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Comparative Preservative Potential of Shea Butter and Coconut Oil on Tomato Fruits (*Solanum lycopersicum*)

Banjo, Temitope Temitayo[1]* and Bankole-Ojo, Olufunsho[2]

[1]Microbiology Programme, Department of Biological Sciences, Crawford University, PMB 2001, Igbesa, Ogun State, Nigeria.
[2]Chemistry Programme, Department of Physical and Earth Sciences, Crawford University, PMB 2001, Igbesa, Ogun State, Nigeria.

*Corresponding author Email: topebanjo4rever@gmail.com, Tel: +234 (0) 703 012 1326

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ABSTRACT: Tomato fruits are perishable. Hence several methods have been adopted in their preservation which have not been generally accepted due to their health implications. Therefore, the aim of this study is to investigate the potential of coconut oil and sheabutter in the preservation of tomato fruits. Tomato fruits were washed and treated with coconut oil and shea butter which was varied at different concentrations of 3, 6, 9, 12 and 15 % (w/v). The tomato fruit was placed in well-aerated baskets for 30 days during which organoleptic observation and microbial analysis were investigated. The GC-MS analysis of the coconut and shea butter samples was carried out. The shea butter displayed a higher mean preservation rate of 62 % compared to that of coconut oil with 25 %. The fungal isolates from the fruits included *Aspergillus niger*, *Candida krusei*, *Fusarium oxysporum*, *Candida species*, *Aspergillus fumigatus*, *Penicillium notatum* and *Aspergillus terreus.* The GC-MS analysis of the coating materials revealed the presence of some compounds that may be responsible for their antimicrobial properties. The study showed that shea butter exhibits the highest preservation rate of tomato fruits thus minimizing waste and economic losses to the farmers and the country in general.

Keywords: *Lycopersicon esculentum*; Coconut oil; Shea butter; Preservation; Coating materials.

Introduction

Tomato which is the edible fruit of the plant *Solanum lycopersicum*, belongs to the family *Solanaceae* (Celma *et al*., 2009). There are different varieties of this fruit resulting in tomatoes with different colour, quality and taste (Gastellum-Barrios *et al*., 2011). Tomato is one of the most widely cultivated and consumed horticultural crops worldwide and is very rich in lycopene (Clement *et al*., 2015). Lycopene helps in reducing the prevalence of some chronic diseases (Basu and Imrha, 2000). The fruit is also rich in vitamins (Watkins, 2008), minerals, sodium, iron, phosphorus, beta-carotene, potassium and magnesium (Passam *et al*., 2007; Freeman and Reimers, 2011). In addition, they are a good source of chromium, pantothenic acid, protein and iron (Preedy and Watson, 2008). These nutrients and the high-water content of tomato fruits make them susceptible to microbial deterioration which leads to a reduction in the quality and market value of tomatoes (Wogu and Ofuse, 2014). Some of the microorganisms that are associated with tomato fruit spoilage include; *Clostridium* sp., *Staphylococcus* sp. and *Bacillus* sp. (Ajayi, 2013), *Klebsiella* sp., *Proteus mirabilis*, *Vibrio* sp. and *Pseudomonas* sp. (Garg *et al*., 2013), *Bacillus subtilis*, *Klebsiella aerogenes*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Proteus mirabilis* and *Staphylococcus aureus* (Wogu and Ofuse, 2014). However due to its perishable nature several post-harvest losses have been recorded in developing nations than in developed countries (Ejale and Abdullah, 2004; Yeboah, 2011). The increased awareness of the effects of chemical preservatives on food crops on the health of consumers has resulted in an intensified effort on the use of organic

or plant materials in the preservation of tomato fruits (Irokanulo *et al*., 2015). The extracts of the soursop plant (*Annona muricata*) and Roselle plant (*Hibiscus sabdariffa*) have been used in the preservation of tomato fruits (Banjo *et al*., 2022). The powder of neem (*Azadirachta indica*) leaves has been reported to be effective against spoilage microorganisms (Hosea *et al*., 2017). Furthermore, Ijato *et al.* (2011) reported the antimicrobial effect of *Vernonia amygdalina* and *Tridax procumbens* in *in-vitro* control of tomato post-harvest fruit rot. There is a need to exploit edible organic and cheaper alternatives for the preservation of this fruit of economic value. One such alternative is the use of coating materials in the preservation of tomato fruits.

Edible coatings are thin films made from polysaccharides, protein and lipids which are applied on the surfaces of food products or fruits to form a thin layer (Corbo, 2010). This thin film controls moisture transfer, the exchange of gases or the oxidation process (Dhall, 2013). Due to the preference of consumers for natural organic materials, there is an increase in research into the development of edible coatings that will replace synthetic waxes for maintaining the quality of postharvest fruits (Senna *et al*., 2014). Some of the edible materials considered in this study for the preservation of tomato fruits are coconut oil and shea butter (Sabharval *et al*., 2016).

Lauric acid, a twelve (12) carbon chain acid, is one of the medium chain fatty acids obtained from some plant oil particularly coconut oil which has been known as one of the most active ingredients and is more predominant in the total saturated fat present (Bruce, 2000 ; Chuah *et al*., 2014). This acid is one of the most active ingredients present in coconut oil and is made up of over 52 % of the total 92 % saturated fats which may be responsible for some healing attributes of coconut oil (Bruce, 2000). Coconut oil exhibits microbicidal activities through the disruption of the bacteria cell membranes (Ogbolu *et al*., 2007). On the other hand, free fatty acids (FFA) of various chain lengths (C8- C18) have antibacterial activity against a range of Gram-positive bacteria, but not against several Gram-negative bacteria (Georgel *et al*., 2005; Skrivanova *et al*., 2005; Drake *et al*., 2008). Variations in the composition of plants and genetic disparity among bacteria and fungi of the same or different species are responsible for the few inconsistencies in the antibacterial and antifungal properties of plant extract. This resulted from the Medium Chain Triglycerides (MCTs) present in coconut oil with anti-bacterial influence because they can disintegrate bacterial cell walls; MCTs also presenting the ability to treat severe bacterial infections that are antibiotic resistant (Bruce, 2000).

Shea butter is a natural product obtained from the *Vitellaria paradoxa* tree which belongs to the family Sapotaceae. Shea butter has been used widely in food production as well as in cosmetics and for medicinal purposes (Honfo *et al*., 2014). Shea butter is made up of oleic, linoleic, stearic and palmitic fatty acids with some unsaponifed matter such as tocopherol, sterols and phenols (Maranz and Wiesman, 2004). It was reported that shea itself exhibits extensive influence in treating a wide range of disorders such as fever, diarrhea, rash, skin disorders, wound infections, toothache, stomachache and others (Ojo *et al*., 2021). In addition, shea butter exhibits some pharmacological activities such as being anti-cancer (Zhang *et al*., 2018), anti-inflammatory (Foyet *et al*., 2014), anti-oxidant (Olasunkanmi *et al*., 2017), anti-fungal, anti-viral (Boyejo *et al*., 2019) and anti-bacterial activity (Ajijolakewu and Awarun, 2015; Wada *et al*., 2019). The phytochemical compounds (steroids and flavonoids) present in shea butter is responsible for their broad-spectrum activity against Gram-positive and Gram-negative bacteria (Wada *et al*., 2019).

Tomato fruit is one of the highly perishable foods and the biodeterioration of this fruit results in economic losses to farmers and consumers. Therefore, there is a need to discover and develop methods to reduce the spoilage of this fruit by increasing its shelf life. However, chemicals have been employed in the preservation of tomato fruits in the form of wax, spray or liquid but these methods have proven detrimental to human health. Hence, the need for this study to investigate the potentials of edible, safer and more economical non-synthetic materials such as coconut oil and shea butter in the preservation of tomato fruits. The aim of this study therefore is to investigate and compare the preservative potential of shea butter and coconut oil on tomato fruits.

Materials and methods

Plant and coating materials: Tomato (*Lycopersicum esculentum var brandywine*) fruits were obtained from Lusada market, Ogun State. The coconut oil was purchased from Agbara, Ogun State. Shea butter was purchased from Ojota market, Lagos State.

Collection and preparation of plant materials: Shea butter emulsion was prepared by melting shea butter sample in a 1L 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 colour. Those with deformity, pigmentation, wrinkle (with a thumb slide), darkened or with bruised areas on or under the skin of the tomatoes were rejected.

Treatment of tomatoes with shea butter and coconut oil as coating materials: Tomato fruits were washed using distilled water and gently rubbed with tidy cotton cloth to remove water. The fruits were dipped in various concentrations of shea butter with coconut oil emulsion and coconut oil for 5 min and one treatment was used as a control with no application of coating material. After being air dried, the fruits were stored in baskets already designated as SBC (Sheabutter with coconut oil emulsion), CO (Coconut oil) and C (Control) at temperature of 22 ˚C and relative humidity of 65 % for quality and shelf-life assessments.

Effects of different concentrations of sheabutter emulsion and coconut oil on tomato preservation: Investigation was carried out on the effects of the coconut oil and shea butter emulsion on tomato fruits according to the methods of Maseret *et al.* (2012). This was monitored for two weeks. The effects of different concentrations of the sheabutter emulsion in the range 3 – 15 % (3, 6, 9, 12 and 15 %) on tomato fruits was also carried out according to the methods of Maseret *et al.* (2012). This was also monitored for two weeks. The tomatoes used as control were washed thoroughly and four was placed in a basket already labelled control (c) without any treatment.

Isolation and identification of spoilage microorganisms

Isolation of spoilage fungi: Spoilage fungi were isolated from bio-deteriorated tomato fruit samples. Using standard microbiological technique (serial dilution), 1 ml of the deteriorated tomato fluid was pipetted and mixed in another 9 ml of sterile distilled water in a test-tube. The test-tube was shaken vigorously to homogenize. The exponential dilution continued to the fourth factor (10^{-4}). One millilitre (1 mL) of the fourth factor was aseptically transferred and plated in duplicate sets using sterile molten lukewarm potato dextrose agar. The poured plates were allowed to set and were incubated **(**Gallenkamp, England) at 27 °C for 48 h. Sub culturing of distinct colonies were carried out to obtain pure cultures for further identification.

Preparation of media: Culture medium used for this evaluation was potato dextrose agar (BDH Chemicals, UK) for fungi. Potato dextrose agar of 39 g was also dissolved in 1 litre of distilled water and boiled to dissolve the medium completely before sterilizing with autoclave at 121 ˚C for 15 min. The pH of the sample was adjusted to 3.5, after adding 10 mL of lactic acid. The medium was thereafter cooled to 55 °C.

Identification of spoilage mould and yeast cells

Identification of spoilage moulds: Identification of the spoilage moulds was carried out by modified needle mount preparation method (Chessbrough, 2006). A small portion of the colony was removed with an inoculation sterile needle into a drop of 70 % ethanol. It was mixed gently to tease the colonies. A drop of lactophenol cotton blue stain was then added and a clean cover slip was gently placed on the preparation. It was examined under 40x objective power of the microscope.

Identification of spoilage yeast cells: The yeast cells isolated from the spoilt tomato fruits were identified according to the method described by Cowan and Steel (1993) and Chessbrough (2006). In this method, germ tube, urea, cycloheximide, glucose tests were carried out.

Gas Chromatography- Mass Spectrometry (GC-MS) analysis of shea butter and coconut oil: Samples of sheabutter and coconut oil were subjected to GC-MS analysis to determine the constituents of these samples. This is an analytical method used to identify different substances that are present within a test samples. It combines the features of Gas-Chromatography and Mass Spectrometry and is widely used for various purposes including drug detection (Sparkman *et al*., 2011). The GC-MS is composed of two major parts - the Gas Chromatograph and the Mass Spectrometer; the Gas Chromatograph, utilizing a capillary column, separates the different molecules within a test sample using their different chemical properties and their relative affinity for the stationary phase of the column, the molecules were retained by the column and then elute at different times (Retention Time). The mass spectrometer captures the eluted molecules, downstream, ionizes, accelerates, deflects and detects them separately. This is achieved by breaking each molecule into ionized fragments and detecting these fragments using their mass-to-charge ratio.

Results

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

The effect of shea butter emulsion on preservation of tomato fruits: The experimental set-up and the effects of sheabutter emulsion on preservation of tomatoes are presented in Plate 1 and Table 1 respectively. The preservative rate of tomatoes coated with sheabutter emulsion was 100 % when compared to the control with 25 % as at the 19th day. However, on the 18th day, the tomatoes used as control had totally deteriorated with 100 % spoilage while, the tomatoes preserved with shea butter emulsion recorded 75 % preservation. Furthermore, there was a complete deterioration (100 %) of the tomatoes preserved with sheabutter on the 30th day. The mean

rate of preservation of tomatoes preserved with sheabutter when compared to that of the control are 62 and 20 %, respectively.

Plate 1: Tomatoes coated with sheabutter emulsion (A) and the control (B)

Table 1: Effects of shea butter emulsion on the rate of preservation (%) of tomato fruits

Time in days	Sheabutter (%)	Control (%)
3	4(100)	3(75)
6	3(75)	2(50)
9	3(75)	1(25)
12	3(75)	1(25)
15	3(75)	1(25)
18	3(75)	0(0.0)
21	3(75)	0(0.0)
24	2(50)	0(0.0)
27	1(25)	0(0.0)
30	0(0.0)	0(0.0)
Mean rate of preservation	62.0	20.0

The effect of coconut oil on preservation of tomato fruits: The experimental set-up and the effects of coconut oil on the preservation of tomatoes are presented in Plate 2 and Table 2 respectively. The preservative rate of tomatoes coated with coconut oil was 50 % when compared to the control with 25 % as at the 9th day. However, on the 18th day, the tomatoes used as control had totally deteriorated with 100 % spoilage while, the tomatoes preserved with coconut oil recorded 25 % preservation. Furthermore, there was a complete deterioration (100 %) of the tomatoes preserved with coconut oil on the 21st day. The mean rate of preservation of tomatoes preserved with coconut oil when compared to that of the control are 25 and 20 % respectively.

Plate 2: Tomatoes coated with coconut oil (A) and the control (B)

Table 2: Effects of coconut oil on the rate of preservation (%) of tomato fruits

Time in days	Coconut oil (%)	Control (%)
3	3(75)	3(75)
6	2(50)	2(50)
9	1(25)	1(25)
12	1(25)	1(25)
15	1(25)	1(25)
18	1(25)	0(0.0)
21	0(0.0)	0(0.0)
24	0(0.0)	0(0.0)
27	0(0.0)	0(0.0)
30	0(0.0)	0(0.0)
Mean rate of preservation	25.0	20.0

Effect of different concentrations of shea butter emulsion on tomato preservation: The different concentrations of shea butter emulsion exhibited significant effects on the preservation of the tomato fruits ($p < 0.05$).The tomatoes treated with the concentration of 3% showed highest preservation rate of 50% when compared to those of 6, 9, 12 and 15 % with preservation rate of 25 % up till the 21st day. However, the control had totally deteriorated after the 15th day. Furthermore, tomatoes treated with sheabutter emulsion with concentrations of 9, 12 and 15 % maintained a preservative rate of 25 %. The mean rate of preservation of the tomatoes with sheabutter treatment of concentrations 3, 6, 9, 12 and 15 % are 47.5, 47.5, 50.0, 50.0, 50.0 and 20.0 respectively (Table 3).

Table 3: Effects of different concentrations of shea butter emulsion on the rate of preservation (%) tomato fruits

Time (Days)	3%	6%	9%	12%	15%	Control
3	4(100)	4(100)	4(100)	4(100)	4(100)	3(75)
6	4(100)	3(75)	4(100)	4(100)	4(100)	2(50)
9	3(75)	3(75)	3(75)	3(75)	3(75)	1(25)
12	3(75)	3(75)	3(75)	3(75)	3(75)	1(25)
15	2(50)	2(50)	2(50)	2(50)	2(50)	1(25)
18	2(50)	2(50)	2(50)	2(50)	2(50)	0(0.0)
21	2(50)	1(25)	1(25)	1(25)	1(25)	0(0.0)
24	0(0.0)	0(0.0)	1(25)	1(25)	1(25)	0(0.0)
27	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
30	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Mean rate of preservation	47.5	47.5	50.0	50.0	50.0	20.0

Identification of spoilage microorganisms from tomato fruits: The microorganisms isolated from the spoilt tomato fruits were identified using their colonial and morphological characteristics (Table 4). The average fungal counts ranged from 1.3 x 10^3 to 2.0 x 10^3 cfu/ml. *Aspergillus niger* had the highest percentage occurrence of 47.27 % in the spoilt tomato fruits examined while *Candida species* and *Candida krusei* each had the lowest percentage occurrence of 3.64 % in the spoilt tomato fruits.

Table 4: Identification of spoilage microorganisms from tomato fruits

Label	Macroscopy	Microscopy	Identity
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	Large globose conidiophores, loose columna	*Aspergilus fumigatus*

Label	Macroscopy	Microscopy	Identity
	colonies	with serated hypha	
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.	*Aspergilus 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	*Penicillium 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	*Fusarium 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.	*Aspergilus niger*
9	Brown-grey filamentous colonies	Large globose conidiophores, loose columna with serated hypha	*Aspergilus fumigatus*

Gas Chromatography-Mass Spectrometry (GC-MS) of shea butter: The GC-MS chromatogram of the sheabutter presented as Figure 1 revealed twenty peaks. This shows that twenty different phytocompounds were present in the shea butter sample. The names and molecular weight of the compounds present in the sheabutter sample used as coating material is shown in Table 5.

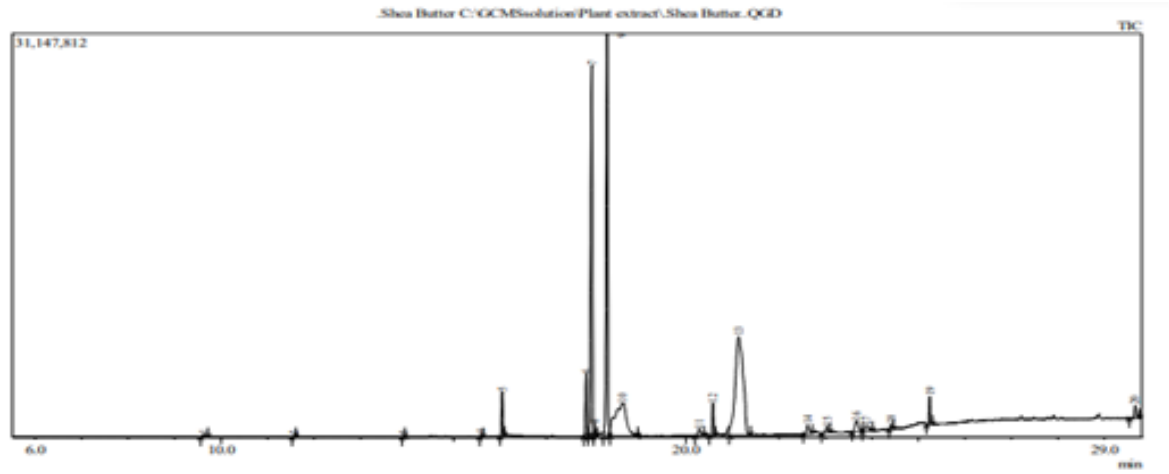

Figure 1: Gas Chromatography-Mass Spectrometry chromatogram of shea butter sample

Gas Chromatography-Mass Spectrometry (GC-MS) of coconut oil: The GC-MS chromatogram of the coconut oil presented as Figure 2 revealed twenty-three peaks. This shows that twenty-three different phytocompounds are present in the coconut oil sample. The names and molecular weight of the compounds present in the coconut oil sample used as coating material is shown in Table 6.

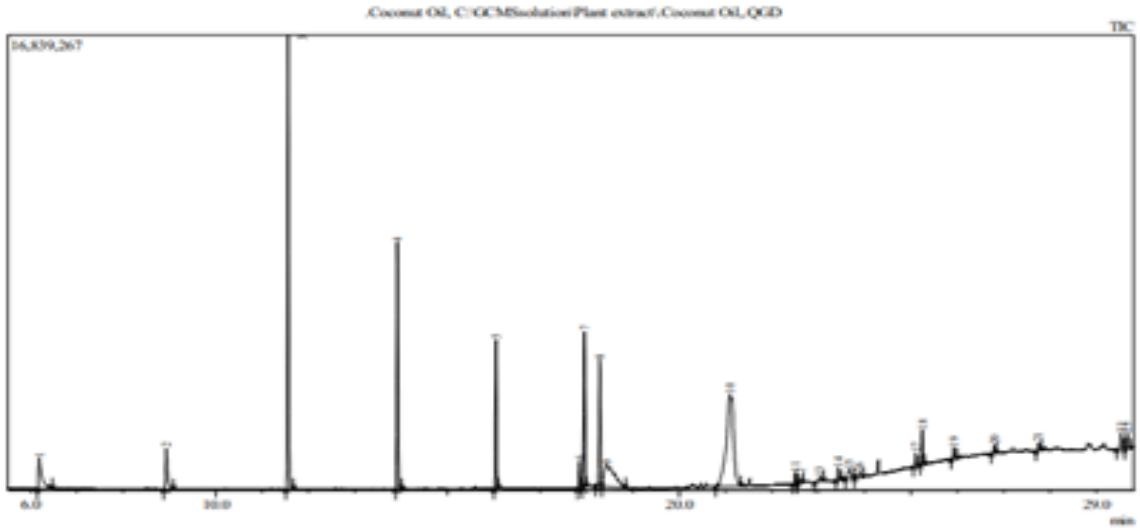

Figure 2: Gas Chromatography-Mass Spectrometry chromatogram of coconut oil sample

Table 5: Gas Chromatography-Mass Spectrometry (GC-MS) analysis of Sheabutter sample

Peak	R. time	Area	Area %	Height	Height%	A/H	Name
1.	9.600	620924	0.19	205853	0.23	3.02	2-Propenoic acid, 3-phenyl-, methyl ester
2	11.558	148060	0.05	7791	0.09	1.90	Methyl tetradecanoate
3.	13.916	79120	0.02	51905	0.06	1.52	Undecanoic acid, 2-methyl-
4.	15.586	280814	0.09	16998	0.19	1.65	5-Eicosene, (E)-
5.	16.040	5557938	1.70	34316	3.86	1.6	Hexadecanoic acid, methyl ester
6.	17.849	993705	3.03	48833	5.49	2.03	9,12-Octadecadienoic acid (Z,Z)-, methyl ester
7.	17.967	704028	21.47	28655	32.24	2.46	9-Octadecenoic acid, methyl ester, (E)-
8.	18.018	2252275	0.77	10236	1.15	2.46	10-Octadecenoic acid, methyl ester
9.	18.301	6774681	23.62	31075	34.96	2.49	Methyl stearate
10.	18.615	8441172	13.45	25230	2.84	7.49	9,19-Cyclo-9.beta.-lanostane-3.beta.,25-diol
11.	20.277	233319	0.71	54394	0.61	4.29	Ethyl iso-allocholate
12.	20.573	501312	1.53	25103	2.82	2.00	Methyl 18-methylnonadecanoate
13.	21.129	8897237	27.36	76561	8.61	1.72	.alpha.-Amyrin
14.	22.613	276392	0.84	71020	0.80	3.89	Heptadecanoic acid, 10-methyl-, methyl ester
15.	23.027	185514	0.57	49734	0.56	3.73	9,19-Cyclolanost-24-en-3-ol, acetate, (3.beta.)-
16.	23.656	462093	1.41	82938	0.93	5.57	13,14-Epoxyoleanan-3-ol, acetate
17.	23.875	224395	0.68	44130	0.50	5.08	1,2-Bis(trimethylsilyl)benzene
18.	24.402	767983	0.23	39829	0.45	1.93	3-Isopropoxy-1,1,1,5,5,5-hexamethyl-3-(trimeth
19.	25.240	4371078	1.33	21935	2.47	1.99	Squalene
20.	29.664	3067162	0.94	99932	1.12	3.07	1,2-Bis(trimethylsilyl)benzene
		32791601	100.00	888777	100.00		

Table 6: Gas Chromatography-Mass Spectrometry (GC-MS) analysis of coconut oil sample

Peak	R. time	Area	Area %	Height	Height%	A/H	Name
1.	6.184	5542473	3.55	1152744	2.08	4.81	Octanoic acid, methyl ester
2.	8.925	4358510	2.79	1516691	2.73	2.87	Decanoic acid, methyl ester
3.	11.555	33042833	21.17	16793427	30.24	1.97	Dodecanoic acid, methyl ester
4.	13.915	15304871	9.80	9127261	16.44	1.68	Methyl tetradecanoate
5.	16.038	9074791	5.81	5513383	9.93	1.65	Hexadecanoic acid, methyl ester
6.	17.844	1931776	1.24	1009230	1.82	1.91	9,12-Octadecadienoic acid (Z,Z)-, methyl ester
7.	17.947	11988669	7.68	5769251	10.39	2.08	9-Octadecenoicacid, methyl ester, (E)-
8	18.279	10500477	6.73	4714774	8.49	2.23	Methyl stearate
9.	18.430	12156375	7.79	813801	1.47	14.94	Lanosterol
10.	21.086	37060144	23.74	3402576	6.13	10.89	.alpha.-Amyrin
11.	22.495	848623	0.54	426871	0.77	1.99	Nonacosane
12.	22.607	571485	0.37	148770	0.27	3.84	1,4-Bis(trimethylsilyl)benzene
13.	23.023	640717	0.41	163178	0.29	3.93	1,2-Bis(trimethylsilyl)benzene
14.	23.421	893065	0.57	462885	0.83	1.93	Heptadecane, 7-methyl-
15.	23.657	1546021	0.99	311531	0.56	4.96	1,2-Bis(trimethylsilyl)benzene
16.	23.874	1087525	0.70	194734	0.35	5.58	2,4,6-Cycloheptatrien-1-one, 3,5-bis-trimethylsilyl
17.	25.100	1067490	0.68	512855	0.92	2.08	Di-n-decylsulfone
18.	25.238	2493568	1.60	1297133	2.3	1.92	Squalene
19.	25.921	945336	0.61	427855	0.77	2.21	Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,15,15
20.	26.792	647764	0.41	298430	0.54	2.17	Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,15
21.	27.746	679478	0.44	288849	0.52	2.35	Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,15
22.	29.531	1852042	1.19	596348	1.07	3.11	1,2-Bis(trimethylsilyl)benzene
23.	29.661	1867207	1.20	592046	1.07	3.15	Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,15
		156101240	100.00	55534623	100.00		

Discussion

The results showed that the natural waxes significantly reduced losses, maintained quality and extended shelf life of tomato fruits. The sheabutter emulsion had the highest mean rate of preservation after 30 days of treatment when compared to that of coconut oil with a very low mean rate of preservation. These may be adduced to the fact that the sheabutter emulsion formed wax coating around the tomato fruits unlike the coconut oil which does not form a waxy coating. Waxing has been reported to delay fruit ripening, reduce water loss, improve quality, and extend shelf life of tomato (Ahmed and Abu-Goukh, 2003). A longer shelf life for the coated tomatoes could be due to the closure of the stomata openings, reduction in transpiration and respiration rate and lesser incidence of microbial activity by the coating formulation as reported previously by many workers (Vignesh and Nair, 2019). Among the coated ones, the increased shelf-life quality offered by sheabutter coated fruits could be attributed to the antimicrobial action offered by the sheabutter emulsion. Some researchers have reported the ability of coating materials to extend the shelf life of tomato fruits (Vignesh and Nair, 2019; Tsai and Su,1999). Furthermore, the coatings might have modified the fruit internal atmosphere, with high levels of carbon dioxide and low levels of oxygen, which slows the process of deterioration as opined earlier by Bosquez-Molina *et al.* (2003) and Gonzalez-Aguilar *et al.* (2005).

The spoilage microorganisms associated with tomato fruits from this study are predominantly fungi. The fungal isolates from the fruits *included Aspergillus niger, Candida krusei, Fusarium oxysporum, Candida species, Aspergillus fumigatus, Penicillium notatum* and Aspergillus *terreus.* Ibrahim *et al.* (2011), isolated *Aspergillus* niger as one of the major fungi responsible for the production of volatile compounds in spoilt tomatoes. Onuorah and Orji (2015), also isolated *Aspergillus niger* from rotten tomato fruits and reported that they are pathogenic on tomato fruits. Wogu and Ofuase (2014), isolated *Aspegillius spp, Penicillum spp* and *Fusarium spp* from spoilt tomato fruits. In a related study, Mbajiuka *et al.* (2014) also isolated *Aspergillius spp* and *Penicillum spp* from spoilt tomatoes as the predominant spoilage microorganisms. The wax coating reduces the penetration of the epicarp of the tomato fruits by microoganisms thus extending the shelf life of the tomato coated with sheabutter wax coating when compared to the tomato fruits without coating (control). In a similar

study by Zhuang and Huang (2003), it was reported that protective effect provided by the edible guar gum coating seems to reduce the rate of development of microorganisms that affect the quality of tomatoes, because the coating acts as a barrier of gases and other substances such as water or other nutrients needed for the growth of microorganisms.

This study revealed that *Aspergillus niger* had the highest percentage occurrence of 45.32% in the spoilt tomato fruits examined while *Candida species* and *Candida krusei* each had the lowest percentage occurrence of 3.64% in the fruits studied. The results agree with the work of Akinmusire, (2011) and Ibrahim *et al.* (2011). They reported that *Aspergillus 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 fruits.

The GC-MS analysis revealed the presence of twenty compounds in sheabutter and twenty-three compounds in coconut oil. Methyl Stearate was recorded to have the highest peak in sheabutter with about 34.96% height and 23.62% area, as shown in the chromatogram. However, undecanoic acid, 2-methyl- had the lowest values with 0.06% height and 0.02% area. Other notable constituents in shea butter include 9-octadecenoic acid, methyl ester, (E)-, 9,12-octadecadienoic acid (Z, Z)-, methyl ester and alpha. -amyrin. In coconut oil, the highest peak was observed in dodecanoic acid, methyl ester with 30.24 and 21.17% height and area, respectively. The lowest was seen in 1,4-bis(trimethylsilyl)benzene followed by 1,2-bis(trimethylsilyl)benzene with 0.27 and 0.29% height, as well as, 0.37 and 0.41% area respectively. All these constituents and their quantity are very instrumental to the preservation of tomato. This is possible due to the antimicrobial properties of these constituents which help to prevent the growth of spoilage organisms (Ajijolakewu and Awarun, 2015; Wada *et al*., 2019).

Conclusion

The present study shows that coating tomatoes with sheabutter prolonged the shelf life of the tomato fruits for 27 days with 25 % preservation rate. Moreover, it has a high mean preservation rate of 62 % when compared to that of the coconut oil with 25 % mean rate of preservation. This suggests that sheabutter coating not only maintained firmness but also improved the postharvest quality during storage at ambient temperature. The sheabutter coating is biodegradable, easily applied, and less expensive (compared with other hydrocolloids and commercial waxes) and it can be used commercially to prolong the storage life of the Roma tomatoes considered in this study. Therefore, this study has established the use of sheabutter in extending the shelf life of perishable tomato fruits thus minimizing wastes and economic loss to the farmer and country in general.

References

Ahmed IH, Abu-Goukh AA: Effect of maleic hydrazide and waxing on ripening and quality of tomato fruit. Gezira J Agric Sci, 1 (2): 59-72. 2003.

Ajayi A: Nature of tomatoes micro flora under storage. Am J Exp Agric, 3(1): 89-101. 2013.

Ajijolakewu KA, Awarun FJ: Comparative antibacterial efficacy of *Vitellaria paradoxa* (Shea Butter Tree) extracts against some clinical bacterial isolates. Not Sci Biol, 7:264–268. 2015.

Akinmusire OO: Fungi species associated with the spoilage of some edible fruits in Maiduguri, North eastern Nigeria. Adv Environ Biol, 5(1):157-161. 2011.

Banjo TT, Oluwole OR, Nzei VI: Preservation of *Lycopersicum esculentum* (tomatoes) with extracts of *Annona muricata* (soursop) and *Hibiscus sabdariffa* (Roselle plant). Trop Life Sci Res, 33(1): 1-22. 2022.

Basu A, Imrha N: Tomatoes versus lycopene in oxidative stress and carcinogenesis: Conclusions from clinical trials. Eur J Clin Nutr, 61(3), 295-303. 2000.

Bosquez-Molina E, Guerrero-Legarreta I, VernonCarter EJ: Moisture barrier properties and morphology of mesquite gum–candelilla wax based edible emulsion coatings. Food Res Int, 1:9-10. 2003.

Boyejo I, Azeez S, Owolabi A, Issah O: Antifungal and phytochemical screening of extract from *Vitellaria paradoxa* (shea butter tree) leaves, barks and roots on dermatophytes. Int J Sci Res Publ, 9(6):884-891. 2019.

Bruce F: The healing miracle of coconut oil. Healthwise Publications, Colorado Springs, pp.1-46.

Celma AR, Cuadros F, López-Rodríguez F: Characterisation of industrial tomato by-products from infrared drying process. J Food Bioprod Proc, 87: 282-291. 2009.

Chessbrough M: Mycology, Medical Laboratory manual for tropical countries. Cambridge University press, London, pp. 372-390. 2006.

Chuah G, Rozanna TD, Salmiah A, Thomas YC, Sa'ari SM: Fatty acids used as phase change materials (PCMs) for thermal energy storage in building material application. University Publication Malaysia. pp. 8-15. 2014.

Clement A, Bacon R, Sirois S, Dorais M: Mature-ripe tomato spectral classification according to lycopene content and fruit type by visible, NIR reflectance and intrinsic fluorescence. Qual Assur Saf Crop Foods, 7(5):747–756. 2015.

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

Cowan ST, Steel KJ: Enterobacteriacea: In Manual for the identification of bacteria. GI Barrow, and RKA Felthan (eds.) Cambridge University Press, London, pp. 213–218. 1993.

Dhall RK: Advances in edible coatings for fresh fruits and vegetables: A review advances in edible coatings for fresh fruits and vegetables. Crit Rev Food Sci Nutr, 53(5): 435-450. 2013.

Drake DR, Brogden KA, Dawson DV, Wertz PW: Thematic review series: Skin lipids. Antimicrobial lipids at the skin surface. J. Lipid Residue, 49: 4-11. 2008.

Efendi D, Hermawati H: The use of bee wax, chitosan and BAP to prolong shelf-life of mangosteen (*Garcina mangostana* L.) fruit. J Hort, 1 (1): 32-39. 2014.

Ejale A, Abdullah H: Preservation of ripe tomato (*Lycopersicum esculentum* Mill) fruits with dried leaf powder of Neem (*Azadirachta indica* A. Juss). Nig J Basic Appl Sci, 22: 344–350. 2004**.**

Foyet HS, Tsala DE, Bodo JZE, Carine AN, Heroyne LT, Oben EK**:** Anti-inflammatory and anti-arthritic activity of a methanol extract from *Vitellaria paradoxa* stem bark. Pharmacogn Res, 7(4): 367-77. 2014.

Freeman BB, Reimers K: Tomato consumption and health: Emerging benefits. Am J Lifestyle Med, 6(2):1-10. 2011.

Garg RK, Batav N, Silawat N, Singh RK: Isolation and identification of pathogenic microbes from tomato puree and their delineation of distinctness by molecular techniques. J Appl Biol Biotechnol 1(4):24–31. 2013.

Gastélum-Barrios A, Bórquez-López RA, Rico-García E, Soto-Zarazúa GM: Tomato quality evaluation with image processing: A review. Afr J Agric Res, 6(14): 3333–3339. 2011.

Georgel P, Crozat K, Lauth X, Makrantonaki E, Seltmann H, Sovath S, Hoebe K, Du X, Rutschmann S, Jiang Z, Bigby T, Nizet V, Zouboulis CC, Beutler B: A toll-like receptor 2-responsive lipid effector pathway protects mammals against skin infections with gram-positive bacteria. J Infec Immunol, 73: 4512-4521. 2005.

González-Aguilar GA, Ruiz-Cruz S, Soto-Valdez H, Vázquez-Ortiz F, Pacheco AR, Wang CY: Biochemical changes of fresh cut pineapple slices -treated with anti-browning agents. Int J Food Sci Technol, 40(4): 377-83. 2005.

Honfo FG, Akissoe N, Linnemann AR, Soumanou M, Van-Boekel MAJS: Nutritional composition of shea products and chemical properties of shea butter: A Review. Crit Rev Food Sci Nutr, 54: 673-686. 2014.

Hosea ZY, Liamngee K, Owoicho AL, Agatsa TD: Effect of Neem leaf powder on post-harvest shelf life and quality of tomato fruits in storage**.** Int J Sustain Dev, 6(10): 1334–1349. 2017.

Ibrahim AD, Musa K, Sani A, Aliero AA, Yusuf BS: Microorganisms associated with the production of volatile compounds in spoilt tomatoes. Res Biotechnol, 2(2):82-89. 2011.

Ijato J, Otoide J, Ijadunola J, Aladejimokun A: Efficacy of antimicrobial effect of *Vernonia amygdalina* and *Tridax procumbens* in in-vitro control of tomato (*Lycopersicon esculentum*) post-harvest fruit rot. Rep Opin, 3(1): 120– 123. 2011.

Irokanulo E, Egbezein I, Owa S: Use of *Moringa oleifera* in the preservation of fresh tomatoes. IOSR J Agric Vet Sci, 8(2): 127– 132. 2015.

Maranz S, Wiesman Z: Influence of climate on the tocopherol content of shea butter. J Agric Food Chem, 52: 2934–2937. 2004.

Maseret D, Ali M, Kassahun B: Evaluation of tomato (*Lycopersicum esculentum* Mill) genotypes for fruit quality and shelf life. Afr J Plant Sci Biotech, 3: 50–56. 2012.

Mbajiuka S, Emmanuel C, Emmanuel E: Isolation of microorganisms associated with deterioration of tomato (*Lycopersicum esculentum*) and pawpaw (*Carica papaya*) fruits. Int J Curr microbiol Appl Sci, 3(5): 501–512. 2014.

Ogbolu DO, Oni AA, Daini OA, Oloko AP: *In vitro* antimicrobial properties of coconut oil on Candida species in Ibadan, Nigeria. J Med Food, 10(2):384–387. 2007.

Ojo O, Kengne MHK, Fotsing MC, Mmutlane EM, Ndinteh DT: Traditional uses, phytochemistry, pharmacology and other potential applications of *Vitellaria paradoxa* Gaertn. (Sapotaceae): A review. Arab J Chem, 14: 1-27. 2021.

Olasunkanmi OO, Akinpelu DA, Adeniyi PO, Ajayi OF, Omololu-Aso J, Olorunmola FO: Investigations into antibacterial, phytochemical and antioxidant properties of *Vitellaria paradoxa* (Gaertn.) stem bark extracts. J Pharm Res Int, 2: 1-17. 2017.

Onuorah S, Orji MU: Fungi associated with the spoilage of post-harvest tomato fruits sold in major markets in Awka, Nigeria. Univers J Microbiol Res, 3(2):11-16. 2015.

Passam HC, Karapanos IC, Bebeli PJ, Savvas D: A review of recent research on tomato nutrition, breeding and postharvest technology with reference to fruit quality. Eur J Plant Sci Biotechnol, 1(1):1-21. 2007.

Preedy VR, Watson RR: Tomatoes and tomato products: Nutritional, medicinal and therapeutic properties. Science Publishers, Enfield, pp. 665. 2008.

Sabharwal PK, Garg M, Sadhu SD, Khas H, Delhi N: Advancement in conventional packaging edible. World J Pharm Res, 2(3): 160-170. 2016.

Senna M, Al-Shamrani K, Al-Arifi A: Edible coating for shelf-life extension of fresh banana fruit based on gamma irradiated plasticized poly(vinyl alcohol)/carboxymethyl cellulose/tannin composites. Mater Sci Appl, 5:395-415. 2014.

Skrivanova E, Marounek M, Dlouha G, Kanka J: Susceptibility of *Clostridium perfringens* to C-C fatty acids. Lett Appl Microbiol, 41: 77-81. 2005.

Sparkman OD, Penton ZE, Kitson FG: *Gas Chromatography and Mass Spectrometry*, Academic press, Amsterdam, pp. 2-13. 2011.

Tsai GJ, Su WH: Antibacterial activity of shrimp chitosan against *Escherichia coli*. J Food Prot, 62(3): 239-243. 1999.

Vignesh RM, Nair BR: Improvement of shelf life quality of tomatoes using a novel edible coating formulation. Plant Sci Today, 6(2):84-90. 2019.

Wada NM, Muhammad MI, Garba AS, Ghazali HM: Antibacterial activity of *Vitellaria paradoxa* seed oil extract and honey against bacterial isolates from wound infection. Int J Biol Phys Chem Stud, 1:16–21. 2019.

Watkins CB: Overview of 1- methylcyclopropene trials and uses for edible horticultural crops. Hortic Sci, 4(1): 86-94. 2008.

Wogu MD, Ofuase O: Microorganisms responsible for the spoilage of tomato fruits, *Lycopersicum esculentum* sold in markets of Benin City, Southern Nigeria. Scholars Acad J Biosci, 2(7): 459-466. 2014.

Yeboah AK: A survey on postharvest handling, preservation and processing methods of tomato (*Solanum lycopersicum*) in the Dormaa and Tano South Districts of the Brong Ahafo Region of Ghana (Unpublished M.Sc. thesis, Kwame Nkrumah University of Science and Technology). 2011. pp. 108.

Zhang J, Li D, Lv Q, Ye F, Jing X, Masters ET, Shimizu N, Abe M, Akihisa T, Feng F: Compositions and melanogenesis-inhibitory activities of the extracts of defatted Shea (*Vitellaria paradoxa*) kernels from seven African countries. J Food Compos Anal, 70:89–97. 2018.

Zhuang RY, Huang YW: Influence of hydroxypropyl methylcellulose edible coating on fresh-keeping and storability of tomato. J Zhejiang Univ Sci, 4(1): 109–113. 2003.