Cogent Food & Agriculture

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/oafa20

Effect of leaf extract of Lantana camara with Maize-based coating on the quality of fresh-cut fruits of Ananas comosus and Musa acuminata

Adedotun Adekunle, Oluwagbenga Adeogun & Yewande Josephine Olorunsuyi |

To cite this article: Adedotun Adekunle, Oluwagbenga Adeogun & Yewande Josephine Olorunsuyi | (2021) Effect of leaf extract of Lantana camara with Maize-based coating on the quality of fresh-cut fruits of Ananas comosus and Musa acuminata, Cogent Food & Agriculture, 7:1, 1917834, DOI: 10.1080/23311932.2021.1917834

To link to this article: https://doi.org/10.1080/23311932.2021.1917834

Published online: 26 Apr 2021.

Adekunle et al., *Cogent Food & Agriculture* (2021), 7: 1917834
https://doi.org/10.1080/23311932.2021.1917834

cogent food & agriculture

FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Effect of leaf extract of Lantana camara with Maize-based coating on the quality of fresh-cut fruits of Ananas comosus and Musa acuminata

Adedotun Adekunle[1], Oluwagbenga Adeogun[1*] and Yewande Josephine Olorunsuyi[1]

Received: 28 February 2020
Accepted: 12 April 2021

*Corresponding author:
Oluwagbenga Adeogun, Department of Botany, University of Lagos, Akoka, Nigeria
E-mail: adeogunoluwagbenga@gmail.com

Reviewing editor:
Manuel Tejada Moral, University of Seville, Seville, Spain

Additional information is available at the end of the article

Abstract: Fresh-cut fruits of *Ananas comosus* (pineapple) and *Musa acuminata* (banana) have a relatively short shelf-life hence the need to enhance their quality. Preservation effect of ethanolic extract of leaf of *Lantana camara* (10%$^{w/}_{v}$) incorporated with maize-based edible coating on fresh-cut fruits of banana and pineapple were determined. To achieve the objective of this study, the pH, total carotenoid content, ascorbic acid, total phenolic content, fungal load, antioxidant activity, total soluble solids, and browning potential of coated fruits at ambient temperature (PEC); untreated fruits (NTS), sodium benzoates (BSB) at ambient temperature and a coated sample (PEC@4) at 4°C were analysed at intervals for 15 days. The quantitative phytochemical constituents of the extracts were assayed. The phytochemical analysis of the extract shows high yields of tannins, flavonoids, anthraquinones, and low yields of alkaloids and cardiac glycosides. The quality assessment of the test fresh-cut fruits revealed that there was higher preservation activity in PEC@4 of banana and pineapple, followed by a considerable efficacy of PEC of banana and pineapple. This study shows the great potential of the extract of

Adedotun Adekunle

ABOUT THE AUTHOR

Prof. Adedotun Adekunle is a Professor of Botany in the Department of Botany, University of Lagos, and he was a former Dean of the Faculty of Science, University of Lagos. He has several publications on Mycology, Plant Pathology, and Ethnobotany.
Dr Oluwagbenga Adeogun is an early career scientist, and he is presently attached as academic staff to the Department of Botany, University of Lagos. He has demonstrated high interest in postharvest pathology with a bias for the use of biocontrol agents from plant sources for enhancement of shelf life and management of diseases in fresh fruits and vegetables.
Miss Yewande Olorunsuyi was an undergraduate student at the Department of Botany, University of Lagos, Nigeria.

PUBLIC INTEREST STATEMENT

Ananas comosus and *Musa sapientum* are highly nutritious fruits that are widely grown in tropical regions. The minimal processing of these fruits encourages deterioration and spoilage due to microbial incursion, and this contributes to limited availability of these fruits to consumers who prefer ready-to-eat fruits and vegetables. Synthetic preservatives have been queried because of health-related side effects. Hence, extracts from plant sources such as *Lantana camara* are being explored as a natural alternative to synthetic preservatives for the preservation of fruits and vegetables. The incorporation of an extract with edible coating from staple foods such as Maize will provide a thin layer with a functional and active compound on the surface of the fruits. This will assist in moderating the incursion of fungi and the exchange of gases, thus maintaining the freshness, texture, and nutritional values of the fruits.

L. camara for the preservation of *Ananas comosus* and *Musa acuminata*, with incorporation of maize-based coating as the carrier of its functional property.

Subjects: Mycology; Food Additives & Ingredients; Food Chemistry

Keywords: Banana; Pineapple; Edible coat; Food spoilage; Lantana camara; Maize

1. Introduction

Fruits are a significant source of essential nutrients for human development. They are reliable sources of vitamin C, folate, β-carotene, potassium, iron, zinc, and calcium (Slavin & Lloyd, 2012). Fruits can be minimally processed; thus, there is an alteration in their original form, but still maintain their current state (Garrett, 2002). The altered fruits are categorised as fresh-cut, and their quality is determined by the consumers based on the combination of different characteristics (Garrett, 2002). The quality of the fruits could be traced to the visual appearance, nutritional value, flavour and texture (Mahajan et al., 2014). The deterioration in the quality of fresh-cut fruits depends on the handling procedures, conditions, and time between harvest and preparation; cultivar, preharvest cultural practices, climatic conditions, maturity at harvest, and harvesting methods (Kader, 2002).

The deterioration in the quality of fresh-cut fruits could also be linked to the contribution of microorganisms, and this can be attributed to poor postharvest handling; therefore, there is a need for stringent activities to maintain the quality of the fruits (Mahajan et al., 2014). Moreover, the demand for safe and quality fruits such as pineapple and banana becomes necessary to alleviate consumers' worries due to the susceptibility of the fruits to microbial attack, which might result in postharvest losses and foodborne diseases (Mahajan et al., 2014).

Banana and pineapple are tropical fruits that can be commercialised as ready-to-eat products due to their sensorial appeasement (Sánchez-Burgos & De Lourdes García-magaña, 2017). They have a short shelf life, which makes longer preservation and marketing difficult. Pineapple (*Ananas comosus*) is native to Central and South America. The total production of pineapple worldwide is around 16 to 19 million tonnes. It contains water, sugars, vitamins A and C, β-carotene. It has a low amount of protein, fat, ash, fibre, and antioxidants (Antoniolli et al., 2012). Pineapple belongs to Bromeliaceae family; it is a non-climacteric, parthenocarpic, multiple fruits often called syncarp or sorosus. It is an herbaceous perennial plant, 0.75–1.5 m tall, with a spread of 0.9–1.2 m. It has a very short, stout stem, and a rosette of waxy, straplike, long-pointed green or red-striped leaves (Hossain & Bepary, 2015).

Banana (*Musa acuminata*) is a climacteric fruit with wide acceptance as economically viable fruit. It is considered a good source of nutrients, including phenols, flavonoids, and antioxidants properties (Youryon & Supapvanich, 2017). It is immensely appreciated because of the convenience of easy peeling off of its skin before eating. Banana belongs to the Musaceae family and native to South Asia; it is an herbaceous flowering plant that develops in a large hanging cluster, made of tiers, and it is usually packed in chunks of 20 mm long (Featherstone, 2015).

The susceptibility of banana and pineapple fruits to contaminants and diseases during postharvest management process, coupled with peeling, cutting, or slicing, reduces the shelf life and creates an avenue for extensive losses of the fruits (Radi et al., 2017). The need to control the losses of fruits to postharvest activities has been widely investigated with the use of synthetic preservatives and antimicrobial agents for the inhibition of the activities of microorganisms. The keen interest in natural antimicrobials over synthetic preservatives is because of the safety concern of consumers towards fruit supplemented with synthetic preservatives, thus raised the apathy of the consumers towards fruits preserved with synthetic preservatives. It has been documented that synthetic preservatives are hazardous to humans, causing diseases associated with hypersensitivity, asthma, and cancer (Bondi et al., 2017).

The consumer's reservation towards synthetic preservatives and the environmental drawbacks associated with the use of non-biodegradable and non-renewable packaging materials for food preservation necessitated the need for biodegradable food materials such as edible coating, which are environmentally friendly and from natural sources. Edible coating is a thin layer biodegradable material with the thickness that is generally less than 0.3 mm, and it is used to enrobe food product to replace or fortify the natural layers and could be consumed as a part of the product or with further removal (Trinetta et al., 2006; Senturk Parreidt et al., 2018). They assist with the protection of the fruits against moisture loss, solute exchange, gas exchange, respiration, and oxidative reactions (Aloui & Khwaldia, 2016; Dhall, 2013).

The use of some polysaccharides that include chitosan, cassava starch, basil-seed gum, and gum acacia, for coating formulations has been widely accepted because of their safety and their ability to carry natural antimicrobials such as essential oil and plant extract as part of the packaging materials (Elsabee & Abdou, 2013; Hashemi et al., 2017; Homez-Jara et al., 2018). The incorporation of active compounds with these edible coatings allows the active packaging to improve the nutritional and quality of the food, without destroying the integrity of the fruits (Senturk Parreidt et al., 2018). However, the application of natural antimicrobial without incorporation encourages the rapid diffusion of bioactive compounds into the tissue of the fruits, and this neutralizes the efficacy of the natural antimicrobial (Aloui & Khwaldia, 2016).

Natural antimicrobials are readily sourced from medicinal spices, herbs, leaves, seed extracts, and essential oils. They have gained acceptance because of the presence of the secondary metabolites, which are the source of antimicrobial activities against foodborne organisms (Arshad & Batool, 2017). Extracts from plants that include *Lantana camara* have been documented to have inhibitory effects on food pathogens such as *Aspergillus niger, Aspergillus flavus, Culvularia lanata, Alternaria alternata* and *Fusarium oxysporium* (Saraf et al., 2011).

Lantana camara (Verbanaceae) is an underutilized, medium-sized perennial aromatic shrub that is native to Central and South America. It has been acknowledged to have antimicrobial activities on microorganisms responsible for spoilage of foods (Deena & Thoppil, 2000; Saini et al., 2017). Bashir et al. (2019) alluded to the presence of saponins, tannins, phlobatannins, flavonoids, terpenoids, and steroids as phytochemical constituents responsible for the antifungal activity of the leaf extract of *Lantana camara* on anthracnose disease of fruits, caused by *Colletotrichum gloeosporioides*.

A preliminary study conducted by the authors during the course of this research revealed that maize-based coating alone did not show any antifungal effect on pathogens associated with fruit; the coating did not inhibit the growth of the pathogens such as *Aspergillus niger, Rhizopus stolonifer*, and *Penicillum digitatum*. This is contrary to the opinion established by Ghosh et al. (2015) that maize-based coating had preservation effect on *Citrus limon* fruit. However, there were inhibitory effects of the ethanolic extract of the leaf of *Lantana camara* on the pathogens.

This informed the aim of this study to determine the effect of the ethanolic extract of the leaf of *Lantana camara*, incorporated with maize-based edible coating on the quality of fresh-cut fruits of banana and pineapple.

2. Materials and methods

2.1. Source of test samples

Fresh fruits of *Musa acuminata* and *Ananas comosus* were harvested from a local farm in Ogun state. The fresh *Lantana camara* leaves were picked from a growing *Lantana camara* plant along the University of Lagos second gate area, Lagos state. The test fruits and leaves were identified and authenticated at the Lagos University Herbarium (LUH), University of Lagos, Akoka. The uniformity, maturity index determined by dry matter content (pineapple: 19.3% and banana:

16.35%), size, and symptomless attributes of the fruits were taken into consideration before the selection of the fruits (Tesfay et al., 2017).

2.2. Preparation of extract from leaf of lantana camara

The harvested leaves of *Lantana camara* were rinsed with distilled water and shade-dried until they were properly dried. The leaves were later ground with the use of pulverising machine to a powdered form of sizes that 100 mm sieve can accommodate. Two hundred grams of the powdered form of the leaves of the test plant were weighed and soaked in 500 mL of ethanol in a tightly sealed jar and allowed for agitation on a shaker for 72 hours. The extracts were filtered with a Whatman, No.1 filter paper and further sieved with a muslin cloth. The filtrate was concentrated to dryness with the use of rotary evaporator. The extracts were kept at 4°C in a refrigerator before use (Ebabhi et al., 2019). Ethanol was selected as the solvent for the extraction of *L. camara* because of the documented evidence in literature about its safety for human consumption, ability to elute most polar compounds, and its solubility capacity for some non-polar compounds (Do et al., 2014).

2.3. Preparation of maize flour

Maize seeds were obtained from a local market in Ota, Ogun state. The seeds were rinsed with 70% ethanol for 60 secs to ward off opportunistic microorganisms before transferring into distilled water for 4 min and subsequently soaked in distilled water for 15 mins to allow for the de-hulling of the seeds. The de-hulled maize was pulverised into flour, with attrition grinding miller to a size range that can pass through 250 µm opening (Adeyeye et al., 2017).

2.4. Preparation of fresh cut fruits of ananas comosus and musa acuminata

The fruits were surface-sterilised with 70% ethanol solution for 1 min and, consequently, washed with distilled water. After washing, they were diced into 2-cm cubes and later sterilised with 70% ethanol for 2 mins and rinsed with water afterwards (Breda et al., 2017). The fruits were left under the laminar flow cabinet for 3 hours.

2.5. Preparation of maize-based coating and plant extract

Five grams of the maize flour were dissolved in 95 mL of distilled water and equilibrated at 70°C for 25 mins and stirred vigorously with the aid of a magnetic stirrer on a hot plate. Subsequently, 2 ml of glycerol were added as a plasticiser to improve the coating mechanical properties, and 10% ($^{w}/_{v}$) of *Lantana camara* extract was added. The resulting solution was homogenised for 5 min.

2.6. Coating treatments

The diced fruits were immersed separately in coated solution; sodium benzoates solution, and distilled water, respectively, for 2 min and dried at ambient temperature (26°C±2) in a laminar flow cabinet for 2 hours. The coated fruits (PEC), fresh-cut fruits treated with Sodium benzoates (BSB), and fresh-cut fruits washed with distilled water (NTS) were stored at ambient temperature (26°C ±2), and another set of fresh-cut fruits (PEC@4) were stored at 4°C.

2.7. Evaluation of quality and shelf life of coated fresh-cut fruits of Ananas comosus and Musa acuminata

The quality of the coated fresh-cut fruits (PEC and PEC@4), as well as the fresh-cut fruits without the coat (BSB and NTS), were determined at intervals of days 0, 3, 9, 12, and 15. The test samples were analysed with the following parametres:

2.7.1. Total soluble solids (%Brix)

The total soluble solids (TSS) of the samples were measured with a handheld refractometer at 20° C. The refractive index was recorded and expressed as % Brix (Martín-Diana et al., 2009).

2.7.2. 2.7.2. pH measurement

The pH of the test sample was determined with a pH metre placed in 20 mL of the test sample and was constantly agitated at ambient temperature. The reading was expressed with the negative logarithm of the hydrogen ion concentration in the test sample solution (Martín-Diana et al., 2009).

2.7.3. Antioxidant capacity (ferric reducing antioxidant power)

The antioxidant capacity of each test sample was determined as described by the method adopted by Rajurkar and Hande (2011), with reduction of Fe^{3+} TPTZ complex, which was colourless to complex Fe^{2+}-tripyridyltriazine, with blue colour. This was formed due to the electron donation of the antioxidants at low pH. The test samples were mixed with 2.7 mL of freshly prepared FRAP reagent (2,4,6-Tripyridyl-S-triazine, $FeCl_3$, acetate buffer). The reaction was measured with the use of spectrophometre at an absorbance of 595 nm after 30 mins of incubation at 37°C in the dark. Trolox was used as the standard to generate the calibration curve, and the antioxidant capacity was expressed in mgTE/100 g.

2.7.4. Total phenolic content (TPC)

A prepared solution of Folin-Ciocalteu reagent (1.8 mL) was added to 40 µL aliquot of the extract of diluted test fresh-cut fruits based on modifications to the method adopted by Złotek et al. (2016) and Ebabhi et al. (2019). The solution was equilibrated at 25°C for 5 min before 1.2 mL of 7.5 g/100 mL Na_2CO_3 solution was added to the test solution. The solution obtained was vigorously stirred and allowed to stay for 1 hour in a test tube at 25°C. The resultant solution was read on a spectrophotometre at 765 nm. The total phenolic content was calculated using a standard curve of Gallic acid generated from different concentrations of gallic acid and expressed as mg of gallic acid equivalents (mg GAE/100 g).

2.7.5. Ascorbic acid content (AA)

2, 6- dichlorophenolindophenol titrimetric method was used to determine the ascorbic acid content of the test fresh-cut fruits (20 g) of *Ananas comosus* and *Musa acuminata* (Martín-Diana et al., 2009). The results were expressed as mg/100 g Fresh Weight (FW).

2.7.6. Browning potential (BP)

The test fruit samples were treated with ethanol for 60 minutes and then centrifuged at 4830rpm (10°C) for 10 mins. The supernatant was retained and diluted with a further amount of ethanol to raise the volume of the aliquot to 25 mL. The absorbance of the aliquot was read with a spectrophotometre at 320 nm, and the results were expressed as absorbance units (Martín-Diana et al., 2009).

2.7.7. Total carotenoid content (TCC)

The method described by Rodriguez-Amaya (2001) was adopted, with slight modifications for the determination of carotenoid content. Four grams of the test sample was dissolved with 10 millilitres of cold pure acetone and homogenised until it was apparent that the residue had become colourless. The homogenate was filtered with the aid of a vacuum pump with inserted Whatman 1 filter papers. The filtered homogenate was mixed with 10 mL of petroleum ether, and the residue obtained was rinsed with distilled water several times to remove acetone. The residue was later allowed to pass through a test tube containing anhydrous sodium sulfate; the test tube was shaken to obtain a homogenous solution and allowed to settle for 10 mins. The solution had two layers, and the upper layer in the tube was poured into a separate tube before analysis. The sample was analysed for carotenoid content using a spectrophotometer (435 nm), and petroleum ether used as a blank sample. The total carotenoid content was expressed as mg/g.

2.7.8. Fungal loads

The fungal loads were determined with a little adjustment to the method described by Adeogun et al. (2017). The test samples were dissolved in sterilised distilled water and homogenised for 60 secs. The homogenate was spread on a Petri dish with prepared potato dextrose agar and

incubated for 48 hours. The isolated fungi were teased into a test tube with distilled water, homogenised and 10-fold serial diluted with distilled water. A drop of the diluted homogenate was pipetted on the ruled area of a clean Neubauer counting chamber. A coverslip was used to cover the chamber, and this allowed the cells to run underneath by capillary action. The cell was allowed to stand for about 10 mins for the viable cells to move to the same focal plane as much as possible. The fungal spores in all grids were counted with the aid of a microscope. The viable cell count was calculated thus:

Viable cells/ml = Number of cells in the total grid x dilution factor x 10^4

2.7.9. Weight loss

The weight of each test sample was determined with an analytical weighing balance. The weight was taken for each test fruit and expressed as a percentage loss of the original weight.

2.8. Quantitative phytochemical analysis of leaf extracts of lantana camara

The quantitative phytochemical determination of the ethanol extracts of the leaf of *L. camara* was analysed with the use of standard methods described by Trease & Evans (2009) and methods adopted by O. Adeogun et al. (2016).

2.9. Data analysis

The data obtained were subjected to analysis of variance (ANOVA), with the pairs of the mean of the test samples distinguished with Tukey's Honest Significant Difference test at 5% significance level. The software package used was the Statistical Package for the Social Sciences (SPSS) tool, version 23.

3. Results and discussion

3.1. Quality assessment of the fresh-cut fruits of ananas comosus and musa acuminata

3.1.1. Total soluble solid

The effect of PEC and PEC@4 and the corresponding effect of BSB and NTS on total soluble solid contents of fresh-cut fruits of banana and pineapple for 15 days are depicted in Figure 1a and 1b. For both test-fruits, there was a significant influence ($P < 0.05$) of the coating treatment on the TSS contents of the test fresh-cut fruits during storage. Figure 1a shows a gradual increase in the TSS contents of fresh-cut fruits of banana during storage, while Figure 1b shows the plodding increase of the TSS content of fresh-cut fruits of pineapple for 15 days storage. There was a more significant increase ($P < 0.05$) in TSS contents of NTS of banana (Day 16.67 ± 0.33 Brix; Day 15: 26.00 ± 0.58

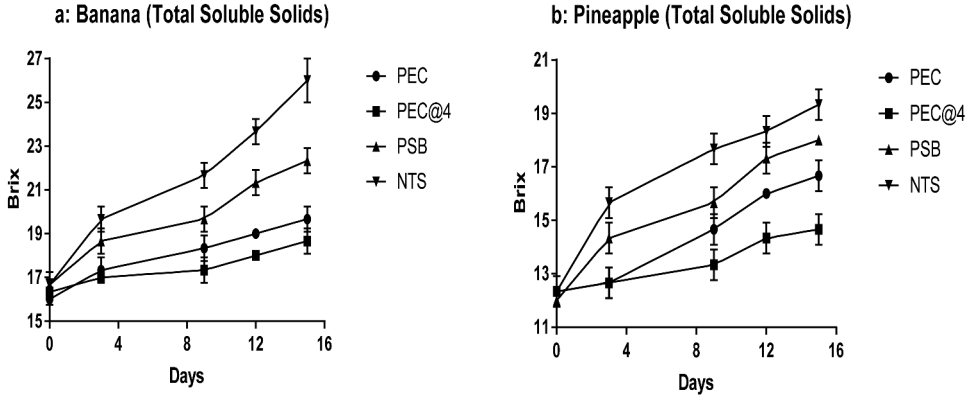

Figure 1. TSS content of coated and non-coated fresh-cut fruits of banana and pineapple stored for 15 days.

Brix) and Pineapples (Day 0: 12.33 ± 0.33 Brix; Day 15:19.33 ± 0.33 Brix) compared to the TSS contents of PEC (Day 0: 16.33 ± 0.33 Brix, Day 15: 18.67 ± 0.33 Brix) and pineapple (Day 0: 12.33 ± 0.33 Brix, Day 15: 14.66 ± 0.33 Brix), which had the least TSS contents increase among the test fruits. Figure 1a and 1b also show that the TSS contents were higher ($P < 0.05$) in PEC: banana (Day 16.00 ± 0.00 00 ± 0.00 Brix; Day 15: 19.67.00 ± 0.33 Brix) and pineapple (Day 12.33 ± 0.33 33 ± 0.33 Brix; Day 15: 16.67 ± 0.33 Brix), compared to the TSS contents of PEC@4. The disparity in the activities of PEC and PEC@4 could be ascribed to more retention of quality of fruit sample at a lower temperature (Maftoonazad & Ramaswamy, 2019).

The higher response of NTS of banana and pineapple could be traced to higher hydrolysis in NTS; the lack of semi-permeable barrier on the surface of NTS increased the hydrolysis of complex carbohydrates in the fruits (Gol & Ramana Rao, 2011). The retention effect in PEC and PEC@4 could be due to the functionality of the semi-permeability of the coating with bioactive compounds, which assisted with the moderation of the metabolic activities in the fruits and, consequently, delayed the increase of TSS contents of the coated fresh-cut fruit (Gol & Ramana Rao, 2011). A similar progressional pattern coupled with delayed increase in TSS content during storage was reported by Márquez Cardozo et al. (2015) when cassava-starch coatings were applied with ascorbic acidic and N-acetylcysteine on *Musa paradisiaca.*

3.1.2. pH

The increase in the pH values of PEC, PEC@4, BSB, and NTS of banana and pineapple, which was influenced by the period of storage, is shown in Figure 2a and 2b, respectively. There were

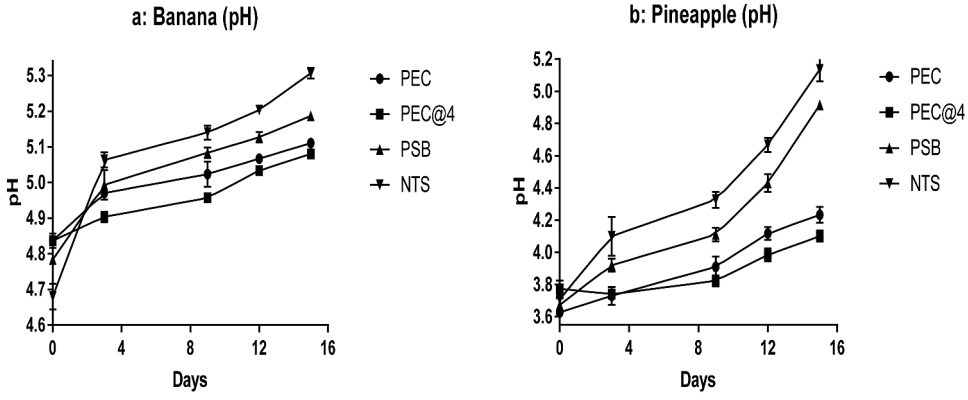

Figure 2. pH values of coated and non-coated fresh-cut fruits of banana and pineapple stored for 15 days.

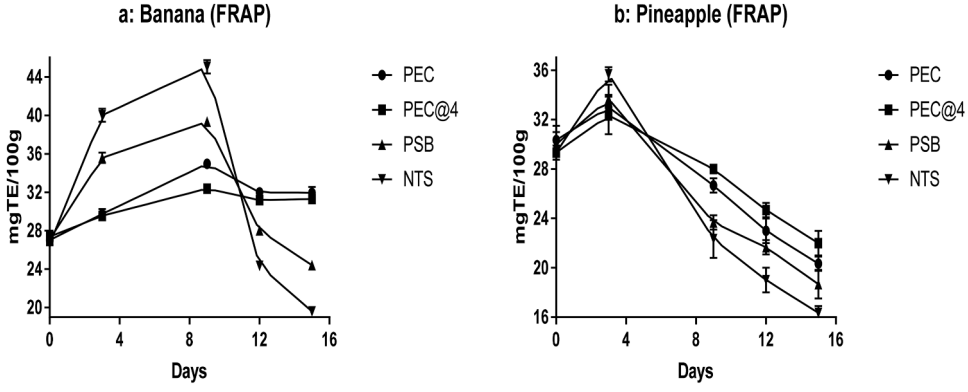

Figure 3. Antioxidant capacity of coated and non-coated fresh-cut fruits of banana and pineapple stored for 15 days.

significantly higher pH values ($P < 0.05$) for NTS of banana (Day 0: 4.68 ± 0.02; Day 15: 5.32 ± 0.03) as depicted in Figure 2a and pineapple (Day 3.71 ± 0.01; Day 15: 5.13 ± 0.04) as shown in Figure 2b, during storage for 15 days. Figure 2a shows that there were lower pH values for PEC (Day 0: 4.83 ± 0.01; Day 15: 5.11 ± 0.06) and PEC@4 (Day 0: 4.84 ± 0.003; Day 15: 5.08 ± 0.006). It was observed in Figure 2b that the pH values of coated fresh-cut of pineapple (PEC: Day 0: 3.63 ± 0.05; Day 15: 4.23 ± 0.02, PEC@4: Day 0: 3.77 ± 0.03; Day 15: 4.10 ± 0.02) were also lower compared to BSB and NTS.

The changes in structural, physiological, and biochemical compositions of the stored fruits during storage was as a result of an accumulation of dry matter content and depolymerisation due to membrane leakage, which might be responsible for the changes in acidity (Ullah et al., 2017). The presence of maize-based protective membranes, enhanced with the extract on the fruits, assisted in reducing the leakages of the cellular membrane, and this contributed to lower acidity in coated fresh-cut fruits of banana and pineapple during storage for 15 days. The extract might have ionized the undissociated acid molecule, thereby inhibiting pH reduction of the pathogenic fungi. This led to an increase in proton concentration for the disruption of the substrate transport by alteration of cell membrane permeability, which delayed the increase in the pH of the PEC and PEC@4, compared to NTS (Davidson, 2012). A similar result showing the delay in pH of tomatoes enhanced with corn-based edible coating and plant extracts was reported by Fufa et al. (2019).

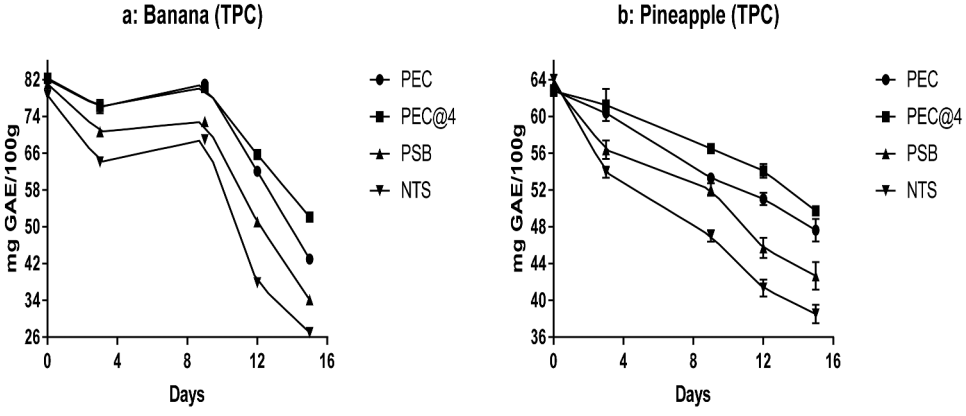

Figure 4. Total phenolic content of coated and non-coated fresh-cut fruits of banana and pineapple stored for 15 days.

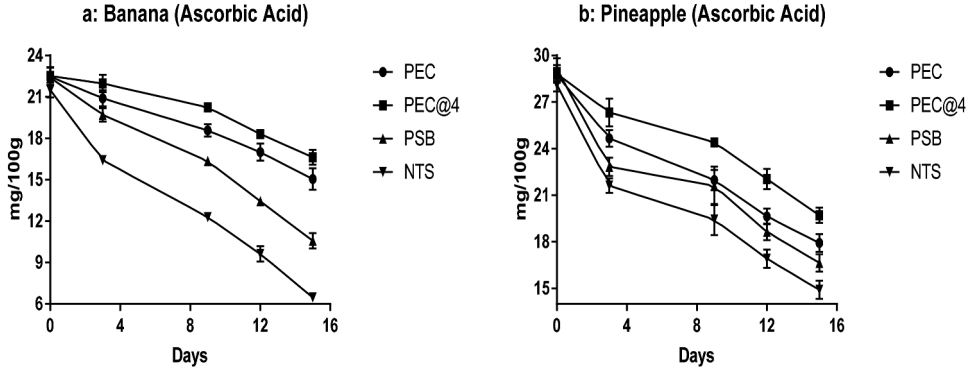

Figure 5. Ascorbic acid content of coated and non-coated fresh-cut fruits of banana and pineapple stored for 15 days.

3.1.3. Antioxidant capacity (ferric reducing antioxidant power)

PEC and PEC@4 reflected a positive response to the antioxidant capacity of both the fresh-cut fruits of banana (Figure 3a) and pineapple (Figure 3b) compared to NTS and BSB of banana and pineapple; this is more evident with PEC@4. There was an increase ($P < 0.05$) in the antioxidant activity of banana fruits from Day 0 to Day 9 across all treatments; this increase was also noticed with PEC and PEC@4 of pineapple fruits, but at Day 0 to Day 3. The increase in the antioxidant capacity of the test fruits in response to early-stage of storage could be associated with the accumulation of phenolic compounds caused by the induction of the phenylpropanoid metabolism (Moreira et al., 2015).

Moreover, there was subsequent significant ($P < 0.05$) reduction in NTS of banana (Day 12: 24.34 ± 0.05 mgTE/100 g; Day 15: 19.60 ± 0.25 mgTE/100 g) and pineapple (Day 9: 22.33 ± 0.88 mgTE/100 g; Day 15: 16.33 ± 0.33 mgTE/100 g) compared to PEC@4 of banana (Day 12: 31.17 ± 0.08 mgTE/100 g; Day 15: 31.96 ± 0.36 mgTE/100 g) and pineapple (Day 9: 28.00 ± 0.00 mgTE/100 g; Day 15: 22.00 ± 0.58 mgTE/100 g), which showed more retention of the antioxidant capacity of the test fruits. The subsequent reduction thereof of the antioxidant capacity of the test fruits could be attributed to an increase in the oxidative reactions and alteration of phenylpropanoid metabolic activities (Salinas-Roca et al., 2018).

3.1.4. Total phenolic content

The defensive response of fruits to injury has been acknowledged to have been initiated through the help of secondary metabolites such as phenolic compounds. They are necessary for the

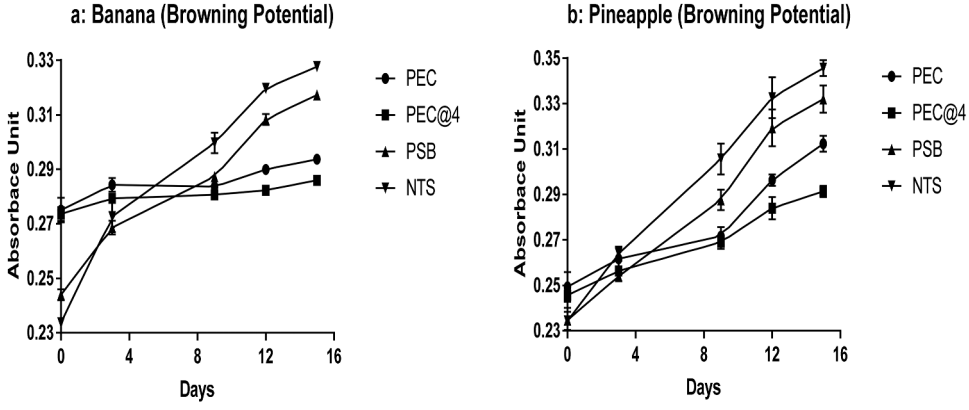

Figure 6. Browning potential of coated and non-coated fresh-cut fruits of banana and pineapple stored for 15 days.

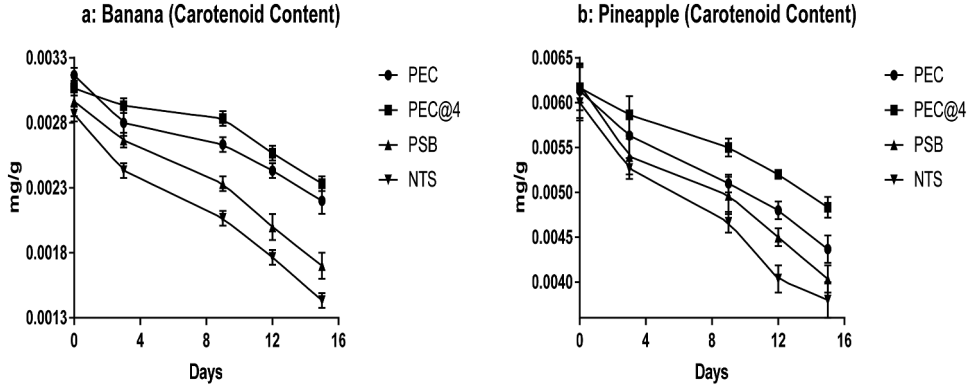

Figure 7. Total carotenoid content of coated and non-coated fresh-cut fruits of banana and pineapple stored for 15 days.

development of fruits and vegetables and are produced as a response to environmental factors such as chilling (López-Palestina et al., 2018). In Figure 4a (banana) and 4b (pineapple), the PEC and PEC@4 of banana and pineapple had significant effect ($P < 0.05$) on the total phenolic content of fresh-cut fruits of banana and pineapple compared to NTS of banana (Day 0: 78.60 ± 0.25 GAEmg/100 g; Day 15: 26.98 ± 0.33 GAEmg/100 g) and pineapple (Day 0: 64.03 ± 0.30 GAEmg/100 g; Day 15: 38.52 ± 0.58 GAEmg/100 g). The variation in TPC activity in PEC, PEC@4, BSB, and NTS of banana and pineapple could be linked to the enzymatic inactivation of the phenylalanine lyase (PAL), which is highly essential for the production and accumulation of phenolic compounds in fruits (Davilla-Avina et al., 2014). The presence of the extract incorporated with maize-based coating might have assisted in lowering the activeness of the enzymes and thus caused gradual inactivation of PAL in the fresh-cut fruits of banana and pineapple.

The variation in the TPC contents of PEC of banana (Day 0: 82.04 ± 0.31 GAEmg/100 g; Day 15: 42.98 ± 0.27 GAEmg/100 g) and pineapple (Day 0: 62.83 ± 0.36 GAEmg/100 g; Day 15: 47.64 ± 0.71 GAEmg/100 g) to the TPC content of PEC@4 of banana (Day 0: 82.32 ± 0.03 GAEmg/100 g; Day 15: 52.14 ± 0.41 GAEmg/100 g) and pineapple (Day 0: 62.79 ± 0.34 GAEmg/100 g; Day 15: 49.75 ± 0.70 GAEmg/100 g) as depicted in Figure 4a and 4b showed a higher TPC content at PEC@4 because of the low storage temperature (4°C). Previous related studies have shown that loss of phenolic compounds could be reduced with the application of coating materials when incorporated with antimicrobial agents; this was observed with reports on fruits of Garambullo, tomatoes and sweet cherries (Davilla-Avina et al., 2014; López-Palestina et al., 2018; Zam, 2019).

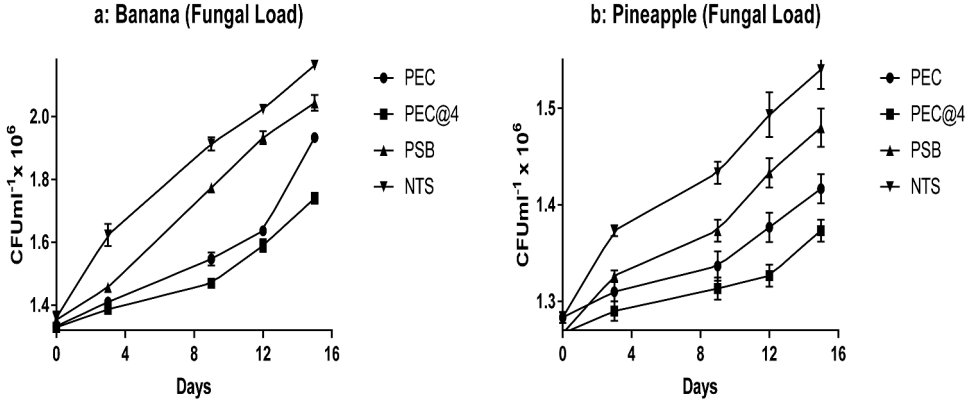

Figure 8. Fungal load of coated and non-coated fresh-cut fruits of banana and pineapple stored for 15 days.

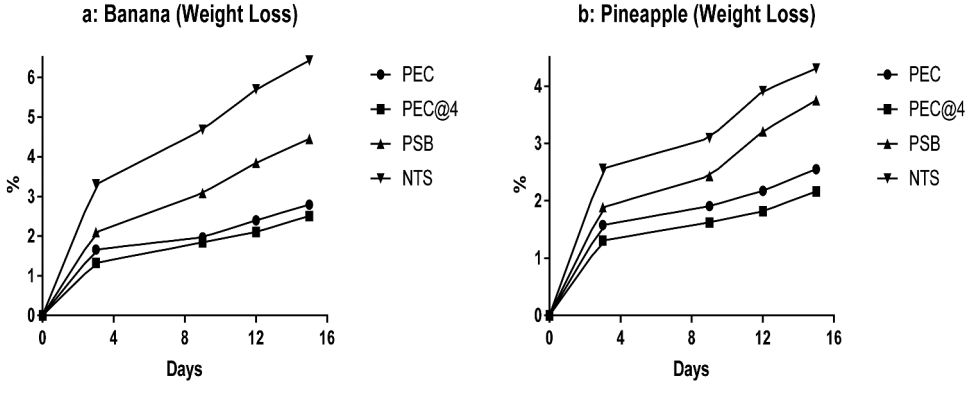

Figure 9. Weight loss of coated and non-coated fresh-cut fruits of banana and pineapple stored for 15 days.

cogent • food & agriculture

Table 1. Quantitative yield of the phytochemical constituents of the ethanolic extract of Leaf of Lantana camara

S/No	Phytochemical constituents	Quantitative yield (mg/100 g)
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

3.1.5. Ascorbic acid content

The ascorbic acid contents of fresh-cut fruits of banana and pineapple are illustrated in Figure 5a and 5b, respectively. Significant differences ($P < 0.05$) between PEC, PEC@4, BSB, and NTB of banana and pineapple were observed for 15-day storage period. There was a drastic reduction in the ascorbic content of NTS of banana (Day 0: 21.50 ± 0.32 mg/100 g; Day 15: 6.47 ± 0.14 mg/100 g) and pineapple (Day 0: 28.11 ± 0.24 mg/100 g; Day 15: 14.91 ± 0.34 mg/100 g) compared to PSB@4 of banana (Day 0: 22.52 ± 0.37 mg/100 g; Day 15: 16.63 ± 0.31 mg/100 g) and pineapple (Day 0: 28.81 ± 0.33 mg/100 g; Day 15: 19.71 ± 0.29 mg/100 g) that had minimal reduction after a storage period of 15 days. It is also apparent in Figure 5a and 5b that PEC@4 provided more extended protection for the ascorbic contents, in contrast to PEC of banana (Day 0: 22.47 ± 0.37 mg/100 g; Day 15: 15.05 ± 0.45 mg/100 g) and pineapple (Day 0: 28.75 ± 0.25 mg/100 g; Day 15: 17.92 ± 0.33 mg/100 g).

The reduction in ascorbic acid contents of the test fresh-cut fruits could be attributed to the stress during the postharvest processing, i.e., slicing and peeling, thereby causing losses of ascorbic acid content (Bierhals et al., 2011). Ascorbic acid is highly responsive to enzymatic oxidation, it is easily degraded in the presence of light, temperature, and when subjected to oxygen concentration (López-Palestina et al., 2018). The low concentration of oxygen due to the moderation of its exchange by the presence of the semi-permeable membrane enhanced with the leaf extract, on the surface of PEC and PEC@4 of banana and pineapple could have assisted in retaining the ascorbic acid in PEC and PEC@4 compared to NTS and BSB of banana and pineapple. A similar position has been reported by Nawab et al. (2017) with a moderate decline in ascorbic acid contents of tomato fruits treated with mango kernel-starch.

3.1.6. Browning potential

The significant increase ($P < 0.05$) in browning potential of fresh-cut fruits of banana and pineapple with regard to storage time are depicted in Figure 6a and 6b respectively. The more pronounced increase ($P < 0.05$) in BP was observed with NTS of banana (Day 0: 0.24 ± 0.0.001AU; Day 15: 0.32 ± 0.001AU) and pineapple (Day 0: 0.23 ± 0.023AU; Day 15: 0.36 ± 0.002AU) compared to PEC of banana (Day 0: 0.28 ± 0.0.003AU; Day 15: 0.30 ± 0.008AU) and pineapple (Day 0: 0.25 ± 0.0.003AU; Day 15: 0.31 ± 0.002AU), with a lower response of BP to storage time. The lowest response in BP was noted with PEC@4 of banana (Day 0: 0.27 ± 0.0.001 AU; Day 15: 0.29 ± 0.001AU) and pineapple (Day 0: 0.25 ± 0.0.001AU; Day 15: 0.29 ± 0.001AU).

Chiabrando and Giacalone (2016) established that the polyphenol oxidase is the primary enzyme responsible for browning reactions. This enzyme aids the hydroxylation of monophenols to o-diphenols and the oxidation of the o-diphenols to their equivalent o-quinones (Chiabrando and Giacalone (2016). The low response of PEC and PEC@4 of banana and pineapple to browning could be linked to the inhibitory potential of maize-based coating incorporated with leaf extract of *Lantana camara* on polyphenol oxidase enzymatic activity (Ozdemir & Gokmen, 2017).

3.1.7. Total carotenoid content

The effect of maize-based coating incorporated with leaf extract of *L. camara* on carotenoid content of fresh-cut fruits of banana and pineapple in response to storage are shown in Figure 7a and 7b, respectively. Generally, it is expected that carotenoid content should decrease with time; it is photo and heat-sensitive (Santoro et al., 2018). There was a rapid reduction ($P < 0.05$) of carotenoid contents with NTS of banana (Day 0: 0.003 ± 0.00 mg/g; Day 15: 0.14 ± 0.00 mg/g) and pineapple (Day 0: 0.06 ± 0.001 mg/g; Day 15: 0.004 ± 0.00 mg/g) compared to gradual decrease in PEC@4 of banana (Day 0: 0.003 ± 0.00 mg/g; Day 15: 0.004 ± 0.00 mg/g) and pineapple (Day 0: 0.062 ± 0.001 mg/g; Day 15: 0.005 ± 0.001 mg/g). The rate of reduction in PEC@4 of banana and pineapple was lower because of the storage condition at 4°C; this is at variance with the carotenoid contents of PEC of banana (Day 0: 0.0032 ± 0.00 mg/g; Day 15: 0.002 ± 0.00 mg/g) and pineapple (Day 0: 0.061 ± 0.001 mg/g; Day 15: 0.004 ± 0.001 mg/g), which expressed higher reduction compared to PEC@4.

The variance in the carotenoid contents of NTS of banana and pineapple could be due to the ability of the extract incorporated with maize-based coatings in delaying the synthesis of carotenoids (Ullah et al., 2017). This study corresponds with the report of Rahimi et al. (2019) that reported the positive effect of edible coating with natural antimicrobials on the degradation of carotenoid content of fruits.

3.1.8. Fungal load

Figure 8a and Figure 8b showed the fungal loads of PEC, PEC@4, BSB, and NTS of banana and pineapple stored for 15 days, respectively. There was a significant ($P < 0.05$) increase in all treatments; this is expected because of the surface area of fresh-cut fruits. The surface environment is quite conducive for the growth of fungi due to the presence of nutrients and moisture that covers the surface of the fruits.

The fungal loads of NTS of banana (Day 0: 1.36 ± 0.0.02 $CFUml^{-1}x10^6$, Day 15: 2.16 ± 0.01 $CFUml^{-1}x10^6$) and pineapple (Day 0: 1.28 ± 0.0.003 $CFUml^{-1}$; Day 15: 1.54 ± 0.01 $CFUml^{-1}x10^6$) had significant higher increase in fungal loads ($P < 0.05$) compared to the PEC@4 of banana (Day 0: 1.33 ± 0.0.01 $CFUml^{-1}$ $x10^6$, Day 15: 1.93 ± 0.01 $CFUml^{-1}x10^6$) and pineapple (Day 0: 1.27 ± 0.001 $CFUml^{-1}x10^6$, Day 15: 1.37 ± 0.01 $CFUml^{-1}x10^6$); likewise the PEC of banana (Day 0: 1.33 ± 0.0.01 $CFUml^{-1}x10^6$, Day 15: 1.74 ± 0.01 $CFUml^{-1}x10^6$) and pineapple (Day 0: 1.28 ± 0.001 $CFUml^{-1}x10^6$, Day 15: 1.42 ± 0.01 $CFUml^{-1}x10^6$). The variation in the fungal loads of PEC@4 and PEC has been established by Erkmen and Bozoglu (2016) that the lower the temperature, the slower the enzymatic activity, chemical reactions, and microbial growth.

The leaf extract of *L. camara* enhanced with semi-permeable membrane influenced the antifungal potential of PEC@4 and PEC, and this might have contributed to the low fungal loads after 15 days of storage. Singh and Srivastava (2012), Fayaz et al. (2017), and Musyimi et al. (2017) have established the antifungal activity of leaf extract of *Lantana camara* against fruit spoilage fungi that includes *Alternaria alternata, Aspergillus flavus, Aspergillus niger*, and *Penicillium* sp. Bashir et al. (2019) documented that the ethanolic extract of *L. camara* inhibited the growth of the *Colletotrichum gloeosporioides*, which might be responsible for anthracnose disease in fruits such as banana and pineapple.

3.1.9. Weight loss

The significant differences ($P < 0.05$) in weight loss with respect to time of storage were observed with PEC and PEC@4 of banana (Figure 9a) and pineapple (Figure 9b) compared to NTS and BSB of banana and pineapple. NTS of banana (Day 0: 0; Day 15: 6.42 ± 0.03%) and pineapple (Day 15: 4.31 ± 0.02%) had greater ($P < 0.05$) weight loss compared to PEC and PEC@4 of banana and pineapple. Metabolic activities with respect to transpiration and respiration are associated with water loss, and this greatly influenced higher weight loss in NTS because of lack of water vapour barrier properties, which is associated with PEC and

PEC@4 of banana and pineapple (Lopoz-Palestina, et al., 2018). The presence of semi-permeable membrane through the maize-based coating, enhanced with the leaf extract of *L. camara* assisted with lower weight loss and retention of moisture content in PEC and PEC@4 of banana and pineapple. However, there was a variance in the response of PEC@4 of banana (Day 0: 0; Day 15: 2.79 ± 0.01%) and pineapple (Day 0: 0; Day 15: 2.16 ± 0.02%) and PEC of banana (Day 0: 0; Day 15: 2.51 ± 0.01%) and pineapple (Day 0: 0; Day 15: 2.55 ± 0.02%) to storage temperature. The lower response of the

PEC@4 is due to the storage of the fruit at low temperature, which has been acknowledged to have higher quality retention of fruits and vegetables in contrast to a higher temperature (Affan et al., 2018). A similar delay in weight loss as a result of physical barrier against moisture loss and reduced transpiration rate due to the activities of edible coatings with antimicrobial agents has been reported by several literature (Ali et al., 2016; Radi et al., 2017; Zam, 2019).

3.2. Quantitative phytochemical analysis of the leaf extract of lantana camara

The quantitative phytochemical compounds present in the leaf extract of *Lantana camara* are depicted in Table 1. The table shows the yield of the phytoconstituents present in the ethanolic extract of the leaf of *L. camara*. Flavonoids had the highest composition (24.23 ± 0.68 mg/100 g) and cardiac glycosides (11.28 ± 0.28 mg/100 g) with the lowest composition in the assayed ethanolic extract of the leaf of *Lantana camara*. The constituents present in the test extracts are similar to what Bashir et al., 2019listed in their work and made mentioned the inhibitory effect of the extract on anthracnose disease caused by *Colletotrichum gloeosporioides* on some fruits.

Most of the phytoconstituents identified from the ethanolic extract of *L. camara* belong to the polyphenol group; polyphenols have been identified to be an important phytochemical that do contribute to the resistance of plants to microorganisms (El-Khateeb et al., 2013. Polyphenols help the plant to resist the growth of fungal pathogens through the altering of the enzymatic processes involved in energy production and structural component synthesis. This is achieved by impairing the permeability barrier of the cell membrane and altering nucleic acids synthesis of the pathogens (2013).

4. Conclusion

Edible coating incorporated with plant extracts has been widely explored for the preservation of fruits and vegetables. However, this study happened to be first to examine the use of ethanolic leaf extract of *L. camara* incorporated with maize-based coating for the enhancement of shelf life of fresh-cut fruits of banana and pineapple. It further established the positive effect of the leaf extract with maize-based edible coating in enhancing the physico-chemical qualities of fresh-cut fruits of banana and pineapple, thereby delaying the response to quality deterioration. The influence of the *L. camara* extract incorporated with the maize-based coating could be ascribed to the presence of the polyphenol group of phytochemicals that include the flavonoids and tannins. These groups of phytochemicals can be further screened to determine the compounds responsible for the preservation activity. The study also observed that the fresh-cut fruits of banana and pineapple processed for storage with the extract, at ambient temperatures could be available for consumption more than the established shelf-life in the open market for non-treated fresh-cut fruits of banana and pineapple. However, the fresh-cuts of banana and pineapple will have a more prolonged shelf-life if stored at a lower temperature (4°C). The test materials used in this study for the preservation of fresh-cut fruits of banana, and pineapple are cheap and readily available; thus, their availability and application will promote more substantial income for the local vendors that are worried about the deterioration of their vend fresh-cut fruits due to fungal incursion.

Funding
The authors received no funding for this study.

Author details
Adedotun Adekunle[1]
ORCID ID: http://orcid.org/0000-0001-6186-664X
Oluwagbenga Adeogun[1]
E-mail: adeogunoluwagbenga@gmail.com
ORCID ID: http://orcid.org/0000-0002-8080-525X
Yewande Josephine Olorunsuyi[1]
[1] Department of Botany, University of Lagos, Akoka, Nigeria.

Competing Interest
The authors declare no competing interests.

Citation information
Cite this article as: Effect of leaf extract of Lantana camara with Maize-based coating on the quality of fresh-cut fruits of Ananas comosus and Musa acuminata, Adedotun Adekunle, Oluwagbenga Adeogun & Yewande Josephine Olorunsuyi, *Cogent Food & Agriculture* (2021), 7: 1917834.

References

Adeogun, O., Adekunle, A., & Ashafa, A. (2016). Chemical composition, lethality and antifungal activities of the extracts of leaf of *thaumatococcus daniellii* against foodborne fungi. *Beni-Suef University Journal of Basic & Applied Sciences*, *5*(4), 356–368. https://doi.org/10.1016/j.bjbas.2016.11.006

Adeogun, O. O., Adekunle, A. A., & Adongbede, E. M. (2017). Effects of leaf extracts of selected plants on quality of stored *citrus sinensis* (sweet orange) juice. *Notulae Scientia Biologicae*, *9*(2), 256–262. https://doi.org/10.15835/nsb9210067

Adeyeye, S. A. O., Adebayo-Oyetoro, A. O., & Omoniyi, S. A. (2017). Quality and sensory properties of maize flour cookies enriched with soy protein isolate. *Cogent Food & Agriculture*, *3*(1), 1278827. https://doi.org/10.1080/23311932.2017.1278827

Affan, F.F.M., Yuliastuti, P., Aldila, L.E. & Jumeri, M. (2018). Controlled temperatures and edible coating treatments on fresh strawberry (Fragaria sp. 'Holibrite') in a tropical environment. Acta Horticulturae, 1201, 7–14. https://doi.org/10.17660/ActaHortic.2018.1201.2

Affan, M., Lestari, R. D. N., & Mangunwikarto, J. (2017). Application of chitosan edible coating on fresh strawberry fruit (Fragaria sp.'Holibert') during storage in a tropical environment. *Acta Horticulturae*, *1210*, 95–102.

Ali, A., Hei, G. K., & Keat, Y. W. (2016). Efficacy of ginger oil and extract combined with gum arabic on anthracnose and quality of papaya fruit during cold storage. *Journal of Food Science and Technology*, *53*(3), 1435–1444. https://doi.org/10.1007/s13197-015-2124-5

Aloui, H., & Khwaldia, K. (2016). Natural antimicrobial edible coatings for microbial safety and food quality enhancement. *Comprehensive Reviews in Food Science & Food Safety*, *15*(6), 1080–1103. https://doi.org/10.1111/1541-4337.12226

Antoniolli, L. R., Benedetti, B. C., Souza Filho, M. D. S. M., Garruti, D. D. S., & Borges, M. D. F. (2012). Shelf life of minimally processed pineapples treated with ascorbic and citric acids. *Bragantia*, *71*(3), 447–453. https://doi.org/10.1590/S0006-87052012000300019

Arshad, M. S., & Batool, S. A. (2017). Natural antimicrobials, their sources and food safety. *Food Additives*, 87. https://doi.org/10.5772/intechopen.70197

Bashir, S., Jabeen, K., Iqbal, S., Javed, S., & Naeem, A. (2019). *Lantana camara*: Phytochemical analysis and antifungal prospective. *Planta Daninha*, *v37*, e019193526. https://doi.org/10.1590/s0100-83582019370100137

Bierhals, V. S., Chiumarelli, M., & Hubinger, M. D. (2011). Effect of cassava starch coating on quality and shelf life of fresh-cut pineapple (*ananas comosus* L. Merril cv "Pérola"). *Journal of Food Science*, *76*(1), E62–E72. https://doi.org/10.1111/j.1750-3841.2010.01951.x

Bondi, M., Lauková, A., De Niederhausern, S., Messi, P., & Papadopoulou, C. (2017). Natural preservatives to improve food quality and safety. *Journal of Food Quality*, 1090932. https://doi.org/10.1155/2017/1090932

Breda, C. A., Morgado, D. L., De Assis, O. B. G., & Duarte, M. C. T. (2017). Effect of chitosan coating enriched with pequi (caryocar brasiliense camb.) peel extract on quality and safety of tomatoes (*lycopersicon esculentum* mill.) during storage. *Journal of Food Processing and Preservation*, *41*(6), e13268. https://doi.org/10.1111/jfpp.13268

Chiabrando, V., & Giacalone, G. (2016). Effects of edible coatings on quality maintenance of fresh-cut nectarines. *Emirates Journal of Food and Agriculture*, (3), 201–207. https://doi.org/10.9755/ejfa.2015-09-771

Davidson, P. M.. (2012). Chemical Preservatives and Natural Antimicrobial Compounds. In M. P. Doyle., L. R. Beuchat, & T. J. Montville (Eds.), *Products In Food Microbiology Fundamentals and Frontiers* (pp. 520–556). ASM Press.

Dávila-Aviña, J. E., Villa-Rodríguez, J. A., Villegas-Ochoa, M. A., Tortoledo-Ortiz, O., Olivas, G. I., Ayala-Zavala, J. F., & González-Aguilar, G. A. (2014). Effect of edible coatings on bioactive compounds and antioxidant capacity of tomatoes at different maturity stages. Journal of food science and technology, 51(10), 2706–2712. https://doi.org/10.1007/s13197-012-0771–3

Dávila-Aviña, J. E., Villa-Rodríguez, J. A., Villegas-Ochoa, M. A., Tortoledo-Ortiz, O., Olivas, G. I., Ayala-Zavala, J. F., & González-Aguilar, G. A. (2014). Effect of edible coatings on bioactive compounds and antioxidant capacity of tomatoes at different maturity stages. *Journal of Food Science and Technology*, *51*(10), 2706–2712. https://doi.org/10.1007/s13197-012-0771-3

Deena, M. J., & Thoppil, J. E. (2000). Antimicrobial activity of the essential oil of *lantana camara*. *Fitoterapia*, *71*(4), 453–455. https://doi.org/10.1016/S0367-326X(00)00140-4

Dhall, R. K. (2013). Advances in edible coatings for fresh fruits and vegetables: A review. *Critical Reviews in Food Science and Nutrition*, *53*(5), 435–450. https://doi.org/10.1080/10408398.2010.541568

Do, Q. D., Angkawijaya, A. E., Tran-Nguyen, P. L., Huynh, L. H., Soetaredjo, F. E., Ismadji, S., & Ju, Y. H. (2014). Effect of extraction solvent on total phenol content, total flavonoid content, and antioxidant activity of *limnophila aromatica*. *Journal of Food and Drug Analysis*, *22*(3), 296–302. https://doi.org/10.1016/j.jfda.2013.11.001

Ebabhi, A. M., Adeogun, O. O., Adekunle, A. A., & Ao, O. (2019). Bio-preservation potential of leaf extracts of *ocimum gratissimum* L. on fresh-cut fruits of *citrullus lanatus* (thunb). *Journal of Applied Sciences and Environmental Management*, *23*(7), 1383–1389. https://doi.org/10.4314/jasem.v23i7.30

El-Khateeb, A. Y., Elsherbiny, E. A., Tadros, L. K., Ali, S. M., & Hamed, H. B. (2013). Phytochemical analysis and antifungal activity of fruit leaves extracts on the mycelial growth of fungal plant pathogens. *Journal of Plant Pathology and Microbiology*, *4*(9), 1–6.

Elsabee, M. Z., & Abdou, E. S. (2013). Chitosan based edible films and coatings: A review.Materials Science and Engineering: C, 33 (4), 1819-1841. https://doi.org/10.1016/j.msec.2013.01.010

Erkmen, O., & Bozoglu, T. F. (2016). *Food microbiology: Principles into practice*. John Wiley & Sons.

Evans, W. C. (2009). *Trease and evans' pharmacognosy E-book*. Elsevier Health Sciences.

Fayaz, M., Bhat, M. H., Fayaz, M., Kumar, A., & Jain, A. K. (2017). Antifungal activity of *Lantana camara* L. leaf extracts in different solvents against some pathogenic fungal strains. *Pharmacologia*, *8*(3), 105–112. https://doi.org/10.5567/pharmacologia.2017.105.112

Featherstone, S. (Ed.). (2015). *A Complete Course in Canning and Related Processes: Volume 3 Processing Procedures for Canned Food Products*. Woodhead Publishing.

Fufa, D. D., Solomon Abera, A. H., & Kumar, V. Effect of Using Plant Extracts with Coating Materials on Physicochemical Quality of Tomato Fruit (*Solanum Lycopersicum* L.) Stored at Ambient Temperature.

Garrett, E. H. (2002). Fresh-cut produce: Tracks and trends. In *Fresh-Cut Fruits and Vegetables* (pp. 10–19). CRC Press.

Ghosh, A., Dey, K., & Bhowmick, N. (2015). Effect of corn starch coating on storage life and quality of Assam lemon (*citrus limon* burn.). *Journal Crop and Weed*, *11*(1), 101–107.

Gol, N. B., & Ramana Rao, T. V. (2011). Banana fruit ripening as influenced by edible coatings. *International Journal of Fruit Science*, *11*(2), 119–135. https://doi.org/10.1080/15538362.2011.578512

Hashemi, S. M. B., Khaneghah, A. M., Ghahfarrokhi, M. G., & Eş, I. (2017). Basil-seed gum containing Origanum vulgare subsp. viride essential oil as edible coating for fresh cut apricots. Postharvest Biology and Technology, 125, 26–34. https://doi.org/10.1016/j.postharvbio.2016.11.003

Homez-Jara, A., Daza, L. D., Aguirre, D. M., Muñoz, J. A., Solanilla, J. F., & Váquiro, H. A. (2018). Characterization of chitosan edible films obtained with various polymer concentrations and drying temperatures. International journal of biological macromolecules, 113, 1233–1240. https://doi.org/10.1016/j.ijbiomac.2018.03.057

Hossain, M., & Bepary, R. H. (2015). Post-harvest handling of pineapples: A key role to minimise the post-harvest loss. *International Journal of Recent Scientific Research*, *6*(9), 6069–6075.

Kader, A. A. (2002). Quality parameters of fresh-cut fruit and vegetable products. In *Fresh-cut Fruits and Vegetables* (pp. 20–29). CRC Press.

López-Palestina, C. U., Aguirre-Mancilla, C. L., Raya-Pérez, J. C., Ramírez-Pimentel, J. G., Gutiérrez-Tlahque, J., & Hernández-Fuentes, A. D. (2018). The effect of an edible coating with tomato oily extract on the physicochemical and antioxidant properties of garambullo (*myrtillocactus geometrizans*) fruits. *Agronomy*, *8*(11), 248. https://doi.org/10.3390/agronomy8110248

Maftoonazad, N., & Ramaswamy, H. S. (2019). Application and evaluation of a pectin-based edible coating process for quality change kinetics and shelf-life extension of lime fruit (Citrus aurantifolium). Coatings, 91, 285–298. https://doi.org/10.3390/coatings9050285

Mahajan, P. V., Caleb, O. J., Singh, Z., Watkins, C. B., & Geyer, M. (2014). Postharvest treatments of fresh produce. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *372* (2017), 20130309. https://doi.org/10.1098/rsta.2013.0309

Márquez Cardozo, C. J., Palacín Beltrán, J. R., & Fuentes Berrio, L. (2015). Effect of cassava-starch coatings with ascorbic acidic and N-acetylcysteine on the quality of harton plantain (musa paradisiaca). *Revista Facultad Nacional de Agronomía Medellín*, *68*(2), 7689–7701. https://doi.org/10.15446/rfnam.v68n2.50985

Martín-Diana, A. B., Rico, D., Barat, J. M., & Barry-Ryan, C. (2009). Orange juices enriched with chitosan: optimisation for extending the shelf-life. *Innovative Food Science & Emerging Technologies*, *10*(4), 590–600. https://doi.org/10.1016/j.ifset.2009.05.003

Moreira, M. R., Cassani, L., Martín-Belloso, O., & Soliva-Fortuny, R. (2015). Effects of polysaccharide-based edible coatings enriched with dietary fibre on quality attributes of fresh-cut apples. *Journal of Food Science and Technology*, *52*(12), 7795–7805. https://doi.org/10.1007/s13197-015-1907-z

Musyimi, D. M., Opande, G. T., Chesire, J., Sikuku, P. A., & Buyela, D. (2017). Antimicrobial potential and screening of phytochemical compounds of lantana camara linn. *IJRDO-Journal of Biological Science*, *3*(6), 18–35.

Nawab, A., Alam, F., & Hasnain, A. (2017). Mango kernel starch as a novel edible coating for enhancing shelf-life of tomato (*solanum lycopersicum*) fruit. *International Journal of Biological Macromolecules*, *103*, 581–586. https://doi.org/10.1016/j.ijbiomac.2017.05.057

Nimitkeatkai, H., Srilaong, V., & Kanlavanarat, S. (2006). Effect of edible coating on pineapple fruit quality during cold storage. In *IV international conference on managing quality in chains-the integrated view on fruits and vegetables quality*, 712, 643–648.

Özdemir, K. S., & Gökmen, V. (2017). Extending the shelf-life of pomegranate arils with chitosan-ascorbic acid coating. *LWT-Food Science and Technology*, *76*, 172–180. https://doi.org/10.1016/j.lwt.2016.10.057

Radi, M., Firouzi, E., Akhavan, H., & Amiri, S. (2017). Effect of gelatin-based edible coatings incorporated with aloe vera and black and green tea extracts on the shelf life of fresh-cut oranges. *Journal of Food Quality*, *2017*, 9764650. https://doi.org/10.1155/2017/9764650

Rahimi, R., ValizadehKaji, B., Khadivi, A., & Shahrjerdi, I. (2019). Effect of chitosan and thymol essential oil on quality maintenance and shelf life extension of peach fruits cv. 'Zaferani'. *Journal of Horticulture and Postharvest Research*, *2*(2), 143–156.

Rajurkar, N. S., & Hande, S. M. (2011). Estimation of phytochemical content and antioxidant activity of some selected traditional Indian medicinal plants. *Indian Journal of Pharmaceutical Sciences*, *73*(2), 146–151. https://doi.org/10.4103/0250-474X.91574

Rodriguez-Amaya, D. B. (2001). *A guide to carotenoid analysis in foods* (Vol. 71). ILSI press.

Saini, V. K., Suthar, S., Karmveer, C., & Kumar, K. (2017). Valorisation of toxic weed *lantana camara* L. biomass for adsorptive removal of lead. *Journal of Chemistry*, 5612594. https://doi.org/10.1155/2017/5612594

Salinas-Roca, B., Soliva-Fortuny, R., Welti-Chanes, J., & Martín-Belloso, O. (2018). Effect of pulsed light, edible coating, and dipping on the phenolic profile and antioxidant potential of fresh-cut mango. *Journal of Food Processing and Preservation*, *42*(5), e13591. https://doi.org/10.1111/jfpp.13591

Sánchez-Burgos, J. A., & De Lourdes García-magaña, M. (2017). Pineapples (Ananas comosus). In *Fruit and Vegetable Phytochemicals: Chemistry and Human Health* (2nd Edition, pp. 1173–1178).

Santoro, K., Maghenzani, M., Chiabrando, V., Bosio, P., Gullino, M. L., Spadaro, D., & Giacalone, G. (2018). Thyme and savory essential oil vapor treatments control brown rot and improve the storage quality of peaches and nectarines, but could favor gray mold. *Foods*, *7*(1), 7. https://doi.org/10.3390/foods7010007

Saraf, A., Quereshi, S., Sharma, K., & Khan, N. A. (2011). Antimicrobial activity of *lantana camara* L. *Journal of Experimental Sciences*, *2*(10), 50–54.

Senturk Parreidt, T., Müller, K., & Schmid, M. (2018). Alginate-based edible films and coatings for food packaging applications. *Foods*, *170*, 1–38.

Singh, P., & Srivastava, D. (2012). Biofungicidal or biocontrol activity of *lantana camara* against phytopathogenic *alternaria alternata*. *International Journal of Pharmaceutical Sciences and Research*, *3*(12), 4818–4821.

Slavin, J. L., & Lloyd, B. (2012). Health benefits of fruits and vegetables. *Advances in Nutrition*, *3*(4), 506–516. https://doi.org/10.3945/an.112.002154

Tesfay, S. Z., Magwaza, L. S., Mbili, N., & Mditshwa, A. (2017). Carboxyl methylcellulose (CMC) containing moringa plant extracts as new postharvest organic edible coating for avocado (*persea americana* mill.) fruit. *Scientia Horticulturae*, *226*, 201–207. https://doi.org/10.1016/j.scienta.2017.08.047

Totad, M. G., Sharma, R. R., Sethi, S., & Verma, M. K. (2019). Effect of edible coatings on 'Misty' blueberry (*vaccinium corymbosum*) fruits stored at low temperature. *Acta Physiologiae Plantarum*, *41*(12), 183. https://doi.org/10.1007/s11738-019-2973-z

Trinetta, V., Scientist, P., Ecolab, R., & Campus, D. (2006). Definition and Function of Food Packaging. In *Reference Module in Food Science*.

Ullah, A., Abbasi, N. A., Shafique, M., & Qureshi, A. A. (2017). Influence of edible coatings on biochemical fruit quality and storage life of bell pepper cv. "Yolo Wonder". *Journal of Food Quality*, 2142409. https://doi.org/10.1155/2017/2142409

Youryon, P., & Supapvanich, S. (2017). Physicochemical quality and antioxidant changes in 'Leb Mue Nang' banana fruit during ripening. *Agriculture and Natural Resources*, *51*(1), 47–52. https://doi.org/10.1016/j.anres.2015.12.004

Zam, W. (2019). Effect of alginate and chitosan edible coating enriched with olive leaves extract on the shelf life of sweet cherries (*prunus avium* L.). *Journal of Food Quality*, 8192964. https://doi.org/10.1155/2019/8192964

Złotek, U., Mikulska, S., Nagajek, M., & Świeca, M. (2016). The effect of different solvents and number of extraction steps on the polyphenol content and antioxidant capacity of basil leaves (*ocimum basilicum* L.) extracts. *Saudi Journal of Biological Sciences*, *23*(5), 628–633. https://doi.org/10.1016/j.sjbs.2015.08.002