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The Potential of Beeswax Coating in the Preservation of Tomato (*Solanum lycopersicum*) Fruits

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HIGHLIGHTS

- Coating tomatoes with beeswax emulsion prolonged the shelf-life of the tomato fruits by 27 days, achieving a 25% preservation rate.
- The coated tomatoes showed a high mean preservation rate of 70%, compared to 20% for control group.
- The study has established the use of beeswax emulsion in extending the shelf-life of perishable tomato fruits thus minimizing wastes and economic loss to the farmer and country in general.

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Abbreviations
GC-MS=Gas Chromatography-Mass Spectometry

ABSTRACT

Background: Tomatoes are fruits that are highly prone to spoilage, making them vulnerable to microbial decay. This research aimed to explore the effectiveness of an edible coating, specifically beeswax, in prolonging the shelf-life of tomato fruits.

Methods: A total of twenty-four tomatoes were procured from the market in September 2021, washed, and subsequently treated with beeswax at varying concentrations of 3, 6, 9, 12, and 15%) (w/v). The tomatoes were then stored in well-ventilated baskets for 30 days, during which organoleptic, biochemical, and microbial assessments were conducted. The Gas Chromatography-Mass Spectrometry analysis of the beeswax samples was performed following standard procedures. The relative percentage of each component was determined by comparing its average peak area to the total area. The mean and standard deviation of the duplicated data were calculated, and significance was assessed using ANOVA at a 95% confidence interval (p-value<0.05) with the aid of the Statgraphics Plus (version 5.0) statistical package.

Results: The beeswax emulsion achieved an optimal preservation rate of 70%, significantly higher than the control group, which had a rate of 20%. Additionally, a mean preservation rate of 68% was noted with the 12% beeswax emulsion, compared to 20% for control after 30 days. Fungal isolates identified from the fruits included *Aspergillus niger*, *Candida krusei*, *Fusarium oxysporum*, *Candida* sp., *A. fumigatus*, *Penicillium notatum*, and *A. terreus*. The Gas Chromatography-Mass Spectrometry analysis of the beeswax indicated the presence of certain compounds that may contribute to its antimicrobial properties.

Conclusion: The findings of this study demonstrate that beeswax emulsion effectively extends the shelf-life of tomato fruits, offering a potential solution to reduce waste and economic losses for farmers and the broader economy

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Introduction

Tomato (*Solanum lycopersicum*) exhibits a limited post-harvest shelf-life, influenced by both external and internal factors, including elevated respiration rates, transpiration, susceptibility to postharvest diseases, and an accelerated ripening process along with senescence (Maqbool et al., 2011). These factors contribute to a decline in the quality of tomatoes, affecting attributes such as flavor, firmness, color, nutritional value, and resistance to bio-deteriorating agents over time (Chauhan et al., 2017). The fruit consists of fleshy internal segments that contain slippery seeds encased in a watery matrix (Ochida et al., 2018). Tomatoes are particularly abundant in lycopene, a compound that offers protective benefits against certain chronic diseases (Clement et al., 2015). Additionally, they are a rich source of vitamins, minerals, sodium (Na), iron (Fe), phosphorus (P), beta-carotene, potassium (K), pantothenic acid, protein, and magnesium (Mg) (Chaudhary et al., 2018). The combination of these nutrients and the high water activity in tomatoes heightens their vulnerability to bio-deterioration, resulting in diminished quality, and economic value (Wogu and Ofuase, 2014).

The microorganisms associated with the spoilage of tomato fruits include *Clostridium* sp., *Staphylococcus* sp., and *Bacillus* sp. (Ajayi, 2013), as well as *Klebsiella* sp., *Proteus mirabilis*, *Vibrio* sp., and *Pseudomonas* sp. (Garg et al., 2013), along with *B. subtilis*, *K. aerogenes*, *P. aeruginosa*, *Salmonella typhi*, *P. mirabilis*, and *S. aureus* (Wogu and Ofuase, 2014).

The perishable nature of tomatoes, coupled with inadequate storage facilities, results in significant post-harvest losses in developing countries, leading to substantial economic repercussions (Banjo and Bankole-Ojo, 2023). Consequently, there is a growing interest in the application of preservatives, with a particular focus on organic or plant-based materials for the preservation of tomatoes, as opposed to chemical preservatives (Irokanulo et al., 2015). Extracts from the soursop plant (*Annona muricata*) and the Roselle plant (*Hibiscus sabdariffa*) have been utilized for the preservation of tomato fruits (Banjo et al., 2022) Neem (*Azadirachta indica*) leaf powder has demonstrated effectiveness against spoilage microorganisms, as noted by Hosea et al. (2017). Additionally, Ijato et al. (2011) documented the antimicrobial properties of *Vernonia amygdalina* and *Tridax procumbens* in the in-vitro management of post-harvest fruit rot in tomatoes. There is a pressing need to explore cost-effective and edible organic alternatives for preserving this economically significant fruit. One such alternative involves the application of coating materials for the preservation of tomatoes.

The technique of edible coating involves the application of thin films composed of polysaccharides, proteins, and lipids onto the surfaces of fruits and vegetables (Corbo, 2010). This thin film serves to extend the shelf-life of produce by regulating moisture transfer, gas exchange, and oxidation processes (Dhall, 2013). In response to consumer preferences for natural organic materials, there has been a surge in research aimed at developing edible coatings that can substitute synthetic waxes for maintaining the quality of post-harvest fruits (Senna et al., 2014). In this study, beeswax is identified as the edible coating material for the preservation of tomato fruits.

In nature, certain insects produce wax, with some members of the *Apoidea* family, particularly bees, producing wax that is highly valued and utilized by humans. The most commonly used wax is beeswax, which is derived from the species *Apis mellifera* and *Apis cerana.* The widespread availability and continuous supply of beeswax can be attributed to the fact that these bee species are extensively cultivated by humans (Kaluza et al., 2016). Beeswax acts as a natural glazing agent, effectively preventing water loss and providing protection during storage. Its rich hydrophobic properties make it a common ingredient in cosmetics and body care products (Fratini et al., 2016).

Tomato fruits are highly perishable and vulnerable to bio-deterioration agents, leading to significant economic losses for both farmers and consumers, particularly in developing countries. Consequently, it is essential to identify and develop safer techniques to minimize spoilage and extend the shelf-life of this fruit. While chemical preservatives, including waxes, sprays, and liquids, have been utilized for tomato preservation, these methods have been found to pose risks to human health. Therefore, this study aims to explore the potential of using edible, safer, and more cost-effective non-synthetic materials, such as beeswax, for the preservation of tomato fruits.

Materials and methods

Plant and coating materials

A total of 24 tomato fruits were obtained from Lusada market, Ogun state in September 2021. Beeswax was purchased from Ojota market, Lagos state, Nigeria.

Collection and preparation of plant materials

Beeswax emulsion was prepared by melting beeswax sample in a one L container at 70 ˚C and heating continuously to attain a temperature of 80-90 ˚C (Efendi and Hermawati, 2014).

The tomatoes selected were fully ripe and red in color. Those with deformity, pigmentation, wrinkle (with a thumb slide), darkened or with bruised areas on or under the skin of the tomatoes were rejected.

Experimental design and treatment of tomato fruits with beeswax as coating materials

A factorial combination of six levels of beeswax coating (control, 3, 6, 9, 12, and 15%) was applied on fully matured red tomatoes in the study. The treatments were arranged in baskets and monitored for a period of 30 days.

A total quantity of 24 tomato fruits was used for the study, where each treatment combination had four fruits. Tomato fruits were washed using distilled water and gently rubbed with a tidy cotton cloth to remove water. The fruits were dipped in various concentrations of beeswax emulsion for 5 min. Untreated tomato fruits were used as a control. After being air dried, the fruits were stored in baskets already designated as BW (beeswax) and C (control) at a temperature of 22 ^{o}C and relative humidity of 65% for quality and shelf-life assessments. The shelf-life of the stored tomato fruits was assessed and data recorded in duplicates on the 3, 6, 9, 12, 15, 18, 21, 24, 27, and 30 days of storage.

Effects of different concentrations of beeswax coating on tomato preservation

The effects of different concentrations of the beeswax emulsion in the range of 3-15% (3, 6, 9, 12, and 15%) on tomato fruits were carried out according to the methods of Maseret et al. (2012). This was monitored for two weeks.

Control

The tomatoes were washed thoroughly and four were placed in a basket already labelled control (C) without any treatment.

Isolation of spoilage fungi

Spoilage fungi were extracted from the bio-deteriorated tomato samples. Employing standard microbiological techniques, specifically serial dilution, one ml of the deteriorated tomato fluid was pipetted and combined with 9 ml of sterile distilled water in a test tube. The test tube was shaken vigorously to ensure thorough mixing. The dilution process was continued up to the fourth dilution factor (10^{-4}). One ml from this fourth dilution was aseptically transferred and plated in duplicate using sterile molten lukewarm potato dextrose agar (BDH Chemicals, UK). The plates were allowed to solidify and subsequently incubated (Gallenkamp incubator located in England) at 27 °C for 48 h. Distinct colonies were sub-cultured to obtain pure cultures for further identification.

Preparation of media

The culture medium utilized for fungal evaluation was potato dextrose agar. A total of 39 g of potato dextrose agar was dissolved in one L of distilled water and boiled to ensure complete dissolution before being sterilized in an autoclave at 121 °C for 15 min. The pH of the medium was adjusted to 3.5 by adding 10 ml of lactic acid (Lobachemi, India, UK). The medium was then cooled to 55 °C.

Identification of spoilage moulds

The identification of spoilage moulds was performed using a modified needle mount preparation technique as outlined by Onuorah and Orji (2015). A small sample of the colony was extracted with a sterile inoculation needle and placed into a drop of 70% ethanol. This mixture was gently agitated to separate the colonies. Subsequently, a drop of lactophenol cotton blue stain (Lobachemi, India) was added, and a clean cover slip was carefully positioned over the preparation. The sample was then examined under a microscope at ×40 objective power (Olympus, Japan).

Identification of spoilage yeast cells

Identification of spoilage yeast cells was conducted on yeast cells isolated from spoiled tomato fruits, following the procedure described by Onuorah and Orji (2015). The yeasts were characterized and identified using urea, germ tube, sugar assimilation, and cycloheximide tests. The identity of each fungus was confirmed with the aid of a mycological atlas.

-Germ tube test

Approximately 0.5 ml of serum was introduced into a sterile test tube. A loopful of yeast was inoculated into the serum and incubated at 37 °C for 4 h. Following incubation, a loopful was transferred to a glass slide, covered with a cover slip, and examined under an ×40 objective lens to assess germ tube production (Onuorah and Orji, 2015).

-Urea test

About 0.5 ml of the overnight yeast broth, incubated at 37 °C, was added to 5 ml of urea solution (Oxoid, UK) containing 1% phenol red indicator (Molychem, India). A color change to pink indicates positive urea utilization, while a yellow color signifies a negative reaction (Onuorah and Orji, 2015).

-Cycloheximide

Approximately 0.5 ml of the yeast sample, incubated overnight at 37 °C, was added to 5 ml of cycloheximide (Molychem, India) solution. A loopful was examined under a microscope for the presence of yeast. The presence of yeast indicates no inhibition by cycloheximide, whereas its absence suggests an inhibitory reaction (Onuorah and Orji, 2015).

-Glucose test

About 0.5 ml of the yeast sample was added to 5 ml of glucose solution containing phenol red indicator and

incubated overnight. A color change from pink to yellow indicates a positive reaction, while a persistent pink color indicates a negative reaction (Onuorah and Orji, 2015).

Gas Chromatography- Mass Spectrometry (GC-MS) analysis of beeswax

The GC/MS analysis of the beeswax was conducted utilizing the Shimadzu GC-MS, Model QP-2010 Ultra, which was fitted with a headspace AOC-5,000 auto-injector. The analysis was performed under the following conditions: column specifications included Rtx-5 MS with a length of 30 m, an inner diameter of 0.25 mm, and a film thickness of 0.25 mm (composed of 5% diphenyl and 95% dimethyl polysiloxane). The detector employed was mass spectrometry, with helium serving as the carrier gas. The oven temperature program commenced at 40 °C, maintained for 2 min, followed by a heating rate of 3 °C per min, ultimately reaching a final temperature of 220 °C with a hold time of 5 min. The GC-MS program parameters included an ion source temperature of 200 °C, an interface temperature of 250 °C, a solvent cut time of 2 min, and a total run time of 60 min. The acquisition mode was set to scan, with an event time of 0.30 s. The scan detector gain mode was relative, with a detector gain of 1.08+0.00 kV, a speed of 1.666, and a mass-to-charge ratio (m/z) range starting at 35.00 and concluding at 500.0 (Montaser et al., 2023).

Statistical analysis

Mean and Standard Deviation (SD) of the duplicated data were analyzed, while significance was determined using ANOVA at a 95% confidence interval (p-value<0.05) with the aid of the Statgraphics Plus (version 5.0) statistical package.

Results and discussion

The result of the preservation potential of beeswax emulsion on tomato fruit in this study was based entirely on the organoleptic tests of the tomato, which includes visual observation, touch, and smell. The tomatoes were considered spoilt if there was evidence of softening, wrinkle, tear, or microbial growth.

The effect of beeswax coating on preservation of tomato fruits

The experimental setup and the effects of beeswax emulsion on the preservation of tomatoes are illustrated in Figure 1 and detailed in Table 1. By the 30th day, complete deterioration (100%) of the tomatoes treated with beeswax was observed based on the organoleptic tests of visual observation, touch, and smell. The average preservation rates for tomatoes treated with beeswax emulsion were 70%, in contrast to 20% for the control group. The findings indicate that natural waxes significantly mitigate losses, uphold quality, and prolong the shelf-life of tomato fruits. The beeswax emulsion demonstrated a superior average preservation rate compared to the control. This can be attributed to the formation of a wax coating around the tomatoes by the beeswax emulsion. Previous studies have indicated that waxing can delay fruit ripening, minimize water loss, enhance quality, and extend the shelf-life of tomatoes (Ahmed and Abu-Goukh, 2003). The extended shelf life of the coated tomatoes may result from the closure of stomatal openings, reduced transpiration, and respiration rates, and decreased microbial activity due to the coating, as noted by various researchers (Vignesh and Nair, 2019). The improved quality and longevity of beeswax-coated fruits can be linked to the antimicrobial properties of the compounds found in beeswax. The effectiveness of coating materials in prolonging the shelf-life of tomatoes has been documented (Vignesh and Nair, 2019; Islam et al., 2023). Additionally, these coatings may have altered the internal atmosphere of the fruit, resulting in elevated carbon dioxide levels, and reduced oxygen levels, which slow the deterioration process, as previously suggested by Bosquez-Molina et al. (2003) and Gonzalez-Aguilar et al. (2005).

Figure 1: Tomatoes coated with beeswax (A) and the control (B)

Table 1: Effects of beeswax emulsion on the preservation of tomato fruits

Time in days	% preservation Beeswax	% preservation Control
3	100	75
6	100	50
9	100	25
12	75	25
15	75	25
18	75	0.0
21	75	0.0
24	50	0.0
27	25	0.0
30	0.0	0.0
Mean rate of preservation	70.0	20.0

Effect of different concentrations of beeswax emulsion on tomato preservation

The varying concentrations of the beeswax emulsion demonstrated notable effects on the preservation of tomato fruits (p<0.05). Specifically, tomatoes treated with a 3% concentration exhibited preservation in two out of four samples (50%) after 15 days. In contrast, the 5% concentration resulted in complete spoilage by the 15th day, with only one out of four samples (25%) preserved after 12 days. The 12% concentration yielded the highest preservation rate, with three out of four samples (75%) remaining intact after 21 days. Additionally, tomatoes treated with a 9% concentration showed that one out of four samples (25%) was preserved after 15 days, while the 12% concentration also indicated that two out of four samples (50%) were preserved after 15 days. Overall, the 12% (w/v) concentration proved to be the most effective in preventing spoilage, with 75% of the tomatoes preserved after 21 days post-treatment. In general, the percentage preservation of tomato fruits increased by increasing the concentration of the beeswax coating. This could be attributed to the antimicrobial property of the beeswax and their ability to prevent moisture loss, thereby creating a modified atmospheric condition which reduces the rate of respiration and ethylene production of the treated tomato fruits. This could probably delay the ripening processes of the tomato fruits and enhance the shelf life of the fruits. (Zewdie et al, 2022). The average preservation rates for the 3, 5, 6, 9, 12, and 15% concentrations of the beeswax emulsion during the study were 42.5, 50, 55.5, 68, 50, and 75%, respectively, compared to a control rate of 20%.

Identification of spoilage microorganisms from tomato fruits

The microorganisms isolated from the spoilt tomato fruits were identified as detailed in Table 2. The average fungal counts varied between 1.3×10^3 and 2.0×10^3 Colony Forming Unit (CFU)/ml *Aspergillus niger* exhibited the highest occurrence rate at 47.27% among the examined spoilt tomatoes, whereas both *Candida* species and *C. krusei* recorded the lowest occurrence rate of 3.64%. The study indicates that the spoilage microorganisms associated with the tomato fruits are primarily fungi. The fungal isolates identified from the fruits included *A. niger*, *C. krusei*, *Fusarium oxysporum*, *Candida* species, *A. fumigatus*, *Penicillium notatum*, and *A. terreus*. Ibrahim et al. (2011) identified *A. niger* as a significant contributor to the production of volatile compounds in spoilt tomatoes. Similarly, Onuorah and Orji (2015) reported the isolation of *A. niger* from decayed tomato fruits, noting its pathogenicity. Wogu and Ofuase (2014) also isolated *Aspergillus* spp., *Penicillium* spp., and *Fusarium* spp. from spoilt tomatoes. In a related investigation, Mbajiuka et al. (2014) found *Aspergillus* spp. and *Penicillium* spp. to be the predominant spoilage microorganisms in spoilt tomatoes. The application of a wax coating significantly reduces the penetration of microorganisms into the epicarp of tomato fruits, thereby prolonging the shelf-life of beeswax-coated tomatoes compared to uncoated control fruits. A similar study by Ruelas-Chacon (2017) indicated that the protective effect of an edible guar gum coating diminishes the rate of microbial development that compromises tomato quality, as the coating serves as a barrier to gases and essential nutrients required for microbial growth (Teheri et al., 2022). This investigation demonstrated that *A. niger* had a notable occurrence rate of 45.32% in the spoilt tomato fruits analyzed, while both *Candida* species *and C. krusei* exhibited the lowest occurrence rate of 3%. The result agreed with the work of Akinmusire (2011) and Ibrahim et al. (2011). They reported that *A. niger* had the highest rate of occurrence in the tomato fruits they studied and concluded that the fungus may be the major organism responsible for the spoilage of tomato fruit.

Table 2: Fungal isolates identified from tomato fruits

Label	Macroscopy	Microscopy	Identity of yeasts and moulds
1	Brownish yellow in colour, aerial reverse appear dirty brown	Conidia are compact, columna, biseraited, ellipsoda. Conidiophores is hyaline smooth walled	*Aspergilus terreus*
2a	White aerial cotton mycelium	Conidiophores are short, single cell. Macroconidia appearing fusiform, slightly curved with pointed tip. Microconidia are abundant, not in chain, non-septate	*Fusarium oxysporum*
2b	Creamy colour, smooth and glaborous	Small, elongated ovoid budding blastoconidia cells	*Candida specie*
3	Brown-grey filamentous colonies	Large globose conidiophores, loose columna with serated hypha	*Aspergilus fumigatus*
4	Creamy colour, smooth and glaborous	Small, elongated ovoid budding blastoconidia cells	*Candida krusei*
5	Green dense, fluffy surface. Dark brown reverse side	Conidia appear single cell, chin phialides and flask shapedfrom single metula. Conidiophores smooth, rough walled	*Penicillium notatum*
6	Numerous black spore, reverse brownish grey	Large conidia, globose with loose colum. Conidiophores are smooth-walled biseriated with septatephiliades. Conidia are globose and rough walled.	*Aspergilus niger*
7a	Numerous black spore, reverse brownish grey	Large conidia, globose with loose colum. Conidiophores are smooth-walled biseriated with septatephiliades. Conidia are globose and rough walled.	*A. niger*
7b	Green dense, fluffy surface. Dark brown reverse side	Conidia appear single cell, chin phialides, and flask shapedfrom single metula. Conidiophores smooth, rough walled	*P. notatum*
8a	White aerial cotton mycelium	Conidiophores are short, single cell. Macroconidia appearing fusiform, slightly curved with pointed tip. Microconidia are abundant, not in chain, non-septate	*F. oxysporum*
8b	Numerous black spore, reverse brownish grey	Large conidia, globose with loose colum. Conidiophores are smooth-walled biseriated with septatephiliades. Conidia are globose and rough walled.	*A. niger*
9	Brown-grey filamentous colonies	Large globose conidiophores, loose columna with serated hypha	*A. fumigatus*

GC-MS of beeswax emulsion

The GC-MS chromatogram of the beeswax emulsion, illustrated in Figure 2, exhibited thirty distinct peaks, indicating the presence of thirty different phytocompounds within the beeswax sample. The compound with the most significant peak is tetracosane, which accounts for 18.03% in height and 22.51% in area. Conversely, the compounds with the least prominent peaks include 3,4-Hexanedione, 2,2,5-trimethyl-, Propanamide, 3,3,3-trifluoro-2-(trifluoromethyl), and oxalic acid, isobutyl neopentyl ester, each exhibiting a percentage height of 0.01% and percentage area values of 0.01, 0.00, and 0.01, respectively. The names and molecular weights of the compounds found in the beeswax sample utilized as a coating material are detailed in Table 3. The GC-MS analysis confirmed the presence of thirty compounds in beeswax, predominantly consisting of fatty acids, and their ester derivatives. These compounds and their respective quantities play a crucial role in the preservation of tomatoes, attributed to the antimicrobial properties that inhibit the proliferation of spoilage organisms (Ajijolakewu and Awarun, 2015; Wada et al., 2019). Previous studies have documented the antimicrobial activities of both naturally occurring and synthetic fatty acid alkyl esters (Chandrasekaran et al., 2011; Huang et al., 2011). While the precise relationship between the structure and antimicrobial efficacy of various fatty acids and their ester derivatives remains unclear, it is hypothesized that the number and presence of double bonds significantly influence the inhibitory effects (Huang et al., 2011). Mechanistically, fatty acids and their ester derivatives disrupt essential fatty acid biosynthesis and degradation processes (Sarkar and Singh, 2022). Additionally, these compounds exhibit antimicrobial properties by interfering with the biochemical integrity of microbial cell membranes and walls (Chen et al., 2010; Lunde et al., 2009).

Table 3: Gas Chromatography-Mass Spectrometry (GC-MS) analysis of beeswax emulsion

Peak	R.time	Area (A)	Area %	Height (H)	Height %	A/H	Name
1.	10.016	249,739	0.01	90,548	0.02	2.76	Alpha.-cubebene
2.	10.207	99,938	0.01	37,773	0.01	2.65	3,4-Hexanedione,2,2,5-trimethyl-
3.	10.597	46,971	0.00	25,097	0.01	1.87	Propanamide, 3,3,3-trifluoro-2-(trifluoromethyl
4.	11.490	116,185	0.01	49,676	0.01	2.34	Oxalic acid, isobutyl neopentyl ester
5.	11.564	699,964	0.04	363,144	0.10	1.93	Dodecanoic acid, methyl ester
6.	12.694	157,805	0.01	94,582	0.02	1.67	Nonane, 3,7-dimethyl-
7.	13.838	219,252	0.01	139,187	0.04	1.58	Sulfurous acid, 2-ethylhexyl
8.	13.919	483,894	0.03	310,108	0.08	1.56	Methyl tetradecanoate
9.	14.925	382,280	0.02	237,118	0.06	1.61	Heptadecane
10.	15.587	350,796	0.02	200,145	0.05	1.75	1-Hexadecanol
11.	15.958	739,935	0.04	448,419	0.12	1.65	Heneicosane
12.	16.041	961,881	0.06	616,493	0.16	1.56	Hexadecanoic acid, methyl este
13.	17.005	4,497,558	0.26	2,522,204	0.66	1.78	Heneicosane
14.	17.848	255,441	0.01	129,220	0.03	1.98	13-Heptadecyn-1-ol
15.	17.949	2,785,469	0.16	1,439,687	0.38	1.93	9-Octadecenoic acid, methyl ester, (E)-
16.	18.175	34,971,431	2.05	16,109,339	4.23	2.17	Heneicosane
17.	18.282	3,134,422	0.18	1,579,365	0.41	1.98	Methyl stearate
18.	19.383	141,056,427	8.27	46,925,495	12.32	3.01	Hexatriacontane
19.	20.074	1,308,561	0.08	614,317	0.16	2.13	Nonacosane
20.	20.549	33,589,6378	19.70	63,679,787	16.71	5.27	Tetracosane
21.	21.153	7,364,413	0.43	3,040,091	0.80	2.42	Nonacosane
22.	21.256	2,761,580	0.16	792,864	0.21	3.48	2-methylhexacosane
23.	21.608	334,148,030	19.59	66,317,642	17.41	5.04	Tetracosane
24.	22.174	25,467,619	1.49	9,183,201	2.41	2.77	Hexatriacontane
25.	22.269	9,125,541	0.54	2,330,294	0.61	3.92	Nonacosane
26.	22.593	328,082,446	19.24	65,082,797	17.08	5.04	Tetracosane
27.	23.135	61,603,671	3.61	20,177,189	5.30	3.05	Hexatriacontane
28.	23.220	20,357,860	1.19	7,742,321	2.03	2.63	Hexatriacontane
29.	23.291	4,090,389	0.24	2,003,679	0.53	2.04	1-Heptacosanol
30.	23.543	383,915,983	22.51	68,709,695	18.03	5.59	Tetracosane
		1,705,331,859	100.00	380,991,477	100.00		

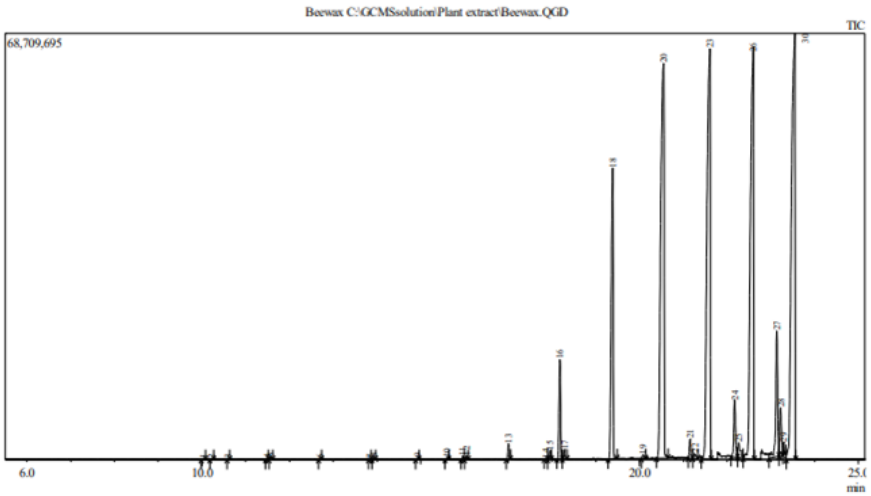

Figure 2: Gas Chromatography-Mass Spectrometry Chromatogram (GC-MS) of beeswax emulsion

Conclusions

The current research demonstrates that applying beeswax emulsion to tomatoes significantly extended their shelf-life by 27 days, achieving a preservation rate of 25%. Furthermore, the mean preservation rate reached 70%, in contrast to the control group, which exhibited a mere 20% preservation. This indicates that beeswax coating not only preserved the firmness of the tomatoes but also enhanced their postharvest quality during storage at room temperature. The beeswax coating is biodegradable, easy to apply, and more cost-effective than other hydrocolloids and commercial waxes, making it a viable option for commercial use to extend the storage life of the Roma

tomatoes examined in this study. Consequently, this research has validated the effectiveness of beeswax emulsion in prolonging the shelf-life of perishable tomato fruits, thereby reducing waste and economic losses for both farmers and the nation as a whole. However, further studies are required to investigate the 12% concentration of beeswax which proved most effective in the preservation of the tomatoes.

Author contributions

T.B designed the study; T.B. and R.M. conducted the experimental work; T.B. analyzed the data; T.B. and R.M. wrote the manuscript; T.B. and R.M reviewed and edited the final manuscript. Both authors read and approved the final manuscript.

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Conflicts of Interest

The authors declare that there is no conflict of interest.

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Ethical consideration

Not applicable.

References

Ahmed I.H., Abu-Goukh A.A. (2003). Effect of maleic hydrazide and waxing on ripening and quality of tomato fruit. *Gezira Journal of Agricultural Science*. 1 : 59-72.

Ajayi A. (2013). Nature of tomatoes microflora under storage. *American Journal of Experimental Agriculture*. 3: 89-101. [DOI: 10.9734/AJEA/2013/2177].

Ajijolakewu K.A., Awarun F.J. (2015). Comparative antibacterial efficacy of *Vitellaria paradoxa* (Shea butter tree) extracts against some clinical bacterial isolates. *Notulae Scientia Biologicae*. 7: 264-268. [DOI: 10.15835/nsb739617]

Akinmusire O.O. (2011). Fungi species associated with the spoilage of some edible fruits in Maiduguri, north eastern Nigeria. *Advances in Environmental Biology*. 5: 157-161.

Banjo T.T., Bankole-Ojo O. (2023). Comparative preservative potential of shea butter and coconut oil on tomato fruits (*Solanum lycopersicum*). *African Scientist.* 24:338-348. [DOI: 10.26538/africanscientist.24.3.20230904]

Banjo T.T., Oluwole O.R., Nzei V.I. (2022). Preservation of *Lycopersicum esculentum* (tomatoes) with extracts of *Annona muricata* (Soursop) and *Hibiscus sabdariffa* (Roselle plant). *Tropical Life Sciences Research*. 33: 1-22. [DOI: 10.21315/tlsr2022.33.1.1]

Bosquez-Molina E., Guerrero-Legarreta I., VernonCarter E.J. (2003). Moisture barrier properties and morphology of mesquite gum–candelilla wax based edible emulsion coatings. *Food Research International*. 36:885-893. [DOI: 10.1016/S0963-9969(03)00097-8]

Chandrasekaran M., Senthilkumar A., Venkatesalu V. (2011). Antibacterial and antifungal efficacy of fatty acid methyl esters from the leaves of *Sesuvium portulacastrum* L. *European Review for Medical and Pharmacological Sciences.* 15: 775-780.

Chaudhary P., Sharma A., Singh B., Nagpal A.K. (2018). Bioactivities of phytochemicals present in tomato. *Journal of Food Science and Technology*. 55: 2833-2849. [DOI: 10.1007/s13197-018-3221-z]

Chauhan O.P., Lakshmi S., Pandey A.K., Ravi N., Gopalan N., Sharma R.K.(2017). Non-Destructive quality monitoring of fresh fruits and vegetables. *Defence Life Science Journal*. 2: 103. [DOI: 10.14429/dlsj.2.11379]

Chen S.C., Biswas C., Bartley R., Widmer F., Pantarat N., Obando D., Djordjevic J.T., Ellis D.H., Jolliffe K.A., Sorrell T.C. (2010). In vitro antifungal activities of bis (*alkylpyridinium*) alkane compounds against pathogenic yeasts and molds. *Antimicrobial Agents and Chemotherapy.* 54: 3233-3240. [DOI: 10.1128/AAC.00231-10]

Clement A., Bacon R., Sirois S., Dorais M. (2015). Mature-ripe tomato spectral classification according to lycopene content and fruit type by visible, NIR reflectance and intrinsic fluorescence. *Quality Assurance and Safety of Crops and Foods*. 1: 1-10. [DOI: 10.3920/QAS2014.0521]

Corbo M.R., Speranza B., Campaniello D., Amato D.D., Sinigaglia M. (2010). Fresh-cut fruits preservation: current status and emerging technologies. In: Mendez-Vilas A. **(**Editor). Current research, technology and education topics. Formatex Research Center, Badajoz. pp: 1143-1154.

Dhall R.K. (2013). Advances in edible coatings for fresh fruits and vegetables: a review. *Critical Reviews in Food Science and Nutrition*. 53: 435-450. [DOI: 10.1080/10408398. 2010.541568]

Efendi D., Hermawati H. (2014). The use of bee wax, chitosan and BAP to prolong shelflife of mangosteen (*Garcina mangostana* L.) fruit. *Jurnal Hortikultura Indonesia*. 1: 32-39. **[**DOI: 10.29244/jhi.1.1.32-39]

Fratini F., Cilia G., Turchi B., Felicioli A. (2016). Beeswax: a minireview of its antimicrobial activity and its application in medicine. *Asian Pacific Journal of Tropical Medicine*. 9: 839-843. [DOI: 10.1016/j.apjtm.2016.07.003]

Garg R.K., Batav N., Silawat N., Singh R.K. (2013). Isolation and identification of pathogenic microbes from tomato puree and their delineation of distinctness by molecular techniques. *Journal of Applied Biology and Biotechnology.* 1: 024-031.

González-Aguilar G.A., Ruiz-Cruz S., Soto-Valdez H., Vázquez-Ortiz F., Pacheco A. R., Wang C.Y. (2005). Biochemical changes of fresh cut pineapple slices treated with anti-browning agents. *International Journal of Food Science and Technology.* 40: 377-383. [DOI: 10.1111/j.1365-2621.2004.00940.x]

Hosea Z.Y., Liamngee K., Owoicho A.L., Agatsa T.D. (2017).

Effect of Neem leaf powder on post-harvest shelf life and quality of tomato fruits in storage**.** *International Journal of Development and Sustainability***.** 6: 1334-1349.

Huang C.B., Altimova Y., Myers T.M., Ebersole J.L. (2011).Short- and medium-chain fatty acids exhibit antimicrobial activity for oral microorganisms. *Archives of Oral Biology*. 56: 650-654. [DOI: 10.1016/ j.archoralbio.2011.01.011]

Ibrahim A.D., Musa K., Sani A., Aliero A.A., Yusuf B.S. (2011). Microorganisms associated with the production of volatile compounds in spoilt tomatoes. *Research in Biotechnology*. 2: 82-89.

Ijato J.Y., Otoide J.E., Ijadunola J.A., Aladejimokun A.O. (2011). Efficacy of antimicrobial effect of *Vernonia amygdalina* and *Tridax procumbens* in in-vitro control of tomato (*Lycopersicon esculentum*) post-harvest fruit rot. *Report and Opinion*. 3: 120-123.

Irokanulo E.O., Egbezein I.L., Owa S.O. (2015). Use of *Moringa oleifera* in the preservation of fresh tomatoes. *IOSR Journal of Agriculture and Veterinary Science*. 8: 127-132. [DOI: 10.9790/2380-0822127132]

Islam M.M., Islam R., Hassan S.M., Karim M.R., Rahman M.M., Rahman S., Hossain M.N., Islam D., Shaikh M.A., Georghiou P.E. (2023). Carboxymethyl chitin and chitosan derivatives: Synthesis, characterization and antibacterial activity**.** *Carbohydrate Polymer Technologies and Applications***.** 5: 100283. [DOI: 10.1016/j.carpta.2023. 100283]

Kaluza B.F., Wallace H., Heard T.A., Klein A.M., Leonhardt S.D. (2016). Urban gardens promote bee foraging over natural habitats and plantations. *Ecological Evolution*. 6: 1304-1316. [DOI: 10.1002/ece3.1941]

Lunde C.S., Hartouni S.R., Janc J.W., Mammen M., Humphrey P.P., Benton B.M. (2009). Telavancin disrupts the functional integrity of the bacterial membrane through targeted interaction with the cell wall precursor lipid II. *Antimicrobial Agents and Chemotherapy*. 53 : 3375-3383. [DOI: 10.1128/AAC.01710-08]

Maqbool M., Ali A., Alderson P.G., Zahid N., Siddiqui Y. (2011). Effect of a novel edible composite coating based on gum arabic and chitosan on biochemical and physiological responses of banana fruits during cold storage. *Journal of Agricultural and Food Chemistry*. 59: 5474-5482. [DOI: 10.1021/jf200623m]

Mbajiuka S., Emmanuel C., Emmanuel E. (2014). Isolation of microorganisms associated with deterioration of tomato (*Lycopersicum esculentum*) and pawpaw (*Carica papaya*) fruits. *International Journal of Current Microbiology and Applied Sciences*. 3: 501-512.

Montaser M., Sayed A.M., Bishr M.M., Zidan E.W., Zaki M.A. ,Hassan H.M. , Mohammed R., Hifnawy M.S. (2023). GC-MS analysis of honeybee products derived from medicinal plants. *Beni-Suef University Journal of Basic and Applied Sciences*. 12: 63. [DOI: 10.1186/s43088-023-00396-3]

Ochida C. O., Itodo A.U., Nwanganga P.A. (2019). A review on postharvest storage, processing and preservation of tomatoes (*Lycopersicon esculentum* Mill). *Asian Food Science Journal*. 6: 1-10. [DOI: 10.9734/AFSJ/2019/44518]

Onuorah S., Orji M.U. (2015). Fungi associated with the spoilage of post-harvest tomato fruits sold in major markets in Awka, Nigeria. *Universal Journal of Microbiology Research.* 3: 11-16. [DOI: 10.13189/ujmr.2015.030201]

Regassa M.D., Mohammed A., Bantte K. (2012). Evaluation of tomato (*Lycopersicum esculentum* Mill) genotypes for fruit quality and shelf life. *The African Journal of Plant Science and Biotechnology*. 3: 50-56.

Ruelas-Chacon X., Contreras-Esquivel J.C., Montañez J., Aguilera-Carbo A.F., Reyes-Vega M.L., Peralta- Rodriguez R. D., Sanchéz-Brambila G. (2017).Guar gum as an edible coating for enhancing shelf- life and improving postharvest quality of Roma tomato (*Solanum lycopersicum*). *Journal of Food Quality*. 2017. [DOI:10.1155/2017/8608304]

Sarkar S.,Singh R.P. (2022). Nyctanthes arbor-tristis L.: Perspective of phytochemical-based Inhibition of fatty acid biosynthesis in Mycobacterium tuberculosis. *International Journal of Plant Based Pharmaceuticals*. 2: 166-175. [DOI: 10.55484/ijpbp.1049943]

Senna M., Al-Shamrani K., Al-Arifi A. (2014). Edible coating for shelf-life extension of fresh banana fruit based on gamma irradiated plasticized poly(vinyl alcohol)/carboxymethyl cellulose/tannin composites. *Materials Sciences and Applications*. 5: 395-415. [DOI: 10.4236/msa.2014.56045]

Taheri F., Jafar Daghighi A., Bodaghi H., Ebrahimi A., Ghasimi Hagh Z. (2022). The effect of 1-methylcyclopropene application incorporated with packaging on the expression of ethylene-related genes and quality maintenance of cherry tomato cultivars. *Journal of Research and Innovation in Food Science and Technology*. 11: 275-290 [DOI: 10.22101/JRIFST.2022.309903.1285]

Vignesh R.M., Nair B.R. (2019). Improvement of shelf life quality of tomatoes using a novel edible coating formulation. *Plant Science Today*. 6: 84-90. [DOI: 10.14719/pst.2019. 6.2.443]

Wada N.M., Muhammad M.I., Garba A.S., Ghazali H.M. (2019). Antibacterial activity of *Vitellaria paradoxa* seed oil extract and honey against bacterial isolates from wound infection. *International Journal of Biological, Physical and Chemical Studies*. 1: 16-21.

Wogu M. D., Ofuase O. (2014). Microorganisms responsible for the spoilage of tomato fruits, *Lycopersicum esculentum*, sold in markets in Benin City, Southern Nigeria. *Scholars Academic Journal of Biosciences*. 2: 459-466. [DOI: 10.36347/sajb.2014.v02i07.012]

Zewdie B., Shonte T.T., Woldetsadik K. (2022). Shelf life and quality of tomato (*Lycopersicon esculentum*) fruits as affected by neem leaf extract dipping and beeswax coating**.** *International Journal of Food Properties*. 25: 570-592. [DOI: 10.1080/10942912.2022.2053709]