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Influence of Leaf Extract of *Lantana camara* Integrated with Maize-based Coating on the Quality of Fresh *Talinum triangulare* and *Telfairia occidentalis* Leaves

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Abstract

Fresh *Talinum triangulare* and *Telfairia occidentalis* leaves have a short shelf life; therefore, there is a need to enhance their shelf life using natural antimicrobials to maintain their freshness. The effect of an ethanolic extract of *Lantana camara* leaf (10% w/v) integrated with a maize-based edible coating on fresh *T. triangulare* and *T. occidentalis* leaves was studied. Fresh *T. triangulare* and *T. occidentalis* leaves were evaluated for quality (pH, total carotenoid content, ascorbic acid, total phenolic content, fungal load, antioxidant activity, total soluble solids and browning potential) using a centered second-order polynomial (quadratic) model over a 9-day period. The pH values, browning potential, total soluble solids, and fungal loads of *T. triangulare* and *T. occidentalis* treated with the ethanolic leaf extract of *L. camara* integrated with maize-based coating had higher values than those of *T. triangulare* and *T. occidentalis* without treatment. Meanwhile, the total carotenoid content, ascorbic acid, total phenolic acid, and total antioxidant capacity of *T. triangulare* and *T. occidentalis* treated with the ethanolic leaf extract of *L. camara* integrated with maize-based coating had reduced values compared to *T. triangulare* and *T. occidentalis* without treatment. The disparity in the quality parameter values indicates bioactivity in *L. camara* integrated with a maize-based coating. This study shows that the integration of the ethanolic extract of the leaf of *L. camara* with the maize-based coating could be used as a biopreservation agent to improve the shelf life of *T. triangulare* and *T. occidentalis*.

Keywords: postharvest; shelf life; storage improvement; vegetable preservation

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INTRODUCTION

The need for safe and high-quality fresh fruits and vegetables has resulted in a rapid increase in the number of fruit and vegetable products available (Qadri et al., 2015). As a result of the acceptance, more production and marketing options have opened up (Adeogun et al., 2017). According to Bvenura and Sivakumar (2017), greater awareness of fruits and vegetables' health benefits has increased direct attention to them as daily meal components. This concentration on fruits and vegetables as crucial diet components is important for Sub-Saharan Africans (SSA).

Fruits and vegetables are currently sold as minimally processed items. To maximize their usefulness and keep their fresh-like features, minimally processed fruits and vegetables go

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through a series of operations: washing, sorting, peeling, slicing, chopping and packaging. Water loss, microbial invasion and enzymatic browning are all encouraged by minimal processing, leading to quality degradation (Muchtadi, 2021). As a result, pathogens in fruits and vegetables must still be reduced or eliminated. The use of synthetic preservatives and antimicrobial compounds to regulate the activities of microorganisms has been extensively investigated to reduce the loss of vegetables and fruits due to postharvest activity. Consumers' preference for fruits and vegetables strengthened with natural antimicrobials over synthetic preservatives could be attributed to safety concerns (Quinto et al., 2019). As a result, there is a growing aversion to fruits and vegetables kept with synthetic preservatives; literature has exposed the dangers of synthetic preservatives in people (Adekunle et al., 2021). They have been linked to various health problems, including hypersensitivity, asthma and cancer (Bondi et al., 2017).

Consumer apathy against the use of synthetic preservatives and the negative impact of non-biodegradable and non-renewable food packaging materials on consumer health prompted the development of environmentally friendly packaging materials, such as edible coatings derived from natural sources (Adekunle et al., 2021). The edible coating is a thin layer of biodegradable and environmentally acceptable substance with a thickness of less than 0.3 mm to improve post-harvest fresh fruits and vegetables by enrobing the food product to replace or fortify the natural layers. It can be consumed as it is or after being removed (Adekunle et al., 2021). They have been shown to protect fruits from moisture loss, solute exchange, gas exchange, respiration and oxidative reactions, among other things (Shiekh et al., 2013).

Many edible coatings have been researched for coating formulations, including locust beans (Kharchoufi et al., 2018), guar gum (Naeem et al., 2018), gum tragacanth (Mohebbi et al., 2012), chitosan (Kharchoufi et al., 2018), methylcellulose (Gunaydin et al., 2017), cassava starch (Chiumarelli and Hubinger, 2012), basil-seed gum (Hashemi et al., 2017) and gum acacia (Mahfoudhi and Hamdi, 2015). They have generally been accepted due to their edibility to humans. The active packing of vegetables is combined with essential oils and plant extracts (Adekunle et al., 2021). Valdés et al. (2017) found that combining natural antimicrobials with these edible coatings allows active packaging to increase the nutrition and quality of food without compromising the integrity of the fruit. Inclusion of the edible coating with natural antimicrobials aids in the efficacy of natural antimicrobials by decreasing the rapid diffusion of bioactive chemicals into the tissue of the fruits (Chouhan et al., 2017).

Natural antimicrobials derived from plants, such as medicinal spices, herbs, leaves, seed extracts, and essential oils, are referred to as secondary metabolites (Negi, 2012). They are of interest because secondary metabolites have antibacterial activity against foodborne pathogens (Gonelimali et al., 2018). Food pathogens such as *Aspergillus niger* and *Aspergillus flavus*, *Culvularia lanata*, *Alternaria alternata* and *Fusarium oxysporium* are susceptible to antifungal properties of *Lantana camara* leaves (Adekunle et al., 2021).

L. camara (Verbanaceae) is an underutilised climbing perennial shrub that forms dense thickets. The stems of *L. camara* are long and weak, square in cross-section, prickly (spiny) with glands on young parts. They are native to Central and South America, as has been thoroughly recorded (Osunkoya et al., 2012). They possess antimicrobial properties that help prevent food spoilage by suppressing microorganism's growth. Saponins, tannins, phlobatannins, flavonoids, terpenoids and steroids are phytochemical constituents that may be responsible for the antifungal effects of *L. camara* (Adekunle et al., 2021). The effect of enriching *L. camara* with a maize-based coating on the quality of fresh *Talinum triangulare* and *Telfairia occidentalis* leaves has not been investigated and the use of *L. camara* extract will provide a platform for peasants to increase the shelf life of their farm produce due to the low cost and availability of the extract for use in food plants. This context led to the need for this research, which sought to determine the effect of ethanolic extract of *L. camara* leaves enriched with maize-based edible coating on enhancing shelf life of *T. triangulare* and *T. occidentalis* leaves. Additionally, natural antimicrobials such as *L. camara* leaves coated with maize are expected to extend the shelf life of vegetables such as *T. triangulare* and *T. occidentalis*, with little or no toxicological impact on the environment and this would contribute to sustainable agricultural development (Lucera et al., 2012).

T. triangulare and *T. occidentalis* leaves are widely consumed and prepared as parts of the vegetable soup in most parts of Southern Nigeria. The stems of *T. triangulare* are erect, simple, or branching, while the roots are tuberous, robust, fleshy, or woody. The lower parts of the leaves are opposite and the upper parts of the leaves are alternate and spirally arranged (Orhuamen et al., 2012). *T. occidentalis* Hook. f., often known as fluted pumpkin, is found mostly found in West and Central Africa, including Benin, Nigeria and Cameroon. In Nigeria, it is commonly consumed as vegetable. *T. occidentalis* is a perennial climbing plant that produces herbaceous stems up to 15 m in length. These stems scramble over the ground and cling to other plants using tendrils as support. In west Africa, the plant is a popular source of food, as well as medicinal, oil and fibre. In Western Africa, it is cultivated economically for its seed and young shoots (Orhuamen et al., 2012; Chukwudi and Agbo, 2017).

MATERIALS AND METHOD

Collection of plant materials

Healthy samples of *T. triangulare* (waterleaf) and *T. occidentalis* (fluted pumpkin) were purchased from two local markets in Abule Oja and Oyingbo areas of the Lagos metropolis and transferred to the Mycology/Plant Pathology Laboratory at the University of Lagos. At the Lagos University Herbarium (LUH), they were authenticated. The Lagos University Herbarium was used to validate healthy leaves of *L. camara* taken on the main campus of the University of Lagos in Nigeria. The fruits were uniform in quality, maturity and size, free of disease symptoms, and used for this study between January and June 2021.

Preparation of plant extract

Healthy leaves of *L. camara* were harvested and shade dried for two weeks, then pulverized into powder and stored in a sterile, airtight container for experimentation. Milled *L. camara* leaves were extracted in absolute ethanol in a ratio of 1:2 w/v. The extract was filtered using Whatman filter paper No. 1832 after 48 hours and concentrated by evaporating at 40 °C in a rotary evaporator. Before usage, the extract was kept at 4 °C in the refrigerator (Adekunle et al., 2021; Souid et al., 2021).

Preparation of starch-based edible coating extract

A total of 5 g of dry ground maize (*Zea mays*) was weighed and the whole of the 5 g was poured into 95 ml of distilled water. This was equilibrated at 70 °C for 25 minutes and aggressively stirred on a hot plate with a magnetic stirrer. Then, 2 ml of glycerol was added as a plasticizer to increase the mechanical quality of the coating. The solution was then homogenized for 5 minutes after adding 10 g of *L. camara* extract (Ebabhi et al., 2019; Kawhena et al., 2022).

Phytochemical analysis of the *L. camara* ethanol extract

The phytochemical analysis of the ethanolic extract of *L. camara* leaves such as flavonoids, tannins, alkaloids, cardiac glycosides and anthraquinone concentrations were all determined by Adekunle et al. (2021).

Quality assessment

Fresh *T. triangulare* and *T. occidentalis* were washed twice in sterile distilled water before dicing into small pieces. Under aseptic conditions, portions of each sample were immersed in the starch-based plant extract solution, others in the sodium benzoate solution, and the rest in distilled water. The samples were soaked for 2 minutes before being removed, placed in separate sieves, and allowed to dry at room temperature for 30 minutes. The samples were kept at 4 °C for 9 days, and examined on days 0, 4 and 9 using the quality parameters determined by Ebabhi et al. (2019); Adeogun et al. (2020a; 2020b).

Total carotenoid test

The total carotenoids were measured using the method developed by Martín-Diana et al. (2009). Maceration was performed on the samples, 25 ml of acetone containing dimethyl sulphoxide was added to the macerated samples (10% in an ice bath). Because carotenoids are light, heat and air-sensitive, this was done without direct lighting. The produced solution was then filtered using a Whatman No. 4 filter paper and washed, and a dimethylsulfoxide solution was added to bring the total volume to 100 ml. The absorbance at 471 nm against an extraction solvent was determined using a spectrophotometer in triplicate for each sample. The total carotenoid was calculated according to the Equation 1.

mg of carotenoids per ml of the sample =

$$\frac{\text{Absmax}}{250} \times \frac{\text{100 ml acetone dilution}}{\text{sample volume (ml)}} \quad (1)$$

Ascorbic acid content

Ascorbic acid concentration was determined using the 2,6-dichlorophenolindophenol titrimetric method with 20 g of fresh weight of the sample (AOAC, 2000). The result was measured in milligrams of ascorbic acid per 100 g of fresh weight (FW) of the plant material.

Total phenolic content

The total phenolic content of the test samples was determined based on the Folin-Ciocalteu method adopted by Złotek et al. (2016); Adekunle et al. (2021). The Folin-Ciocalteu reagent was prepared and 1.8 ml was added to a 40-litre aliquot of the diluted vegetable extract. After 5 minutes of equilibration at 25 °C, 1.2 ml of 7.5 g 100 ml^{-1} Na_2CO_3 solution was added to the solution. The resulting solution was vigorously stirred before being placed in a test tube at 25 °C for 1 hour. A spectrophotometer was used to measure the solution at 765 nm. The total phenolic content was calculated using a gallic acid standard curve at various concentrations and reported as mg gallic acid equivalents per 100 g (mg GAE 100 g^{-1}).

pH measurement

The pH of the samples in solution (20 ml) was determined at ambient temperature with constant agitation using a pH meter. It was expressed as the concentration of negative logarithm of the hydrogen ions in a solution (Ayub et al., 2021).

Total soluble solids (°Brix)

The total soluble solids were determined based on the method adopted by Owolabi et al. (2021). The samples were measured with a handheld refractometer at 20 °C. The refractive index was recorded and expressed as °Brix.

Fungal load

Total fungal count was performed using a modified method by Adekunle et al. (2021). The samples were homogenized for 60 seconds after being dissolved in sterile distilled water. The homogenate was then inoculated in a petri dish with solidified potato dextrose agar and allowed to grow for 48 hours. The isolated fungus was teased into a test tube with distilled water, homogenized and then serially diluted with distilled water ten times. A drop of the diluted homogenate was pipetted onto a clean Neubauer counting chamber's ruled area. The chamber was covered with a coverslip, which allowed the cells to run underneath due to capillary action. The cell was left to stand for around 10 minutes to allow the viable cells to move as close as possible to the same focal plane. A microscope was used to count the fungus spores in each grid. The viable cell count was calculated using Equation 2.

Viable cells ml^{-1} =

$$\text{number of cells in the total grid} \times \text{dilution factor} \times 10^4 \quad (2)$$

Total antioxidant capacity

The antioxidant capacity of the test vegetables was measured using the method described by Rajurkar and Hande (2011), which involved reducing the colorless Fe^{3+} tripyridyltriazine complex to the blue Fe^{2+-} tripyridyltriazine complex. This resulted from the electron donation at low pH. The samples were combined with 2.7 ml of ferric reducing antioxidant power assay reagent that had been produced (2,4,6-tripyridyl-S-triazine, $FeCl_3$, acetate buffer). After 30 minutes of incubation at 37 °C in the dark, the reaction was measured with a spectrophotometer at an absorbance of 595 nm. The calibration curve was created using Trolox as standard and the antioxidant capacity was measured in mg TE 100 g^{-1}.

Potential browning

Aliquots from the test vegetable were soaked in ethanol for 60 minutes before centrifuged for 10 minutes at 4830 rpm (10 °C). The supernatant was then kept and ethanol was added to bring the total volume of the supernatant up to 25 ml. The aliquot's absorbance was measured at 320 nm using a spectrophotometer and the results were reported in absorbance units (Adeogun et al., 2017).

Statistical analysis

Data analysis used the centered second-order polynomial (quadratic) model (Equation 3). The data were curve-fitted into non-linear regression. GraphPad Prism version 8.4.3 was used for this analysis.

$$Y = B0+B1*(X-\bar{X})+B2*(X-\bar{X})^2 \quad (3)$$

Where: Y = axis is the secondary or vertical axis of a system of coordinates; B0 = is the estimate of ß0 based on the data; B1 = is the population coefficient of the independent variable x_1; and X = is the principal or horizontal axis of a system of coordinates.

RESULTS AND DISCUSSION

Quantitative phytochemical analysis of the leaf extract of *L. camara*

The quantitative phytochemical compounds present in the ethanolic extract have been established by Adekunle et al. (2021). The yield of phytoconstituents found in the ethanolic extract of *L. camara* leaf is shown in Table 1. Flavonoids (24.23±0.68 mg 100 g^{-1}) had the highest content in the tested ethanolic extract of *L. camara* leaves, while cardiac glycosides (11.28±0.28 mg 100 g^{-1}) had the lowest composition.

Polyphenols have been recognized as an important phytochemical that contributes to plant resistance to microorganisms. Polyphenols modify the enzymatic processes involved in energy production and the synthesis of structural components, allowing the plant to withstand the growth of fungal infections. This is achieved by compromising the cell membrane's permeability barrier and changing pathogen nucleic acid production (Adekunle et al., 2021).

Table 1. Quantitative yield of the phytochemical constituents of the extract of *L. camara* leaves

S/No	Phytochemical constituents	Quantitative yield (mg 100 g^{-1})
1.	Flavonoids	24.23±0.68
2.	Tannins	21.79±0.56
3.	Alkaloids	13.24±0.42
4.	Cardiac glycosides	11.28±0.28
5.	Anthraquinone	16.49±0.46

Source: Adekunle et al. (2021)

Quality assessment

Total carotenoid content

Figures 1a and 1b show the influence of a maize-based coating containing *L. camara* leaf extract on the carotenoid content of individual fresh leaves of *T. triangulare* and *T. occidentalis* after storage. Because the carotenoid content is affected by light and heat, it is expected to decrease over time (Santoro et al., 2018). Figure 1a shows the variation in the carotenoid content of the leaves of *T. triangulare* without treatment on day 9 (0.235±0.38 mg g^{-1}) and *T. triangulare* treated with sodium benzoates on day 9 (0.234±0.09 mg g^{-1}) to *T. triangulare* leaves treated with the extract of *L. camara* leaves incorporated with a maize-based coating based on day 9 (0.264±0.5 mg g^{-1}). Figure 1b shows equally the difference in *T. occidentalis* leaves without treatment on day 9 (0.202±0.35 mg g^{-1}) and *T. occidentalis* leaves treated with sodium benzoate on day 9 (0.242±0.242 mg g^{-1}) compared to *T. occidentalis* treated with leaf extract of *L. camara* incorporated with maize-based coating on Day 9 (0.312±0.7 mg g^{-1}). As illustrated in the figures, *T. triangulare* and *T. occidentalis* without treatment and those treated with sodium benzoate experienced a quick decline. Furthermore, the coating agent, which contained the leaf extract of *L. camara* and maize-based flour, helped delay the carotenoid content in *T. triangulare* and *T. occidentalis* treated with leaf extract of *L. camara* incorporated with maize-based coating. The ability of the extract of maize-based coating to postpone carotenoid synthesis in *T. triangulare* and *T. occidentalis* compared to carotenoid content in *T. triangulare* and *T. occidentalis* leaves without treatment could be associated with the delayed and interrupted synthesis of carotenoid contents by coating agents (Adekunle et al., 2021). This study supports the findings of Ebabhi et al. (2019), that an edible coating containing natural antimicrobials could reduce the degradation of carotenoid content in fruits.

Ascorbic acid

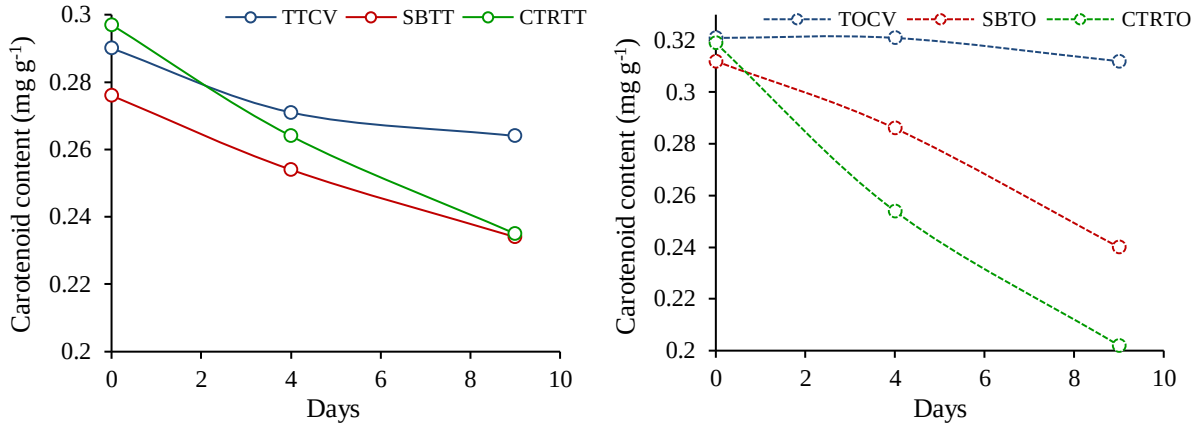
The nonlinear regression curve, as depicted in Figures 2a and 2b, showed the highest individual activity with the extension of shelf life of the leaves of *T. triangulare* and *T. occidentalis* with the leaf extract of *L. camara* and the maize-based coating. The extension of shelf life, as noticed from the figures, indicated that there were variations in *T. triangulare* (Day 9: 10.28±2.15 mg 100 g^{-1}) and *T. occidentalis* (Day 9: 24.13±0.34 mg 100 g^{-1}) compared to leaves without treatment of *T. triangulare* on Day 9 (4.23±0.14 mg 100 g^{-1}) and *T. occidentalis* on Day 9 (15.23±0.43 mg 100 g^{-1}). Equally, the variation was also noticed in *T. triangulare* (Day 9: 10.28±0.15 mg 100 g^{-1}) and *T. occidentalis* (Day 9: 24.13±0.34 mg 100 g^{-1}) leaves treated with sodium benzoate solution.

Stress reduced the ascorbic acid content of most vegetables during post-harvest processing, resulting in ascorbic acid losses (Mieszczakowska-Frąc et al., 2021). Ascorbic acid is extremely susceptible to enzyme oxidation in the presence of light, heat, and oxygen concentration and degrades rapidly (Wang et al., 2018). The presence of a semi-permeable membrane enhanced with leaf extract on the surface of *T. triangulare* and *T. occidentalis* leaves may have aided in the retention of ascorbic acid in *T. triangulare* and *T. occidentalis* leaves compared to *T. triangulare* and *T. occidentalis*

treated with sodium benzoate solution and *T. triangulare* and *T. occidentalis* without any treatment. The higher retention was due to the moderation of oxygen exchange by the presence of a semi-permeable membrane enhanced with leaf extract. A significant reduction in ascorbic acid concentration was observed in tomato fruits treated with mango kernel starch. Furthermore, the presence of a semi-permeable membrane added to the leaf extract showed a similar outcome with the leaves of *T. triangulare* and *T. occidentalis* test (Nawab et al., 2017).

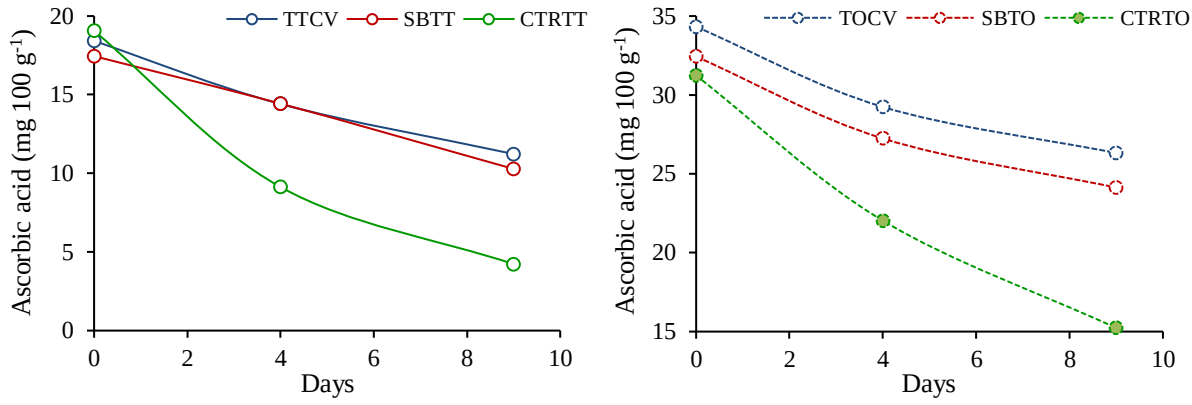
Total phenolic content

Fruits' defense response to injury is thought to have been triggered by secondary metabolites such as phenolic compounds. They are essential for developing and resisting fruits and vegetables from pathogenic infections and are produced in response to climatic conditions, such as cooling (Kołton et al., 2022). Figures 3a and 3b depict the variation in the nonlinear regression fit curve of the *T. triangulare* and *T. occidentalis* leaves treated with *L. camara* leaf extract and maize-based coating, leaves without treatment, and leaves treated with Sodium benzoates. On day 9, there was greater retention of phenolic contents of *T. triangulare* (18.06±0.26 mg GAE 100 g^{-1}) and *T. occidentalis* (12.06±0.24 mg GAE 100 g^{-1}) leaves treated with leaf extract of *L. camara* and maize-based coating compared to the *T. triangulare* (9.07±0.34 mg GAE 100 g^{-1}) and *T. occidentalis* (3.27±0.25 mg GAE 100 g^{-1}) leaves without treatment.



a. *T. triangulare* b. *T. occidentalis*

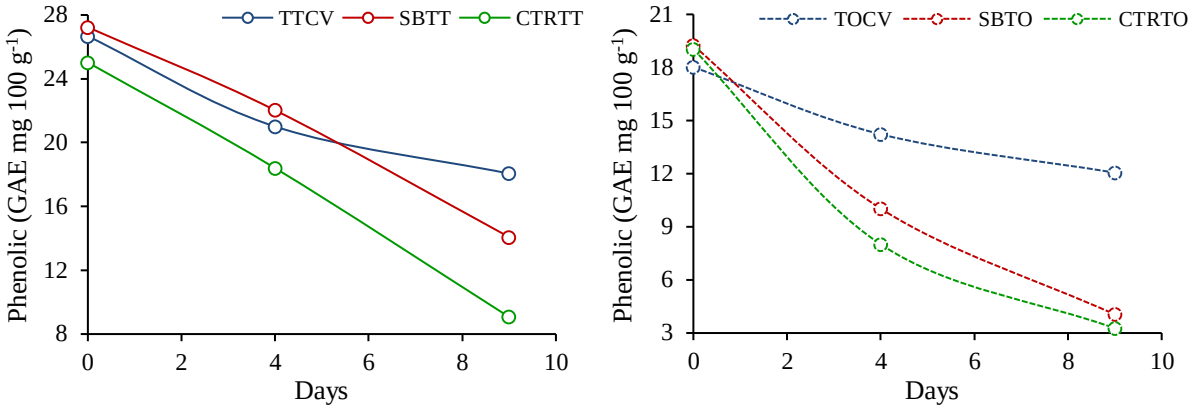
Figure 1. Total carotenoid contents of coated and non-coated leaves stored for 9 days



a. *T. triangulare* b. *T. occidentalis*

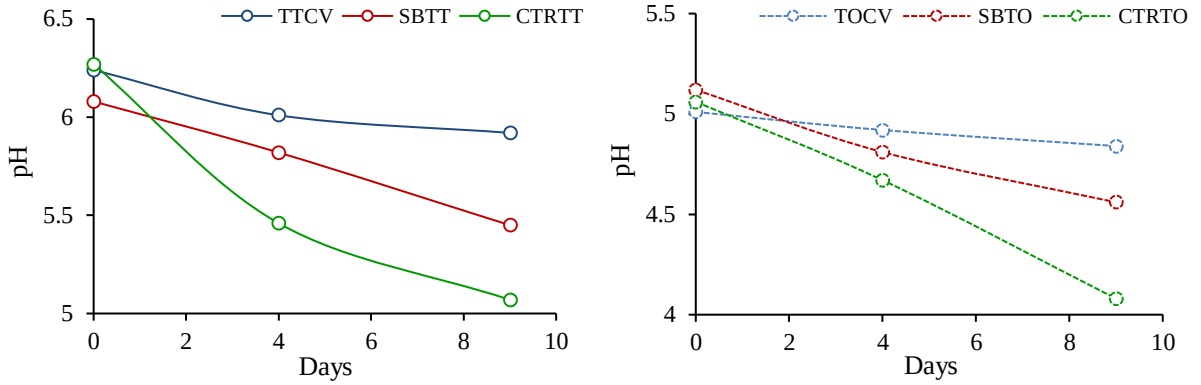
Figure 2. Ascorbic acid contents of coated and non-coated leaves stored for 9 days

Note: TTCV = *T. triangulare* treated with *L. camara* with maize coating; SBTT = *T. triangulare* treated with Sodium benzoate; CTRTT = *T. triangulare* without treatment; TOCV = *T. occidentalis* treated with *L. camara* with maize coating; SBTO = *T. occidentalis* treated with Sodium benzoate; CTRTO = *T. occidentalis* without treatment



a. *T. triangulare* b. *T. occidentalis*

Figure 3. Total phenolic contents of coated and non-coated leaves stored for 9 days



a. *T. triangulare* b. *T. occidentalis*

Figure 4. pH of coated and non-coated leaves stored for 9 days

Note: TTCV = *T. triangulare* treated with *L. camara* with maize coating; SBTT = *T. triangulare* treated with Sodium benzoate; CTRTT = *T. triangulare* without treatment; TOCV = *T. occidentalis* treated with *L. camara* with maize coating; SBTO = *T. occidentalis* treated with Sodium benzoate; CTRTO = *T. occidentalis* without treatment

The higher retention of the phenolic contents in *T. triangulare* and *T. occidentalis* enhanced with the incorporation of leaf extract of *L. camara* and maize-based coating could be linked to the enzymatic inactivation of the phenylalanine lyase (PAL), which is particularly important for the production and storage of phenolic compounds in fruits (Adekunle et al., 2021). The presence of extract, paired with a maize-based coating, may have contributed to lowering enzyme activity, leading to PAL inactivation in *T. triangulare* and *T. occidentalis* leaves enhanced with the leaf of *L. camara* and maize-based coating. Furthermore, reports on Garambullo fruits, tomatoes, and sweet cherries (Dávila-Aviña et al., 2014; López-Palestina et al., 2018; Zam, 2019) show that when coating materials are incorporated with antimicrobial agents, phenolic compounds are retained.

pH

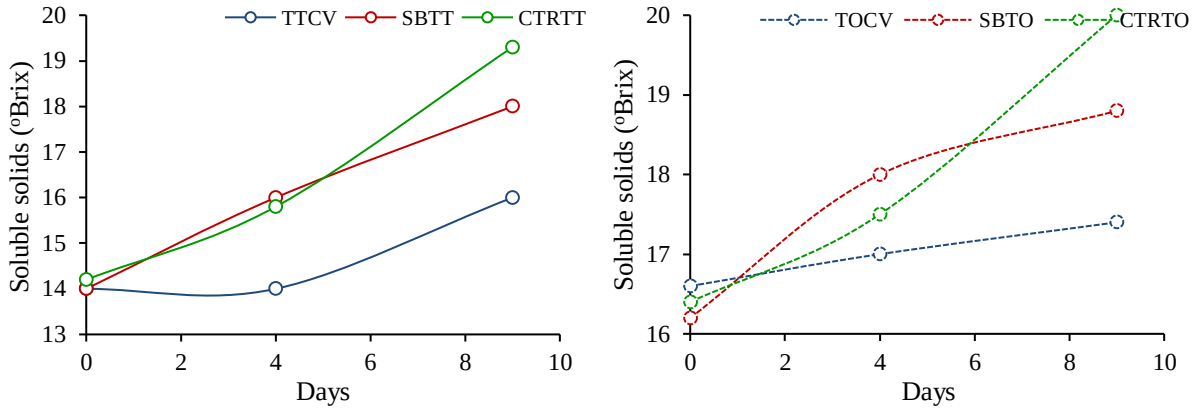
Figures 4a and 4b show an increase in the pH values of all test samples and the storage duration influenced this based on the nonlinear regression curve in Figures 4a and 4b. During storage for 9 days, *T. triangulare* (5.07±0.78) and *T. occidentalis* (4.08±0.34) leaves without treatment on day 9 had higher pH values ($P < 0.05$). The leaves of *T. triangulare* (5.92±0.07) and *T. occidentalis* (4.84±0.05) enhanced with the incorporation of leaf extract of *L. camara* and maize on day 9 had lower pH values. The pH values of the leaves of *T. triangulare* and *T. occidentalis* treated with leaf extract from *L. camara* and maize-based coating were also lower than leaves of *T. triangulare* (5.45±0.09) and *T. occidentalis* (4.56±0.08) treated with Sodium benzoate solution on day 9 respectively.

The buildup of dry matter content and depolymerization due to membrane leakage caused changes in structural, physiological and biochemical contents of stored vegetables throughout storage, which may be accountable for the variations in acidity (Giné-Bordonaba et al., 2017). The presence of maize-based protective membranes on the vegetables, which were strengthened by the extract, helped reduce cellular membrane leakage. This resulted in decreased acidity in *T. triangulare* and *T. occidentalis* leaves enhanced with the incorporation of leaf extract of *L. camara* and maize-based coating after 9 days of storage. The extract may have ionized the undissociated acid molecule, preventing pathogenic fungi from lowering their pH. When compared to *T. triangulare* and *T. occidentalis* leaves without treatments, this resulted in a rise in proton concentration, which disrupted substrate transport by altering cell membrane permeability, delaying the increase in pH of the *T. triangulare* and *T. occidentalis* leaves enhanced with the incorporation of leaf extract of *L. camara* and maize-based coating (Adekunle et al., 2021). Fufa et al. (2019) published a similar result, demonstrating that a corn-based edible cover and plant extract increased the delay in the pH of tomatoes.

Total soluble solids (TSS)

Figures 5a and 5b illustrate the effects of leaf extract of *L. camara* with maize-based coating on *T. triangulare* and *T. occidentalis* leaves during storage for 9 days. The coating treatment on *T. triangulare* (day 9: 16.00±0.00 °Brix) and *T. occidentalis* (day 9: 17.40±0.00 °Brix) leaves exhibited a higher effect on fresh *T. triangulare* and *T. occidentalis* leaves during storage compared to *T. triangulare* (19.30±0.00 °Brix) and *T. occidentalis* (day 9: 20.00±0.00 °Brix) leaves at day 9 without any treatment. Based on the fit of the nonlinear regression curve, the TSS contents increased in the untreated leaf samples than the TSS content of treated *T. triangulare* and *T. occidentalis* (Day 0: 14.00±0.00 °Brix; Day 9: 16.00±0.00 °Brix) leaves.

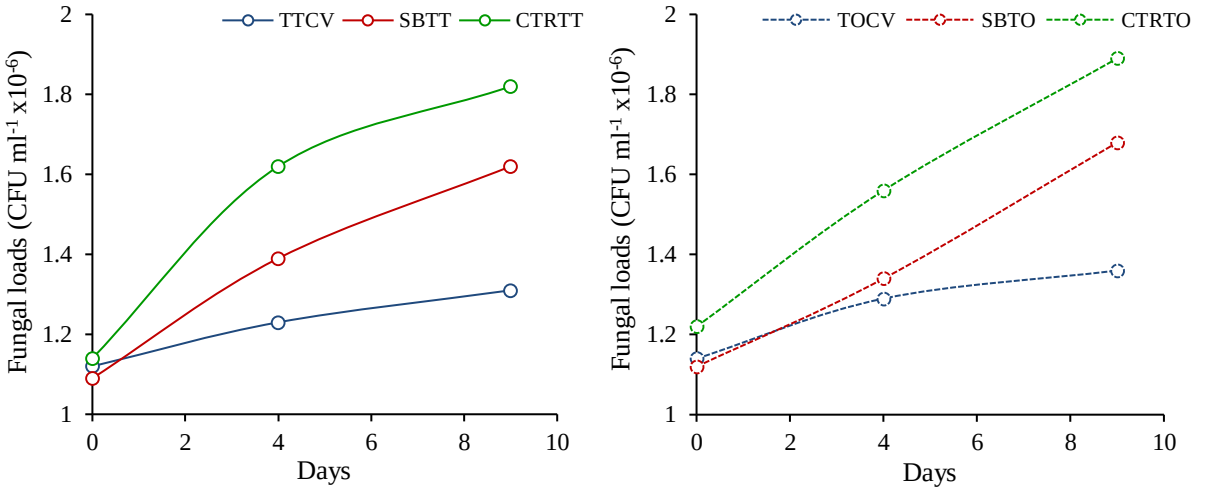
However, during the storage of test vegetables, the total soluble solids content will increase with storage time (Kumar et al., 2021); consequently, due to the lack of a semi-permeable barrier on the surface of *T. triangulare* and *T. occidentalis* leaves without any treatments, the hydrolysis of complex carbohydrates in vegetables was accelerated and resulting in a greater response (Gol and Ramana Rao, 2011). The semi-permeability of the bioactive chemical coating, which helped control metabolic activities in vegetables and as a result, delayed the increase in TSS levels of the treated vegetables, could explain the retention effect of TSS of *T. triangulare* and *T. occidentalis* treated with the leaves of *L. camara* and maize-based coating. When cassava starch coatings containing ascorbic acid and N-acetylcysteine were applied to *Musa paradisiaca*, Márquez Cardozo et al. (2015) observed a similar progressional trend with a delayed increase in TSS contents.



a. *T. triangulare* b. *T. occidentalis*

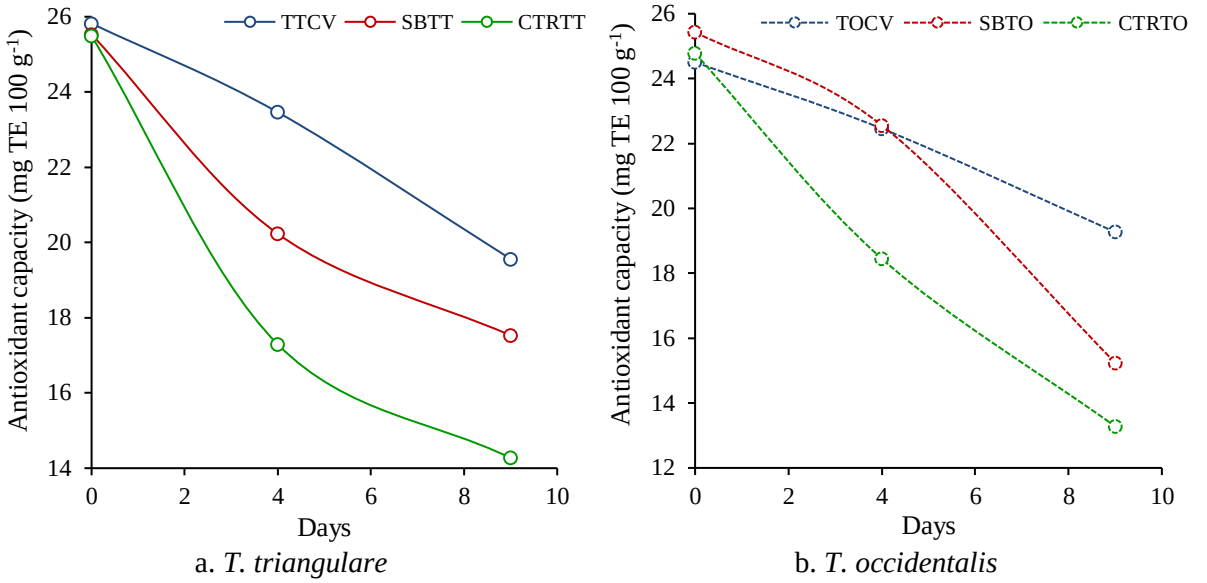
Figure 5. Total soluble solid of coated and non-coated leaves stored for 9 days

Note: TTCV = *T. triangulare* treated with *L. camara* with maize coating; SBTT = *T. triangulare* treated with Sodium benzoate; CTRTT = *T. triangulare* without treatment; TOCV = *T. occidentalis* treated with *L. camara* with maize coating; SBTO = *T. occidentalis* treated with Sodium benzoate; CTRTO = *T. occidentalis* without treatment



a. *T. triangulare* b. *T. occidentalis*

Figure 6. Fungal loads of coated and non-coated leaves stored for 9 days



a. *T. triangulare* b. *T. occidentalis*

Figure 7. Antioxidant capacity of coated and non-coated leaves stored for 9 days

Note: TTCV = *T. triangulare* treated with *L. camara* with maize coating; SBTT = *T. triangulare* treated with Sodium benzoate; CTRTT = *T. triangulare* without treatment; TOCV = *T. occidentalis* treated with *L. camara* with maize coating; SBTO = *T. occidentalis* treated with Sodium benzoate; CTRTO = *T. occidentalis* without treatment

Fungal loads

Figures 6a and 6b depict the non-linear regression curve fitting for the variance in the activities of the leaves of *L. camara* incorporated with maize-based coating on fungal loads of test fresh *T. triangulare* (day 9: $1.31x10^6$±0.29 CFU ml^{-1}) and *T. occidentalis* (day 9: $1.36x10^6$±0.42 CFU ml^{-1}) leaves, as well as the corresponding fungal loads of fresh *T. triangulare* (day 9: $1.82x10^6$±0.33 CFU ml^{-1}) and *T. occidentalis* (day 9: $1.89x10^6$±0.14 CFU ml^{-1}) leaves without treatments, as well as *T. triangulare* (day 9: $1.62x10^6$±0.67 CFU ml^{-1}) and *T. occidentalis* (day 9: $1.68x10^6$±0.45 CFU ml^{-1}) leaves treated with sodium benzoates solution after 9 days of storage.

To help control the higher fungal loads on *T. triangulare* and *T. occidentalis*, which is expected due to the large surface area of the test vegetables, which serve as fungal growth substrates, the leaf extract of *L. camara* combined with a maize-based coating aided in the inhibition of the growth of fungi. Furthermore, the addition of a maize-based coating to the leaf extract of

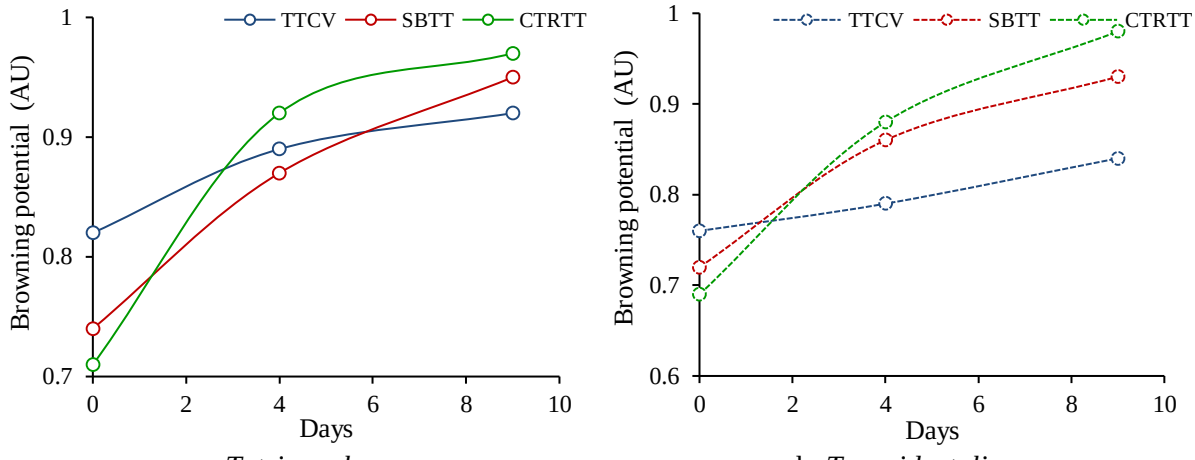
L. camara fortified the test vegetables with a semi-permeable membrane that hindered the growth of the fungal loads in *T. triangulare* and *T. occidentalis*. This bolstered why the fungus loads were so low after 9 days of storage. *L. camara* extract has antifungal effectiveness against *A. flavus*, *A. niger*, *Colletotrichum falcatum* and *Magnaporthe oryzae* (Fayaz et al., 2017; Sreeramulu et al., 2017; Mansoori et al., 2020). The ethanolic extract of *L. camara* inhibited the growth of *C. gloeosporioides*, a fungus associated with fruit and vegetable roots (Bashir et al., 2019). In their report on fresh-cut oranges, Radi et al. (2017) established that gelatin-based edible coatings containing Aloe vera, and black and green tea extracts inhibited the growth of microbes on fresh-cut oranges, which is similar to what is established in this study.

Antioxidant capacity (FRAP)

As seen in Figures 7a and 7b, the nonlinear regression curve shows a delayed increase in treated fresh *T. triangulare* (day 9: 19.56±2.24 mg TE 100 g^{-1}) and *T. occidentalis* (day 9: 19.27±2.16 mg TE 100 g^{-1}) leaves compared to fresh *T. triangulare* (day 9: 14.27±0.88 mg TE 100 g^{-1}) and *T. occidentalis* (day 9: 13.28±2.20 mg TE 100 g^{-1}) leaves without treatments, and *T. triangulare* (day 9: 17.53±2.05 mg TE 100 g^{-1}) and *T. occidentalis* (day 9: 15.24±2.14 mg TE 100 g^{-1}) leaves enhanced with sodium benzoates. The retention of the antioxidant capacity of the test vegetables with the enhancing agent in response to storage could be attributed to the accumulation of phenolic compounds created by the activation of the phenylpropanoid metabolism (Anton et al., 2017; Sharma et al., 2019; Adekunle et al., 2021). Anjum et al. (2020) established a similar observation regarding guava; established the decline in antioxidant capacity in guava and posited that the combined application of gum Arabic and garlic extract prevented the decline of antioxidant capacity in treated guava fruits compared to untreated guava fruits.

Browning potential

The browning potential of the test vegetables increases with storage time, as seen in Figures 8a and 8b. On day 9, the browning potentials of fresh *T. triangulare* leaves were 0.92±0.26 AU and *T. occidentalis* leaves were 0.84±0.24 AU when treated with the leaf of *L. camara* and a maize-based coating, respectively, compared to *T. triangulare* on day 9 (0.97±0.23 AU) and *T. occidentalis* on day 9 (0.98±0.19 AU) without treatments. The lower increase in the browning potential of the treated vegetables may be attributable to the coating agent, in contrast to the greater increase in browning potential of the untreated samples.



a. *T. triangulare* b. *T. occidentalis*

Figure 8. Browning potential of coated and non-coated leaves stored for 9 days

Note: TTCV = *T. triangulare* treated with *L. camara* with maize coating; SBTT = *T. triangulare* treated with Sodium benzoate; CTRTT = *T. triangulare* without treatment; TOCV = *T. occidentalis* treated with *L. camara* with maize coating; SBTO = *T. occidentalis* treated with Sodium benzoate; CTRTO = *T. occidentalis* without treatment

The polyphenol oxidase enzyme is the major enzyme involved in browning reactions, according to Adekunle et al. (2021). The enzyme is involved in the conversion of monophenols to o-diphenol and o-diphenols to o-quinones (Chiabrando and Giacalone, 2016). The inhibitory effect of maize-based coating combined with *L. camara* leaf extract on polyphenol oxidase enzymatic activity could explain the lower response of *T. triangulare* and *T. occidentalis* leaves enhanced with the leaf of *L. camara* and maize-based coating after day 0 (Adekunle et al., 2021). This work confirms a similar study by Adekunle et al. (2021), which similarly confirmed the delay in polyphenol oxidase enzyme activity that contributes to the browning activity in treated test vegetables.

CONCLUSIONS

The combination of an ethanolic extract of *L. camara* with a maize-based coating had a substantial effect on the leaves of *T. triangulare* and *T. occidentalis* after 9 days of storage. This study was able to determine the effect of the enhancing agent on the total carotenoid, ascorbic acid and total phenolic contents, as well as the pH values, total soluble solids, fungal loads, antioxidant capacity, and browning potential of *T. triangulare* and *T. occidentalis* leaves on their shelf life extension. This enhancing agent can be utilized as a fungicide for the postharvest treatment of vegetables if developed commercially.

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