmoladun et al., 2020). When combined with gum arabic, the composite coating likely formed a more cohesive and hydrophobic layer that slowed down respiration and pigment degradation, resulting in better colour and overall acceptability. Similar results have been reported in plantain and banana fruits coated with polysaccharide-lipid composites (Maftoonazad & Ramaswamy, 2019; Othman et al., 2021). The control (E) also received relatively high scores for appearance and texture, which may indicate that the 15-day storage duration was within an acceptable ripening stage for consumption. However, the coated samples generally showed improved sensory stability compared to untreated fruits under longer storage periods in other studies (Ali et al., 2010; Maqbool et al., 2011).

Fruits coated with gum arabic + bay leaf extract were least preferred by panelists in all sensory parameters. The low scores may be associated with the extract's characteristic strong herbal odour and possible phytochemical-induced surface discoloration, which could negatively affect consumer perception. Bay leaves are rich in eugenol and 1,8-cineole, known for their pungent aroma and potential to impart off-flavours in coated produce (Gamal et al., 2021). Additionally, this treatment showed an earlier decay incidence (Table 4), which likely contributed to its reduced sensory appeal. Treatments A and B (gum arabic combined with cinnamon and clove extracts) showed moderate ratings, which align with previous findings that essential oils from these spices enhance microbial stability but may slightly alter flavour and odour perception due to their intense volatile components (Prakash et al., 2018; Sharma et al., 2020).

**Table 7: Sensory properties of the stored plantains**

| Sample | Colour | Appearance | Odour | Texture | General Acceptability |
|---|---|---|---|---|---|
| **A** | $3.30\pm0.36^{b}$ | $3.30\pm0.39^{b}$ | $3.70\pm0.35^{b}$ | $3.40\pm0.51^{b}$ | $3.60\pm0.41^{b}$ |
| **B** | $2.40\pm0.30^{a}$ | $2.05\pm0.30^{a}$ | $3.30\pm0.32^{ab}$ | $2.75\pm0.35^{b}$ | $3.00\pm0.34^{ab}$ |
| **C** | $1.70\pm0.23^{a}$ | $1.70\pm0.23^{a}$ | $2.50\pm0.27^{a}$ | $1.75\pm0.24^{a}$ | $2.25\pm0.30^{a}$ |
| **D** | $5.35\pm0.31^{c}$ | $5.65\pm0.31^{c}$ | $5.70\pm0.26^{c}$ | $5.65\pm0.31^{c}$ | $6.05\pm0.17^{c}$ |
| **E** | $6.85\pm0.32^{d}$ | $6.95\pm0.27^{d}$ | $6.75\pm0.32^{d}$ | $6.95\pm0.29^{d}$ | $6.85\pm0.27^{c}$ |
| **F** | $7.45\pm0.38^{d}$ | $7.30\pm0.32^{d}$ | $6.90\pm0.33^{d}$ | $7.60\pm0.34^{d}$ | $7.75\pm0.25^{d}$ |

The result shows the mean ± standard error of 20 panelists. Means with unshared superscripts in the same row are significantly different ($p < 0.05$). A= gum arabic + Cinnamon, B= gum arabic + Clove, C= gum arabic + bay eaf, D=gum arabic, E= Control, F= gum arabic + shea butter

**Conclusion and Recommendation**

The findings of this study clearly demonstrated that gum arabic-based edible coatings, enhanced with natural bio-preservatives, serve as an effective and sustainable solution for significantly extending the shelf life of plantains in tropical environments. The combination of gum arabic and shea butter proved to deliver the best results, successfully maintaining fruit firmness, color, and sensory appeal, while restricting weight loss to just 32% and ensuring nutritional quality remains intact. In contrast, the coatings made with gum arabic paired with clove and cinnamon exhibited superior antimicrobial effects, achieving an impressive reduction in bacterial counts of over 80% and completely eradicating fungal growth. These composite coatings operate through complementary mechanisms, moisture regulation, gas exchange control, and strong antimicrobial action, making them a viable, cost-effective alternative to synthetic preservatives. This approach is particularly advantageous for smallholder farmers who operate in regions with inadequate cold-chain infrastructure.

Future research should focus on optimizing coating concentrations, exploring nano- or microencapsulation

techniques for controlled bioactive release, and evaluating the coatings across diverse plantain cultivars and climatic conditions. Broader techno-economic analyses and consumer acceptance studies were also suggested to support large-scale application and commercialization.

**Acknowledgment**

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