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QUALITY OF *Solanum lycopersicum* COATED WITH TOMATO SEED OIL DURING STORAGE IN MAKURDI, BENUE STATE

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ABSTRACT

Quality of tomato fruits (*Solanum lycopersicum*) coated with tomato seed oil during storage was evaluated. Oil was extracted using solvent extraction method (n-hexane) from dried seeds of two varieties of tomato fruits, of Roma VF (Ra) and Riogrande (Rg). Healthy fruits of the two varieties of tomato were harvested at breaker stage by hand picking from the experimental farm and coated with the tomato seed oil (TSO) and stored at room temperature ranging from 25.9 -35.0 ˚C. The oil yield for both Riogrande and Roma VF is at 35 % and 38 % ($^{w}/_{w}$) on a dry weight basis. Other results indicated that the shelf life, vitamin C content, Beta carotene and lycopene content of the treated tomato fruits for both varieties increased from days 0 to 20 while the controls increased from days 0 to 12. The treated fruits showed a statistical difference ($p< 0.05$) in firmness when compared to untreated (control) fruits on Days 12 (Rg 0.35,Ra 0.15) and 16 (Rg 0.45, Ra 0.15) while the other days of storage showed no significant differences at ambient conditions. The results of this study established that both oil extracted from the seeds of Riogrande and Roma VF varieties of tomato fruits possess natural preservative that increase the shelf life and maintain the physicochemical quality of tomato fruits during storage.

Keywords: Tomato seed oil, Roma VF tomato fruit, Riogrande tomato fruit, shelf life, Beta carotene content

INTRODUCTION

Tomato is one of the most popular and widely grown vegetable crops in the world and belongs to the family *Solanaceae* with a total annual production of approximately 160 million tons. It is the second most important source of nourishment (after potatoes) globally (Mohan *et al.*, 2016). It is considered a cash and industrial crop in many parts of the world not only because of its economic importance, but also its nutritional value to human diet (Ayandiji and Adeniyi, 2011). After harvest of tomato fruits from the farm, the process of ripening may continue and tomatoes can become overripe very rapidly which in most cases could result in postharvest losses, and the need for it to be pretreated becomes necessary. Being a climacteric and perishable vegetable, most tomatoes fruits species have a very short life span. Global postharvest losses of tomato are as high as 30-40% (Agrios, 2005) but this is much higher in under developed countries in Africa like Nigeria due to lack of improve processing facilities. Nigeria is the second largest producer of tomato in Africa after Egypt and the sixteenth largest producer in the world (Ebimieowei *et al.,* 2013a). Sadly, it is also estimated that about 50% of the tomato fruits produced in Nigeria is lost because of poor postharvest handling practices and lack of appropriate storage facility. Benue State, Nigeria is one of the leading tomatoes producing states and the farmers throwing away baskets of tomato fruits which are a common sight as a result of poor storage before it get to the final consumer (Kator *et al.*, 2018). The objective of this research is to study the effect of tomato seed oil coated on tomato fruits, and the physicochemical parameters related to tomato quality during storage and its role in extending the shelf life of the fruits.

MATERIALS AND METHODS

Healthy tomato fruits of two improved varieties; Riogrande and Roma VF were carefully harvested at breaker stage from an experimental farm in Wanune, Tarka local government area of Benue state and were authenticated in the Department of Biological Sciences, Benue State University, Makurdi, Nigeria. The fruits were selected on the bases that they were all of similar sizes and maturity level with absence of diseased symptoms and defects. The fruits were well arranged in crates (plastic crates) and stored in a well-ventilated portion of the Biology laboratory. The experiment was carried out in the Biology and Chemistry laboratories of the Benue State University, Makurdi. The study was carried out during the period of May- October, 2019 after a preliminary experiment in April, 2019 with temperatures and relative humidity (RH) within the region fluctuate between 25.9 °C to 35.0 °C and 25 % to 79 % respectively using Digital Thermo Hygrometer (THERMO, TFA, Germany).

Oil extraction from the seeds sample

The tomato seeds were separated and cleaned from pulp with water and then dried in an oven at 60ºC for 3 days. The dried seeds of the two varieties of tomato fruits were milled to powder using a mechanical grinder (AOCS, 2001). 10 g of the powdered tomato seeds sample was put into a porous thimble and placed in a Soxhlet extractor, using 300 ml of n-Hexane (with boiling point of about 40-60°C.) as extracting solvent for six (6) hours repeatedly until the required quantity of oil was obtained. The oil obtain was placed in a water bath at70°C to remove the excess solvent from the extracted oil. The oil was kept in the refrigerator (0˚C to 4˚C) without further treatment until needed for further analysis (AOAC, 2005).

Determination of fatty Acid composition

The oils were subjected to methylation or derivatization as described by AOAC (2012). The extracted oil was methylated into fatty acid methyl ester (FAME). Then 1 ml Hexane was put into 0.1 ml of the oil, and 1 ml of sodium methoxide

solution (1.55 g NaOH in 50 ml methanol) was added to the oil solution. The solution was stirred using a Vortex stirrer for 10 seconds and the solution was allowed to stay for 10 minutes to separate the clear- coloured FAME solution from a cloudy aqueous layer. The top layer was carefully collected and the oil was measured using a UV-Vis DAD detector at a predetermined wavelength. The analysis was carried out using GC-MS Shimadzu QP 2010. A 1µl sample was injected into GC-MS operated using a 30-meter-long glass column M, 0.25 mm diameter and 0.25 µm thickness with CP-Sil 5CB stationary phase with a pre-programmed oven temperature of 60-220^{o}C with a temperature rise rate of 10^{o}C / min. The carrier gas was 12 kPa pressurized Helium with a total rate of 30 mL / min, and a split ratio of 1:50. From the chromatogram, the type and content of fatty acids belonging to saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids were determined. The oil samples were evenly daubed on the GCM spectrophotometer. Spectroscopic absorption in the infrared region was obtained with a resolution of 2cm^{-1} 3 scans and thin the wavelength range of 800- 4000 cm^{-1}

Physico-chemical and organoleptic properties of the extracted oil

The physico-chemical properties of the two varieties of tomato seed oil and their organoleptic properties were determined according to standard analytical methods recommended by AOAC (2007).

Treatment and storage of tomato fruits

Healthy tomato fruits of the two improved varieties were washed in clean water to remove dirt and air dried before the treatment. The tomato fruit was treated by dipping each tomato fruit variety in the extracted oil. The fruits was removed and arranged on wooden racks in plastic crates and stored at ambient temperature.

Fruit weight determination (g)

Tomato fruits were placed on a digital weighing balance and the readings was recorded throughout the storage period.

Shelf life studies

Shelf lives of tomato fruits were evaluated by counting the number of day's tomato fruits were still acceptable for marketing and consumption. It was decided based on appearance and spoilage of fruits.

Firmness (N/cm)

Firmness was measured as the maximum penetration force (N) reached during tissue breakage using a standard probe. The firmness of the fruits was determined using a penetrometer (Kumah *et al.,* 2011).

Vitamin C/Ascorbic acid content

Ascorbic acid was determined using the method described by AOAC (1990). Indophenol blue solution was standardized using vitamin C by shaking 3.0ml of standard vitamin C solution (0.800 mg/ml) with 0.1% indophenol blue solution in a graduated cylinder until the reaction mixture changed to a blue or purple colour. The final volume of the reaction mixture was recorded and used to calculate the molarity of indophenol.

Molarity of indolphenol = $\frac{Conc.of\ vitamin\ C \times Volume\ of\ vitamin\ C}{Volume\ of\ indolphenol}$

Then exactly 3.0ml of the sample was introduced into a graduated cylinder and while shaking, indophenol solution was added until the reaction mixture changed to a blue or purple colour. The final volume was recorded and the concentration of vitamin C in the sample was calculated and expressed in mg/ml using the formula above.

Beta-carotene (mg/100 g) content

Tomato fruits were chopped into small pieces and ground into a fine paste by an electric blender for one minute. 10 ml of the juice was transferred into a beaker after which 10 ml of petroleum ether was added and the solution was vortex for 1 minute. The solution was filtered through Whatman filter paper and the filtrate was taken for spectrophotometric determination. Sample absorbance was measured at 451 nm and beta-carotene was calculated using the formula as given by Ibitoye (2005).

ß-carotene = A451 x 19.96 [mg / 100 g]

Where: A451 - absorbance at 451 nm 19.96 - extinction coefficient

Lycopene (mg/100 g) content

Lycopene content was determined by the method describe by Segal and Barbu (1982), where in the extraction processes using spectrophotometer, a solution of water and alcohol in a 1:1 ratio was added in the tomato paste. The amount of lycopene extracted was the difference between absorbance at wavelength λ1 = 570 nm and absorbance at wavelength λ1 = 780 nm. Amount of lycopene in the sample was calculated using the formula:

$$Lycopene = \frac{(A\lambda 1 - A\lambda 2)}{m} \times 100 [\text{mg/100g}]$$

Where $A_{\lambda 1}$ = Sample absorbance at 570nm

$A_{\lambda 2}$ = Sample absorbance at 780nm

m = Mass of tomato paste in grams

Temperature and relative humidity

The temperature and relative humidity in the storage room was evaluated throughout the storage period using a digital thermometer combined with hygrometer. The thermometer was placed in the storage room and readings were recorded for both temperature and relative humidity in the mornings, afternoons and evenings.

Experimental design

4 x 2 factorial experiments in Complete Randomized Design was adopted for the experiment resulting in 8 treatments and replicated 3 times. 30 fruits were harvested from each plot, resulting in 720 fruits

Statistical Analysis

Data were presented as mean value ± standard deviation and analyzed by multiple factor analysis of variance (ANOVA) using SPSS 10.0 software (SPSS, Chicago, IL, USA). Statistically significant differences between means would be determined by Duncan's multiple range tests at $P \leq 0.05$. T-test was used to determine significant different in the pathogenicity of fungi isolates.

Table 1: Physicochemical Properties of oils from two varieties of tomato seeds

Physiochemical properties	Riogrande	Roma VF	FAO/WHO Standard
Oil yield (%) (w/w)	35.590	38.355	38-40
Refractive index	1.466	1.468	1.468-1.471
Density	0.903	0.898	0.896- 0.898

Specific gravity	0.9125	0.9085	0.900-1.160
Acid value (mEq/kg)	6.0545	1.351	4.000
Iodine value (I_2/100g)	88.680	65.500	80- 106
Saponification value (mg KOH/g)	208.5915	216.576	181.4±2.60
Peroxide value (mmol/kg)	2.9945	955	10.000
Odour	slightly spicy	slightly spicy	
Colour	red-yellowish	red-yellowish	
Appearance at room temperature	transparent liquid	transparent liquid	

Values are mean ± common difference of three replicates.

Table 2: Fatty acids compositions of oils from two varieties of tomato seeds

Fatty acids	Name	Symbol	Riogrande	Roma VF	ANOVA
Saturated	Myristic	C14:0	0.171^{b}±0.00	0.222^{c}±0.00	0.001
	Palmitic	C16:0	22.610^{a}±0.07	33.660^{c}±0.45	0.001
	Stearic	C18:0	9.045^{b}±0.06	10.705^{c}±0.02	0.001
	Arachidic	C20:0	0.315^{a}±0.01	0.645^{b}±0.02	0.001
	Behenic	C22:0	0.320^{b}±0.01	1.340^{c}±0.01	0.001
	Lignoceric	C24:0	0.180^{b}±0.01	1.285^{c}±0.01	0.001
Monounsaturated	Margaroleic	C17:1	0.305^{b}±0.01	0.170^{a}±0.01	0.002
	Oleic	C18:1	23.405^{c}±0.02	22.115^{a}±0.17	0.001
	Gadoleic	C20:1	0.405^{b}±0.01	0.220^{a}±0.01	0.008
Polyunsaturated	Linoleic	C18:2	35.605^{b}±0.01	26.520^{a}±0.55	0.002
	Linolenic α	C18:3n3	3.080^{c}±0.01	1.895^{a}±0.03	0.001
	Linolenic	C18:3n6	4.320^{b}±0.01	1.045^{a}±1.32	0.051

These values are mean ± common difference of three replicates. Means across rows with the same superscript were not significantly different at $p \leq 0.05$

Table 3: Total weight loss (%) of tomato at different days after storage

Varietie	Day4	Day8	Day12	Day16	Day20	ANOVA
RgContr	5.45±0.28	10.89±0.43	12.78±0.44	14.76±0.47	16.81±0.44	0.001
$RgT_{100\%}$	5.50±1.44	10.78±1.75	12.78±1.92	14.47±2.09	16.77±2.26	0.166
RaContr	11.92±0.09	23.63±0.06	29.42±0.01	35.35±0.01	41.25±0.2	1.039
$RaT_{100\%}$	6.53±0.31	21.67±4.46	23.95±4.64	26.23±4.82	28.51±5.00	0.193

Weight loss at Day zero was taken as 0 %. Values are mean ± standard error of three replicates. Means across rows were not significantly different at $p \leq 0.05$.

RgContr = Riogrande Tomato fruits Control (no treatment)

$RgT_{100\%}$ = Riogrande Tomato fruits treated with Riogrande tomato seed oil

RaContr = Roma VF Tomato fruits Control (no treatment)

$RaT_{100\%}$ = Roma VF Tomato fruits treated with Roma VF tomato seed oil

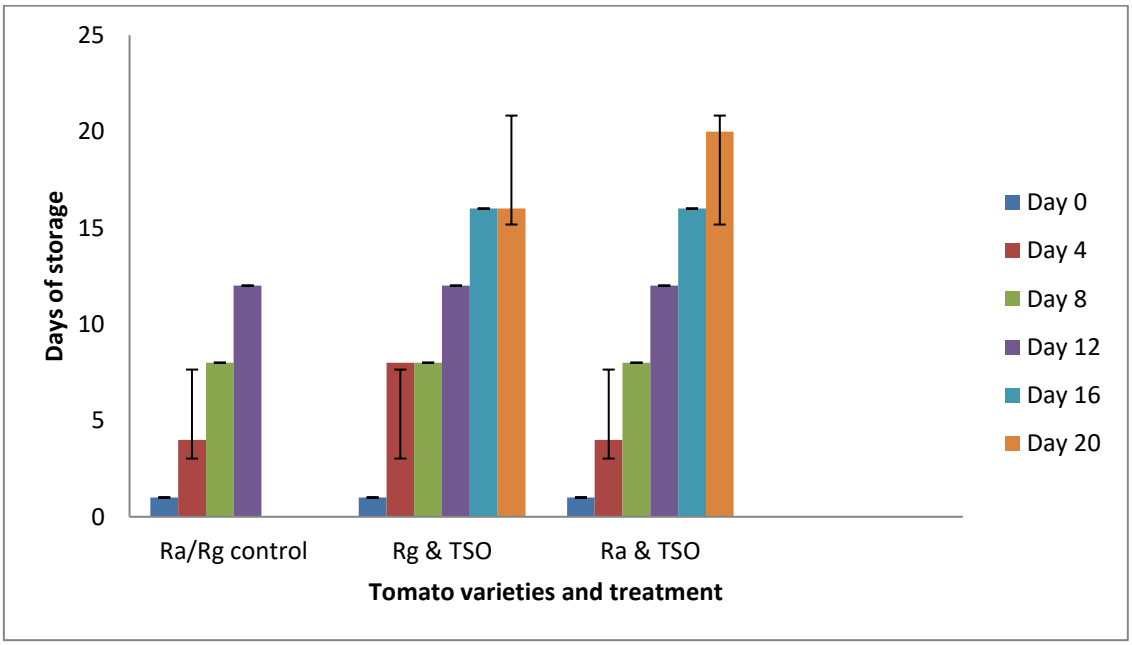

Figure 1: Shelf life of Riogrande and Roma VF tomato fruit coated with tomato seed oil

Table 4: Firmness (N/cm) of tomato fruit varieties treated with tomato seed oil stored under ambient conditions

Sample	Day 0	Day 4	Day 8	Day 12	Day 16	Day 20
RgContr	2.700±000	2.000±0.000^{ef}	1.800±0.000^{gh}	1.350±0.070^{ef}	1.050±0.070^{e}	0.850±0.000^{ef}
RgT$_{100\%}$		1.950±0.070^{cd}	1.850±0.070^{bcd}	1.700±0.000^{bcd}	1.500±0.070^{abc}	1.200±0.070^{cd}
RaContr	2.550±050	2.100±0.141^{f}	1.650±0.070^{fe}	1.250±0.070^{de}	1.000±0.000^{e}	0.850±0.141^{ab}
RaT$_{100\%}$		1.800±0.000^{cde}	1.650±0.141^{def}	1.400±0.000^{abc}	1.150±0.141^{abc}	0.800±0.000^{bc}
ANOVA (sig,)		0.001	0.001	0.001	0.001	0.001

Values are mean ± common difference of three replicates. Means across rows with the same superscript were not significantly different at p≤0.05.
RgContr = Riogrande Tomato fruits Control (no treatment)
RgT$_{100\%}$ = Riogrande Tomato fruits treated with Riogrande tomato seed oil
RaContr = Roma VF Tomato fruits Control (no treatment)
RaT$_{100\%}$ = Roma VF Tomato fruits treated with Roma VF tomato seed oil

Table 5: Vitamin C/ L-ascorbic acid (mg 100 g−1) content of tomato varieties treated with TSO

	Day 0	Day 4	Day 8	Day 12	Day 16	Day 20
RgContr	5.506±0.107^{a}	7.062±0.277^{e}	9.328±0.132^{c}	12.782±0.059^{d}	15.628±0.000^{c}	11.062±0.086^{a}
RgT$_{100\%}$		5.189.±0.043^{a}	8.777±2.079^{b}	11.098±0.284^{ab}	15.150±0.000^{c}	18.862±0.107^{c}
RaContr	2.008±0.287^{e}	4.460±0.226^{abc}	7.007±0.287^{a}	10.830±0.335^{ab}	14.635±1.013^{de}	13.062±0.079^{b}
RaT$_{100\%}$		3.612±0.434^{bc}	5.106±0.086^{a}	8.325±0.060^{a}	11.010±0.263^{b}	14.062±0.132^{c}
ANOVA (sig,)	0.001	0.001	0.001	0.001	0.001	0.001

Values are mean ± common difference of three replicates. Means across rows with the same superscript were not significantly different at p≤0.05.
RgContr = Riogrande Tomato fruits Control (no treatment)
RgT$_{100\%}$ = Riogrande Tomato fruits treated with Riogrande tomato seed oil
RaContr = Roma VF Tomato fruits Control (no treatment)
RaT$_{100\%}$ = Roma VF Tomato fruits treated with Roma VF tomato seed oil

Table 7: Beta-carotene (mg 100 g^{-1}) content of tomato varieties treated with tomato seed oil

Sample	Day 0	Day 4	Day 8	Day 12	Day 16	Day 20
RgContr	0,044±0.000^{a}	0.077±0.000^{c}	0.097±0.000^{b}	0.021±0.000^{ab}	0.004±0.000^{a}	0.001±0.000^{a}
RgT$_{100\%}$		0.036±0.005^{c}	0.084±0.029^{a}	0.075±0.005^{ab}	0.054±0.026^{ab}	0.003±0.008^{c}
RaContr	0.033±0.000^{c}	0.043±0.002^{a}	0.070±0.011^{a}	0.020±0.006^{ab}	0.016±0.049^{ab}	0.001±0.000^{c}
RaT$_{100\%}$		0.029±0.008^{ab}	0.079±0.020^{a}	0.035±0.023^{c}	0.025±0.011^{ab}	0.004±0.002^{c}
ANOVA (Sign)	0.001	0.002	0.063	0.001	0.361	0.002

Values are mean ± common difference of three replicates. Means across rows with the same superscript were not significantly different at p≤0.05.
RgContr = Riogrande Tomato fruits Control (no treatment)
RgT$_{100\%}$ = Riogrande Tomato fruits treated with Riogrande tomato seed oil
RaContr = Roma VF Tomato fruits Control (no treatment)
RaT$_{100\%}$ = Roma VF Tomato fruits treated with Roma VF tomato seed oil

Table 8: Lycopene (mg 100 g^{-1}) content of tomato varieties treated with tomato seed oil

	Day 0	Day 4	Day 8	Day 12	Day 16	Day 20
RgCont	0.007±0.000^{a}	0.020±0.000^{a}	0.067±0.000^{a}	0.095±0.000^{a}	0.085±0.000^{a}	0.015±0.000^{a}
RgT$_{100\%}$		0.016±0.005^{a}	0.039±0.007^{a}	0.117±0.123^{a}	0.109±0.003^{a}	0.054±0.015^{a}
RaCont	0.003±0.000^{a}	0.009±0.013^{a}	0.014±0.137^{a}	0.107±0.000^{a}	0.035±0.004^{a}	0.010±0.006^{a}
RaT$_{100\%}$		0.013±0.015^{a}	0.023±0.003^{a}	0.124±0.007^{a}	0.114±0.028^{a}	0.065±0.000^{a}
ANOVA (Sign)	0.000	0.019	0.768	0.336	0.370	0.020

Values are mean ± common difference of three replicates. Means across rows with the same superscript were not significantly different at p≤0.05.
RgContr = Riogrande Tomato fruits Control (no treatment)
RgT$_{100\%}$ = Riogrande Tomato fruits treated with Riogrande tomato seed oil
RaContr = Roma VF Tomato fruits Control (no treatment)
RaT$_{100\%}$ = Roma VF Tomato fruits treated with Roma VF tomato seed oil

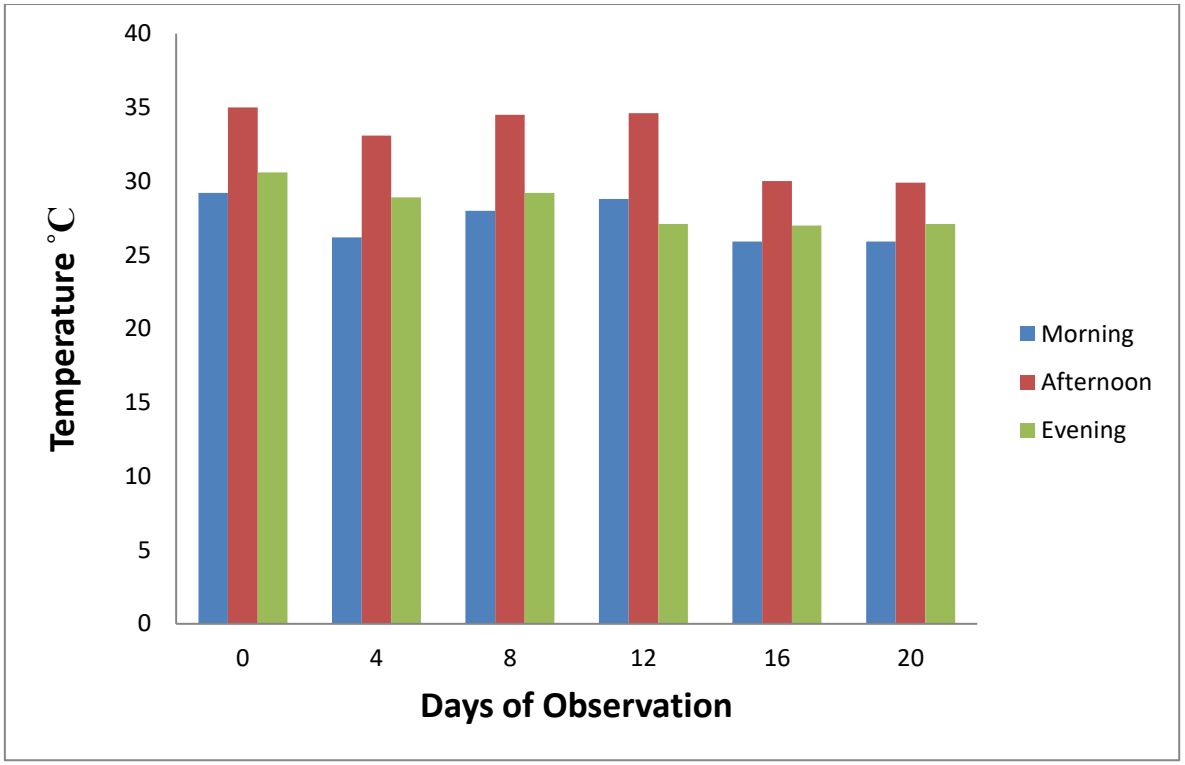

Figure 2: Temperature of the room during storage of tomato fruits

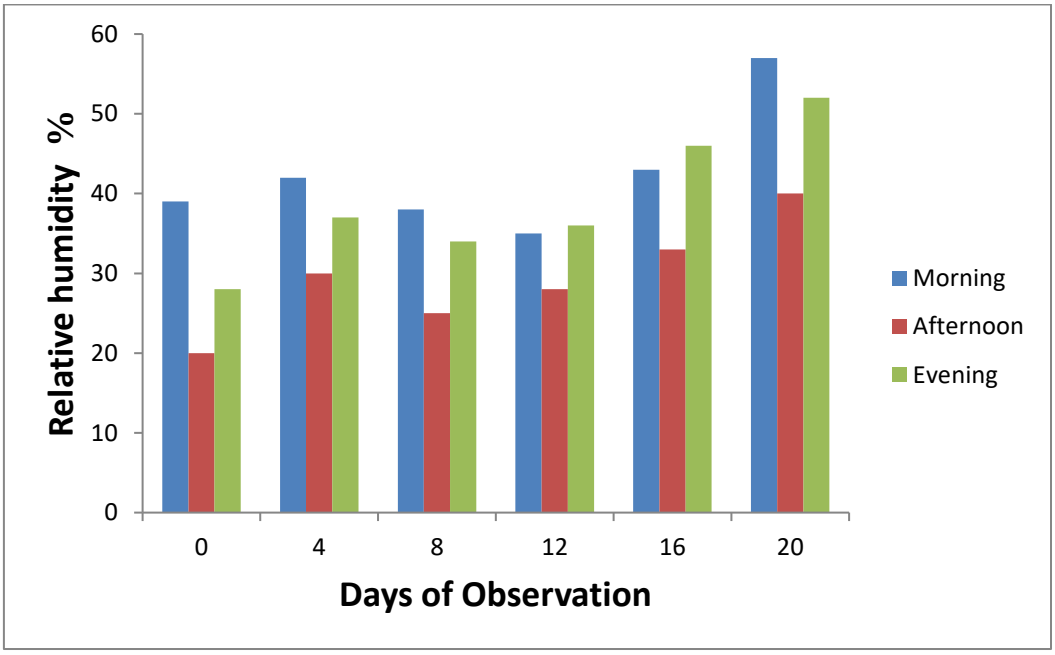

Figure 3: Relative humidity of the room during storage of tomato fruits

RESULTS AND DISCUSSION

Table 1 represents the physio-chemical and organoleptic properties of the two varieties of tomato seed oil. The oil extracted from the tomato seed has a mild tomato fruit-like odor and the color is red-yellowish, the percentage oil yield is 35 % to 38 % on a dry weight basis that are similar to those of other investigators (Botinestean *et al.*, 2012). The refractive index of the oil, the specific gravity and the physical properties of the extracted oil for Riogrande and Roma VF varieties were all in agreement with the FAO/WHO (Tsaknis *et al.*, 1999) international standard for edible oil. For the chemical properties of the extracted oil, the acid value for Riogrande seed oil (6.0545 mEq/kg) was higher than the acid value specified for edible oil by FAO/WHO (Tsaknis *et al.*, 1999) but this value was almost in agreement with Literature (5.0386 mEq/kg) reported by AOAC (1999). While the acid value for Roma VF was 1.3510 mEq/kg, this value is lower than the acid value specified for edible oil by FAO/WHO (Tsaknis *et al.*, 1999) which may be due to variety difference and nature of soil as low acid value indicates low number of fatty acids in the Roma VF variety. The iodine value of the Riogrande tomato seed oil variety is 88.680 I_2/100g while the Roma VF tomato seed oil variety is 65.500 I_2/100g, where both varieties of the oil are in agreement with the FAO/WHO

(Tsaknis *et al.,* 1999) standard for edible oil, which means that most of the fatty acids are unsaturated for Riogrande tomato seed oil and saturated for Roma VF. The Saponification value of the Riogrande tomato seed oil and Roma VF tomato seed oil was significantly different ($p<0.05$), 208.5915 and 216 .576 mg KOH/g oil respectively, these values are far higher than FAO/WHO standard of 181.4±2.60 mg KOH/g oil, and all other values reported in the literature. Peroxide value was 2.9945 and 9.955 mmol/kg for Riogrande and Roma VF tomato seed oil respectively. They were significantly ($p<0.05$) different from each other. The peroxide value for the Riogrande variety is by far lower than FAO/WHO standard of 10 (mmol/kg). A low peroxide value increases the suitability of the oil for a long storage due to low level of oxidative and lipolytic activities which also act as a natural preservative on the fruit coated with the extracted oil

There was a general increase in weight loss in all the treatments from day 4 to day 20. The treated fruits with TSO recorded significantly ($P < 0.05$) low weight loss compared to the control as shown in Tables 3. However, the control fruit showed a significant difference in weight loss compared with the treated fruits. The mechanism for these positive effects is based on the hygroscopic properties of oil, which enables formation of a barrier to water diffusion between the fruit and the environment, thus avoiding its external transference. Statistically significant difference ($P < 0.05$) was observed in weight loss among the treatments. The treated Roma VF tomato fruits had the lowest weight loss during the storage time while the highest weight loss was recorded in the Riogrande tomato fruits variety although; no significant difference was observed in both varieties. However, the variation in percent weight loss was highly significant due to the effects of variety at all the day of storage. The rate at which water is lost depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere. The tomato seed oil served as a barrier, thereby restricting water transfer. The results obtained in Table 3 are also in agreement with work of other researchers such as Mahmoud and Savello (1992) and Avena-Bustillos *et al.*. (1997) who concluded that coating /films with oil significantly conserved water content in fruits

The effect of tomato seed oil on the treated tomato fruits of both varieties on the shelf life of tomato on days 0, 4, 8, 12, 16, and 20 was not significant ($P \geq 0.05$). The shelf life of treated tomato fruits for both varieties increased from days 0 to 20 while the controls increased from days 0 to 12, but no significant differences were observed between the treatments and the controls as shown in Figure 1. The shelf life of the tomato fruit was considerably influenced by the coating of the extracted oil on the fruits due to the presences of low level of oxidative and lipolytic activities of the tomato seed oil (Ameh *et al.,* 2023). The longest shelf life (Day 20) was found in the treated tomato fruits whereas minimum shelf life (Day12) was found in the untreated (control) fruits. Shriveling, over ripening, discoloration and mold growth were predominant on the control fruits on termination of shelf life at Day 12 while the increase in shelf life of the treated samples was also due to the reduction of various gaseous (O_2 and CO_2) exchange from the inner and outer atmosphere (Mandal *et al.,* 2017)

Table 4 show a general decrease in the firmness of tomato fruits from 2.70 N/cm 0 to 0.600 N/cm during the storage duration. Firmness of tomato fruits stored progressively decreased during storage time form Day 0 to Day 20 and there was a significant ($p<0.05$) difference among the treatments. The treated fruits showed a statistical difference in firmness when compared to the control fruits on Days 12 and 16 while the other days of storage showed no significant differences. Ramirez *et al.* (2004) reported that loss of firmness during the storage period is a normal behaviour during the maturation of tomato fruits, since the increase in the ethylene concentration in this stage promotes the synthesis of polygalacturonase, the enzyme responsible for softening. The treated Riogrande tomato fruits firmness gradually decreases but with no significant differences observed while the control having the highest firmness value of 2.700 and 2.550 N/cm on Day 0 drastically decreases to 1.350 and 1.250 N/cm on Day 12. Though the treated Roma VF tomato fruits produce low firmness value (1.800 and 1.600 N/cm) on Day 4 and gradually decreases but retains part of its firmness over the storage period at Day 20. The tomato fruits coated with the extracted oil (containing Beta Carotene and other unsaponifiable compound) from the seed exerted a beneficial effect on the fruit firmness such that by the end of the storage period, the treated tomato fruits gave rise to fruits with higher firmness values than the Control.

The vitamin C content increases gradually over the entire storage period of the 20 days (Table 5) even as ripening was observed, unlike the control samples where the peak of the vitamin C content is at Day 16 of the storage period and then decrease in the vitamin C content. The decrease in vitamin C content of the control samples of tomato fruit during storage may be attributed to the biochemical processes of slow ripening rate that the fruit undergo before and after harvest (Liamngee et al., 2019). But for the coated samples with tomato seed oil, the high content of the vitamin C in the tomato fruits could be attributed to the delay in ripening since respiration and transpiration are slow as a result of the effect of the oil. Moneruzzaman *et al*. (2009) reported that, as the tomato fruit ripens, the ascorbic acid content decreases, therefore, measures to control rapid ripening of tomato fruit has a great influence on the nutrient retention as well as extension of storage life of the fruit.

Table 7 show a general increase from 0.033 to 0.097 mg 100 g^{-1} in the beta- carotene content of both varieties of tomato fruits during storage from day 0 to day 8. While from day 12 to day 20 show a decrease in the beta- carotene content from 0.064 to 0.001 mg 100 g^{-1}. Both controls show an increase in its beta- carotene content from day 0 and reached a peak at day 8 but decreases drastically at day 12 to day 20.The treated tomato fruits with tomato seed oil increased in its beta-carotene content and reached its peak at day 8 (0.084 mg 100 g^{-1}), unlike the control that decreases drastically in its beta-carotene content after day 8. The treated samples only decrease gradually and at day 16 a higher beta- carotene content of 0.054 mg 100 g^{-1} was recorded. The extreme loss of beta- carotene at day 20 of storage indicated an inappropriately long storage time (Lewinsohn *et al.,* 2005). Beta- carotene content losses in the tomato fruits after day 20 may have been converted or isomerized into other derivative compounds including flavour and aroma constituents (Lewinsohn *et al.,* 2005) or it was converted back into lycopene (Alba *et al.,* 2000).

Table 8 show a general increase from 0.016 to 0.124 mg 100 g^{-1} in lycopene content of tomato fruit during storage. The effect of both the control and treatment on the lycopene content of the tomato varieties showed no significant difference ($P < 0.05$). Data from the Table showed that lycopene content of tomato increases gradually from day 0 to day 12 (producing the highest lycopene content) and decline as it get to day 20 during the storage period. It was also reported by Javanmardi and Kubota (2006) that lycopene content normally increases from maturity to ripening stages and then decreases toward senescence during storage. At day 16 and day 20, the lycopene content for all the samples (both

control & treated fruits) gradually decreases in their lycopene content with the sample treated with tomato seed oil still having higher lycopene content for both tomato varieties. However, the pattern of lycopene accumulation may be influenced by different treatments and storage condition. Among the two varieties studied, the Roma VF tomato fruit treated with Roma VF tomato seed oil generally gave higher lycopene content value on Day 12 (0.124 mg 100 g^{-1}), Day 16 (0.114 mg 100 g^{-1}) and Day 20 (0.065 mg 100 g^{-1}) respectively.

Temperature and relative humidity are factors responsible for red colour pigment formation; favor ascorbic acid synthesis, increase or decrease respiration rate of fruits, and loss of weight of fruits (Kator *et al.,* 2018). Figure 2 show the temperature range of room during storage of tomato fruits for 20 days of storage period. The room temperature during the storage period has the least temperature of 25.9 ˚C during the morning hour and has the highest temperature of 35.0 ˚C during the afternoon hour. The high temperature range during the storage had a large effect on degradation of chlorophyll as well as carotenoid development, since it has been reported that the formation of lycopene depends on the temperature range (Leoni, 1992). As fruit develops from immature green to ripe, the progressive increase in carotenoid content is directly proportional to the increase in all-trans-lycopene concentration within the plastids whose synthesis is favored at a temperature above 30°C (Thompson *et al.,* 2000). The temperature range observed in Figure 2 shows a higher temperature range that favor development of lycopene structure of the tomato fruits which was observed to continue to increases all through the storage period. This agreed with the report that the development of lycopene structure will be optimized at temperatures of 12 °C and 32 °C (Leoni, 1992). Colour development in tomato is sensitive to temperature, having a better plastid conversion when temperature is above 12 ˚C and below 30 ˚C (Javanmardi and Kubota, 2006). Respiration and metabolic activities within harvested climacteric fruits like tomato are directly related to the temperature of the ambient environment. High temperature can hasten the rate of respiration (CO_2 production) in harvested or stored fruits products (Kator *et al.,* 2018). Temperatures above 25 °C will increase respiration rate, red colour pigment formation, and develop more ethylene than fruit in chilled storage (McDonald et al., 1999). The knowledge of the right temperature management during storage of tomatoes is of importance in extending the shelf life of the fruit whilst maintaining fruit qualities.

Figure 3 showhe Relative humidity of the storage room during storage of tomato fruits for 20 days. During the study period relative humidity of the storage room varied from 25 % to 57 % (v/v) respectively. The optimal values of relative humidity for mature green tomatoes are within the range of 85 to 95 % (v/v) but 90 to 95 % (v/v) for firmer fruits as reported by Kator *et al.,* (2018). During the study, it was observed that the control tomato fruits were shrinking during storage, this may be due to the variation in relative humidity. Suslow and Cantwell (2009) reported that below optimal range of relative humidity, evapotranspiration increases resulting in shriveled fruits. The treated tomato fruits with tomato seed oil show no sign of shrinking during the storage period at Day 4, 8, 12 but slight sign of shrinking was observed on Day 16 and Day 20 respectively. This may be due to the effect of the tomato seed oil directly on the skin of the tomato fruits samples. Tomato fruits are very high in moisture content and susceptible to shrinkage after harvest. Water loss from harvested fruit produce is predominantly caused by the amount of moisture present in the ambient air expressed as relative humidity (Hong *et al.,* 1999). The effect of the oil and its chemical makeup may have prevented evapotranspiration from the skin of the tomato fruits thereby enabling moisture content retention and delayed ripening being triggered even when relative humidity is low for tomato fruits storage as shown in figure 3.

CONCLUSION

The results of this study established that both oil extracted from Riogrande and Roma VF tomato seed varieties possess the ability to increase the shelf life and maintain the physicochemical quality of tomato fruits during storage. Coating with the tomato seed oils offer the tomato fruits protection from bruising by being slippery, shininess and retard its maturation by delaying ripening. The extracted oil from tomato seeds are not only safe for consumption, it is an alternative means of converting tomato seeds from waste to wealth for maintaining postharvest physiology and management of crops.

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