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Research Article

Assessment of locally produced waxing materials on the shelf life and fruit quality of two tomato varieties (Solanum lycopersicum).

R. Osae * G. Essilfie ** J. O. Anim ***

Abstract
The study was conducted to assess the effect of different waxing materials on the quality attributes of tomato fruits. A 2 x 8 factorial experiment layout in complete randomized design with 16 treatment combinations and 3 replication was adopted. The materials that were used for the experiment are two (2) varieties of tomatoes (Pectomech and Power Rano) and seven (7) waxing material (shea butter, cassava starch, beeswax, and a combination of shea butter + cassava starch, shea butter + beeswax, cassava starch + beeswax, shea butter + cassava starch + beeswax) and a control. Results from the experiment indicated that all waxing treatments delayed the development of weight loss, firmness, pH, total soluble solids, and total titrable acidity. The results also suggested that edible wax coatings delayed the ripening process and colour development of tomato fruits during the storage period and extended the shelf life. However Beewax treatment and its combinations performed better than the other treatments. It was therefore recommended that locally produced wax such as Beewax, Shea butter, Cassava Starch treatments and their combinations could be a good technology for preserving the quality and extending the shelf life of fresh tomato fruit as well as maintaining the physical and chemical properties.

Keywords
locally produced waxing materials-shelf life-Solanum lycopersicum-storage-tomato varieties

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1. Introduction

Tomato (Solanum lycopersicum.) is a major horticultural crop with an estimated global production of over 129 million metric tons (F.A.O., 2008). It is one of the most widely used vegetables in world (Chapagain and Wiesman, 2004). Tomato is a crop of high economic importance in many countries as it is a relatively short duration crop and gives a high yield (Obeng-Ofori, Ofosu-Anim, et al., 2007). It is economically attractive and the area under cultivation is increasing daily in Ghana. Tomato is the most important crop in recently established dry season gardens in the Northern and Upper Regions of Ghana and in the Southern Volta Region. It is also a fairly important cash crop in the outskirts of urban areas in the forest zone (Obeng-Ofori, Ofosu-Anim, et al., 2007). Tomato of the nightshade family is consumed in diverse ways, including raw, as an ingredient in many dishes and sauces and in drinks. The tomato fruit, classified as a vegetable in trade, is a prominent "protective food" (Alam et al., 2007). In Ghana, the focus of the various stakeholders in the tomato industry has mostly been on improved production capacities of farmers. However, after investing a lot in producing the vegetables, the produce are lost along the postharvest chain through poor handling and preservation. As observed by Robinson and Kolavalli (2010), in Ghana, the agricultural sector in general and the tomato sector in particular have not met their potential. In this sector, production seasonality, the dominance of rain fed agriculture, high perishability of the vegetable, lack of ready market, lack of reasonable alternative uses of the vegetable and poor pricing are some of the problems faced by farmers. In addition, poor postharvest practices account for the recurrent seasonal postharvest losses of tomatoes. Bani et al. (2006) revealed that tomato losses incurred along the route alone amounted to 20% from Bolgatanga to Accra. Any degree of postharvest loss of tomatoes has consequences to farmers, traders and consumers. Not only are losses clearly a waste of food, but also represents a similar waste of human effort, farm inputs, livelihoods, investments and scarce resources such as water (World Resource Institute, 1998). Kader, (2005) reported that, the reduction of postharvest losses of perishables is of major importance when striving for improved food security in developing countries like Ghana. As more fresh fruits are needed to supply the growing population in developing countries, more produce is transported to nonproducing areas and more commodities are stored longer to obtain a year round supply. Therefore, post harvest loss prevention technology measures become paramount (Oyekanmi, 2007). The perishability of tomatoes requires the development of technologies that will reduce the postharvest deterioration and extend its shelf life (Gonzalez- Aguilar et al., 2009).The use of edible coatings or waxing appears to be a promising approach to minimize these problems and preserve the freshness of tomatoes (Gonzalez-Aguilar et al., 2010a). The aim of this study is to assess the effects of the different waxing materials on the shelf life and quality attributes of tomato fruits.

2. Materials and Methods

The experiment was conducted in the Physiology Laboratory of the Department Crop Science, in the University of Ghana. The materials used for the experiment were two (2) varieties of tomatoes (Pectomech and Power Rano) and seven (7) waxing materials (shea butter, cassava starch, beeswax, and a combination shea butter + cassava starch, shea butter + beeswax, cassava starch + beeswax, shea butter + cassava starch + beeswax) and a control.

Table 1. DISCRIPTION OF MATERIALS

	TREATMENTS	RATIOS
T_0	Control	
T_1	Shea butter	
T_2	Cassava starch	
T_3	Beeswax	
T_4	Shea butter + Cassava starch	1:01
T_5	Shea butter + Beeswax	1:01
T_6	Beeswax + Cassava starch	1:01
T_7	Shea butter + Cassava starch + Beeswax	1:01:01
V_1	Pectomech	
V_2	Power Rano	

A 2 x 8 factorial experiment layout in complete randomized design with 16 treatment combinations was adopted. The tomato varieties were grown under farmers' condition in Fanteakwa District. The fruits were harvested at the physiological stage of maturity and transported to the laboratory of the Department of Crop Science. The fruits were sorted to remove diseased or bruised ones, washed using chlorinated water to remove dirt, spray residues, disease spores and air dried under room conditions. The cleaned and dried fruits were divided into 16 lots each containing 30 fruits. Each treatment was replicated three times.

2.1 Wax application method

The tomato fruits were briefly dipped or submerged completely in a bath of melted wax such as beeswax and shea butter at a temperature of 45oC. Upon removal, the beeswax and shea butter solidified almost instantaneously. The tomato fruit was ready for packing within a minute after dipping. The cassava starch slurry was prepared by mixing 400g of cassava starch with 1.5 liters of water. This solution was then heated up to 50oC whiles continuously stirring until the starch was gelatinized. The cooked starch was allowed to cool and the fruits were dipped in it completely for 30 seconds to ensure that the fruit was completely covered with the starch. The coated fruits were allowed to air dry. All lots of fruits were packed according to the experimental layout and stored at room temperature in the laboratory after the wax application. The concentrations of wax used were by volume in a ratio of 1:1 and 1:1:1 for the treatment combinations respectively.

2.2 Data collection

Data on randomly selected fruits in each treatment per replication was recorded at 0, 5, 10, 15, and 20 days of storage during the experiment on the following quality indices (Gonzalez Aguilar et al., 2009).

2.2.1 Weight loss (%)

For the determination of weight loss during storage, 3 fruits were marked at the start of experiment from each treatment and kept separate for periodic weighing using an electronic balance (Park et al., 1994). The percent weight loss was calculated as follows:

2.2.2 Firmness

Firmness of fruits was measured by using a penetrometer (Model FT327-8mm). Three tomato fruits were sampled randomly from each treatment and their firmness was determined according to the manufacturer's instructions.

2.2.3 pH of fruits

The pH of fruit juice was measured by using a digital pH meter (Symphony, Model SB70P). Three fruits were randomly sampled from each unit and pH values of the juice were measured according to Association of Official Analytic Chemist (AOAC) method (1990).

2.2.4 Total Soluble Solids

Total soluble solids were determined for three fruits using a digital refractometer at room temperature. The refractometer was calibrated with distilled water and 3drops of juice from the homogenized sample were placed on the prism of the refractometer and the reading taken. The determinations were done in triplicate and the mean values were recorded.

2.2.5 External Colour

Measurements of skin colour were taken from each fruit (three fruits per treatment), using a Minolta colorimeter (model CR-300; Minolta Corp., Ramsey, NJ, USA). The values were obtained on a CIELAB scale (L*, a*, b*). The L*, a*, b* values represent luminosity, redness and yellowness of the fruit, respectively. To obtain the real colour changes of the fruit, a* values were analyzed for the external colour and expressed in percentage.

2.2.6 Total Titrable Acidity

Three fruits from each treatment were homogenized in 100mls of distilled water in a kitchen blender. The homogenized solution was filtered through a muslin cloth. Ten milliliters of the filtrate was transferred into a 125mls conical flask and 100mls of distilled water was added to the filtrate. Three drops of phenolphthalein indicator was added to the filtrate and titrated against the alkaline, 0.1N of NaOH until the final colour turned pink. The titre values were recorded and the percentage citric acid was calculated using the method described by Mitcham et al., (1996).

$$\frac{\%Acid = MlsNaoHxNormality(NaoH)x0.064^*}{VolumeofSample(ml)} X100$$

Where 0.064*= acid milliequivalent factor.

2.2.7 Shelf Life of fruits

The fruits were kept at room temperature until they started to rot. The number of days taken before rotting was observed on fruit was recorded as the shelf life.

2.2.8 Temperature and Relative Humidity of the storage area.

Temperature and relative humidity of the storage area was measured during the storage period using thermo hygrometer.

	Temperature oc		Relative Humidity (%)	
	Min.	Max.	Min.	Max.
Mean	26.4	30.1	81	85.5

3. RESULTS

3.1 Percentage Weight Loss (% WL following different waxing treatment.

The percentage weight loss of the two tomato varieties increased with the storage period and was higher for the control fruits in the two varieties than the treated fruits from day 5 to day 20 (Figure.1.). However, the control for the two varieties had a shelf life of ten days. The maximum weight loss (29.49%) from day 5 to day 10 for the Pectomech variety was recorded for the control and this figure was statistically different (p>0.05) from the weight loss figures of the other treatments and their combinations. The minimum weight loss (5.55%) was recorded with BW treatment. There was a significant decrease in % WL due to waxing and varietal effect. BW treatment was statistically different (p>0.05) from SB and CS. However, there was significant effect of waxing/variety interactions on % WL. Comparing fruits treated with SBCS, SBBW and BWCS, those with SBCS recorded the highest weight loss (8.68%), followed by SBBW (5.76%) then BWCS (5.71%). The difference in % Weight loss between the two (BWCS and SBBW) was statistically different from SBCS. Interestingly, from day 15 - day 20, there was also a significant decrease in % WL in waxing and variety effect. The highest weight loss (38.7%) was recorded with CS coated fruits whilst BW coated fruits recorded the lowest (24.35%). However BW, CS and SB coated fruits were the same statistically (Appendix 1.1). On the other hand, there was also significant effect of waxing/variety interactions on % WL. SBCS recorded the highest weight loss (38.5%) whiles SBBW recorded the lowest weight loss (27.9%). In all, BW and its combination reduced weight loss than the other treatments and their combinations (Figure 2).

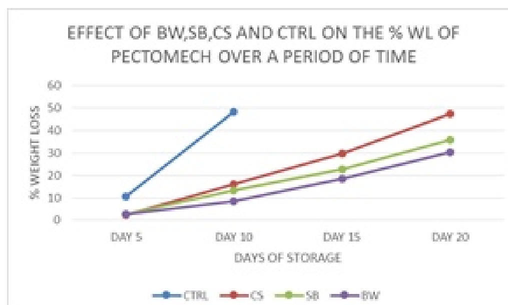

Figure 1. Changes in % WL following different waxing treatment on Pectomech.

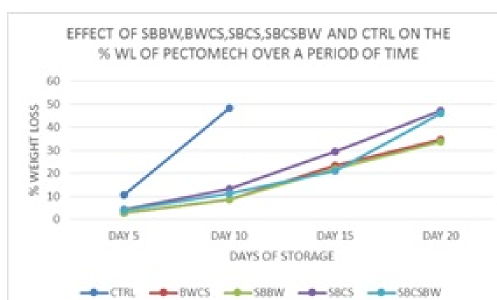

Figure 2. Changes in % WL following different waxing treatment on Pectomech.

For the Power variety, the maximum weight loss (45.34%) from day 5 to day 10 was recorded for the control fruits and the figure was statistically different ($p>0.05$) from the other treatments and their combinations. The minimum weight loss (5.91%) was recorded with the BW treatment. There was a significant loss in % WL due to waxing effect. BW treatment was significantly different in weight loss ($p>0.05$) from SB and CS. (Figure.3). However, there was a significant effect of waxing/varieties interactions on the % WL. SBCS recorded the maximum weight loss (9.92%) whiles SBBW recorded the minimum weight loss (6.23%). The % WL in SBBW was not significantly different ($p>0.05$) from BWCS .However, from day 15 to day 20, the results shows that there was a significant increase in percentage weight loss in waxing and variety. The maximum weight loss (52.59%) was recorded with the CS treatment. BW treatment showed the minimum weight loss (26.5%). There was significant difference between the interactions. BW treatment and its combinations reduced weight loss than the other treatments (Figure. 4). In all, the percentage weight loss in fruits was higher in Power than the Pectomech.

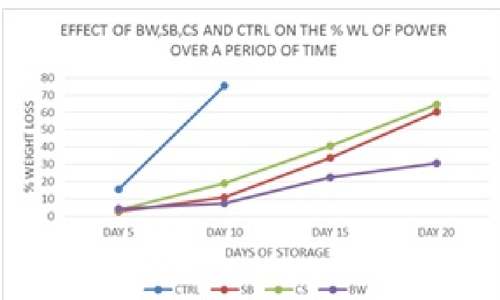

Figure 3. Changes in % WL following different waxing treatment on Power.

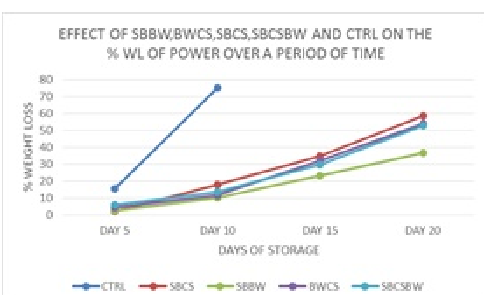

Figure 4. Changes in % WL following different waxing treatment on Power.

3.2 Firmness of tomato varieties following different waxing treatment.

The study showed that there was a significant decrease in firmness from day 0 to day 20 and the control fruits were softer than than the treated fruits. There was significant difference ($p<0.05$) with waxed fruits and between varieties as well as their interactions. The control for both varieties had a shelf life of ten days. Pectomech fruits in the control treatment recorded the lowest value (2.52) for firmness from day 0 to day 10 and it was significantly different ($p<0.05$) from the other treatments and their combinations. The SBBW coated fruits recorded the highest value (3.89) for firmness however this was not significantly different ($p<0.05$) from the other treatment and their combinations. However, from day 15 to day 20, SBBW treatment recorded the highest firmness (2.37) which was not significantly different ($p<0.05$) from BW (2.29), BWCS (2.03) and SB (1.83) coated fruits. Fruits coated with CS recorded the lowest firmness (1.28) and was significantly different ($p<0.05$) from the other treatments and their combinations. The firmness values for fruits coated with SBCS and SBCSBW were similar statistically (Table .2). The changes in firmness of Pectomech that occurred after 20 days of storage following the different waxing treatment are shown in the Table 2.

Table 2. Effect of different waxing material on the firmness of Pectomech tomato.

	Day 0	Day 5	Day 10	Means	Day 15	Day 20	Means
BW	4.27	3.7	3	3.68a	2.5	2.07	2.29a
BWCS	4.27	3.56	3.02	3.61a	2.25	1.81	2.03a
CS	4.67	2.67	2	3.11a	1.5	1.07	1.28c
CTRL	4.37	2.17	1.03	2.52b			
SB	4.44	3.17	2.57	3.39a	2.08	1.57	1.83a
SBBW	4.43	3.93	3.3	3.89a	2.65	2.08	2.37a
SBCS	4.33	2.75	2.23	3.11a	1.52	1.07	1.3
SBCSBW	4.07	3	2.53	3.20a	2.04	1.37	1.70b
Fpr.(0.05)	0.53	<0.01	<0.01		0.006	0.016	

All means sharing similar letters are statistically non-significant at 0.05 probability level.

For Power, the lowest firmness from day 0 to day 10 was recorded with the control fruits (1.97) and was significantly different ($p<0.05$) from the other treatments and their combinations. The highest firmness was recorded with BW treatment (3.57) which was not significantly different ($p<0.05$) from the other treatments except SBCS and the control. A Similar trend was observed from day 15 to day 20. SBCS treatment recorded the lowest firmness (1.06) and was significantly different ($p<0.05$) from the other treatments and their combinations. A significant highest firmness was recorded with BW treatment (2.32) as compared to the other treatments except SBCS treatment. The changes in firmness of Pectomech that occurred after 20 days of storage following the different waxing treatment are shown in (Table 3).

3.3 Total Soluble Solids (TSS) or % Brix on tomato varieties following different Waxing treatment.

Table 3. Effect of different waxing material on the firmness of power tomato.

	Day 0	Day 5	Day 10	Means	Day 15	Day 20	Means
BW	4.02	3.52	3.17	3.57a	2.57	2.07	2.32a
BWCS	3.97	3.2	2.4	3.19a	1.74	1.42	1.58a
CS	3.93	2.42	1.93	2.76a	1.27	0.91	1.09a
CTRL	3.77	1.4	0.73	1.97c			
SB	3.87	3.01	2.4	3.09a	1.8	1.33	1.57a
SBBW	4.07	3.52	2.75	3.45a	2.13	1.73	1.93a
SBCS	3.9	2.5	1.67	2.69a	1.18	0.93	1.06b
SBCSBW	4.03	2.93	2	2.99a	1.53	1.2	1.37a
Fpr.(0.05)	0.53	<0.01	<0.01		0.006	0.016	

All means sharing similar letters are statistically non-significant at 0.05 probability level.

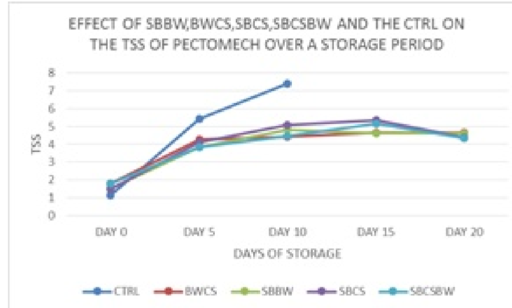

Figure 6. Changes in TSS of Pectomech following different waxing treatments.

The changes that occurred in Total Soluble Solids (TSS) showed that, there was a significant increase in TSS from day 0 to day 10 and a gradual decline from day 10 to day 20 for both tomato varieties studied. (Figure 5- 6). For Pectomech, there was a significant difference in waxing and varietal effect as well as the interaction from day 0 to day 10. The control fruit had maximum TSS (4.49) which was statistically different (p>0.05) from fruits of the other treatments and their combinations. BW treatment fruits had the lowest TSS (3.1) which was statistically different (p<0.05) from those of SB (3.62) and CS (3.8) treatments. There was a significant effect of waxing/variety interaction on TSS. SBCS fruits had the highest TSS (3.55) whiles SBBW fruits recorded the lowest TSS (3.17).The TSS from day 15 to day 20 showed a gradual decline (Figure 4.2.3).SBCS recorded the highest TSS (4.87) which was significantly different (p<0.0.5) from the other treatments and their combinations. BW treatment fruits showed the lowest TSS (4.1) which was significantly different (p<0.05) from fruits of SB (4.45) and CS (4.73). There was significance difference in the interaction but TSS in BWCS was not statistically different from SBCSBW.

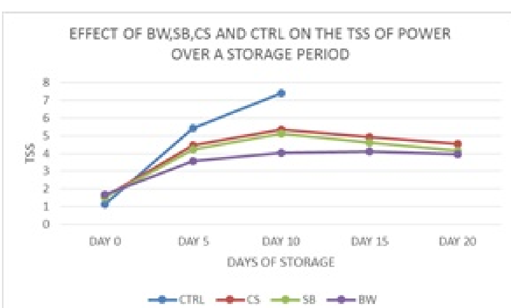

Figure 5. Changes in TSS of Pectomech following different waxing treatments

For Power, there was a significant increase in TSS from day 0 to day 10 and a gradual decline from day 10 to day 20 (Figure 7.). However from day 0 to day 10, the control treatment retained the highest TSS (5.08) which was statistically different (p>0.05) from the other treatment and their combinations. BW treatment showed the lowest TSS (3.7) which was statistically different (p<0.05) from the other treatment and their combinations. There was significant effect of waxing/variety interaction on TSS. However, BWCS was not significantly different (p<0.05) from SBCS and SBCSBW. On the other hand, from day 15 to day 20, there was a gradual decline in TSS. CS treatment recorded the highest TSS (5.65) which was significantly different (p>0.0.5) from the other treatment and their combinations.BW treatment showed the lowest TSS (4.67). There was a significant effect of waxing/variety interaction on TSS (Figure 8).

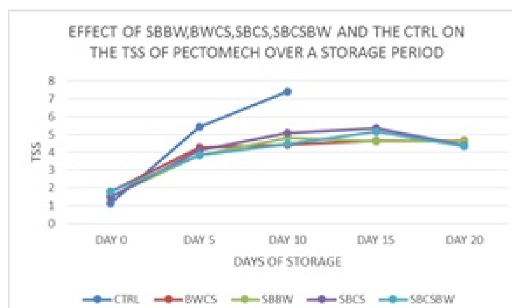

Figure 7. Changes in TSS of Power following different waxing treatments.

3.4 TTA of tomato varieties following different Waxing treatment.

The study showed that there was a significant (p<0.05) decrease in TTA from day 0 to day 20 as well as a significant difference in waxing and variety effect and their interactions. For Pectomech, there was a significant difference in TTA due to waxing and varietal effect as well as the interactions from day 0 to day 10. BW treatment recorded the highest TTA (0.79) and was significantly different (p<0.05) from the other treatment and their combinations. The control fruits recorded the lowest TTA

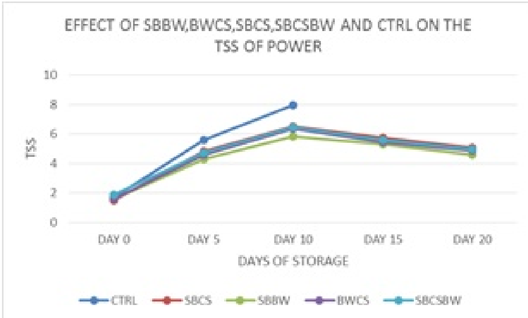

Figure 8. Changes in TSS of Power following different waxing treatments.

(0.55). However, BW treatment was not significantly different ($p<0.05$) from BWCS, SBBW and SB.A Similar trend was also observed from day 15 to day 20. The highest TTA (0.55) was recorded with the BW treatment with CS treatment having the lowest TTA (0.36). The BW treatment was significantly differently ($p<0.05$) from the other treatment and their combinations but there was no significant differences between BWCS and SBBW (Figure 9- 10).

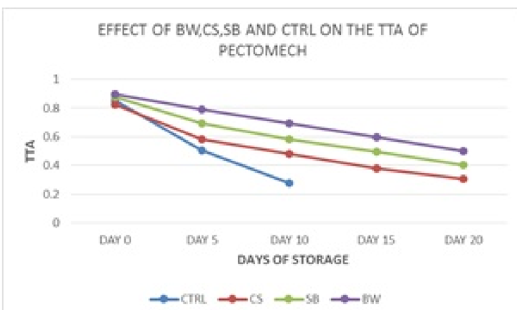

Figure 9. Changes in TTA of Pectomech following different waxing treatments.

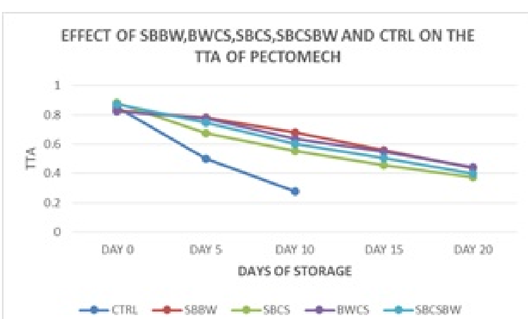

Figure 10. Changes in TTA of Pectomech following different waxing treatments

For Power, there was a significance difference in TTA following waxing and variety effect as well as their interactions. A similar trend was also observed from day 0 to day 10 and there was a gradual decline in TTA as well (Figure 11 - 12). BW treatment recorded the highest TTA (0.80) whiles the control fruits recorded the lowest TTA (0.52). BW treatment was not significantly different ($p<0.05$) from BWCS, SBBW, SB, CS and SBCSBW. However, from day 15 to day 20, there was also a significant difference ($p>0.05$) in TTA due to waxing and variety effect as well as the interactions. BW treatment recorded the highest TTA (0.54) and it was significantly different ($p>0.05$) from the other treatment and their combinations. CS treatment recorded the lowest TTA (0.31).

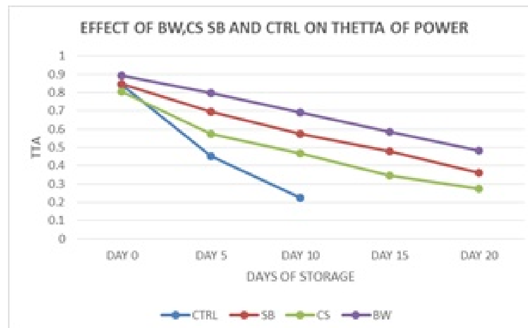

Figure 11. Changes in TTA of Power following different waxing treatments

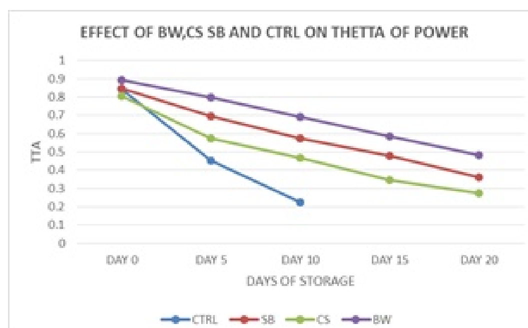

Figure 12. Changes in TTA of Power following different waxing treatments

3.5 pH of tomato varieties following different Waxing treatments.

It was noted that, there was a significant ($p<0.05$) increase in pH from day 0 to day 20. For Pectomech, it was noted that there was a significant difference in pH following waxing and varietal effect as well as their interaction from day 0 to day 10. The control treatment recorded the highest pH (3.95) and was not statistically different ($p<0.05$) from other treatments and their combinations except BW and SBBW treatments. However, BW treatment recorded the lowest pH (2.6) and it was not statistically different ($p>0.05$) from SBBW treatments. A Similar trend was observed from day 15 to day 20. The highest pH (4.94) was recorded with SBCS treatment and it was not significantly different ($p<0.05$) from other treatments except BW and SBBW treatment. However, BW treatment recorded the lowest pH (3.8) and it was also not significantly different ($p<0.05$) from SBBW. The changes in pH of Pectomech that occurred after 20 days of storage following the different waxing treatment are shown in figure (13- 14.).

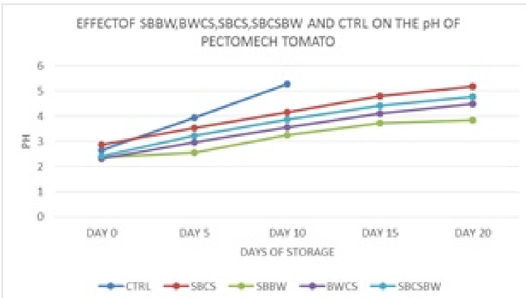

Figure 13. Changes in pH of Pectomech following different waxing treatments.

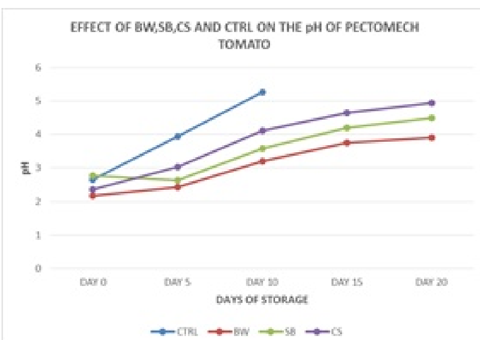

Figure 14. Changes in pH of Pectomech following different waxing treatments.

For Power, there was also a significance increase in pH from day 0 to day 20. However from day 0 to day 10, the control treatment recorded the highest pH (3.86) and was not significantly difference ($p<0.05$) from the other treatment and their combinations. BW treatment recorded the lowest pH (2.64) and was significantly different ($p<0.05$) from other treatment and their combinations. The study also showed that there was significant effect ($p<0.05$) on pH as a result of waxing/variety interactions. Day 15 to day 20 also follows a similar trend. The highest pH (5.07) was recorded with SBCS treatment and was not significantly different ($p<0.05$) from the other treatment and their combinations. BW treatment recorded the lowest pH (3.8) and was significantly different ($p<0.05$) from the other treatment and their combinations. The changes in pH of power that occurred after 20 days of storage following waxing/variety effect are shown in figure (15 - 16).

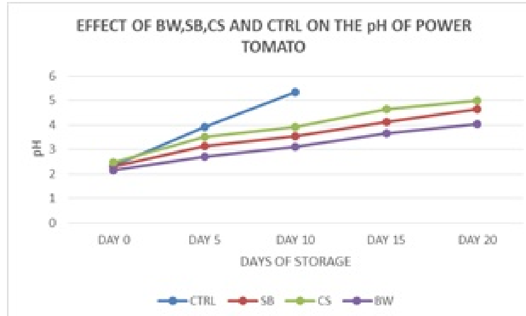

Figure 15. Changes in pH of Power following different waxing treatments.

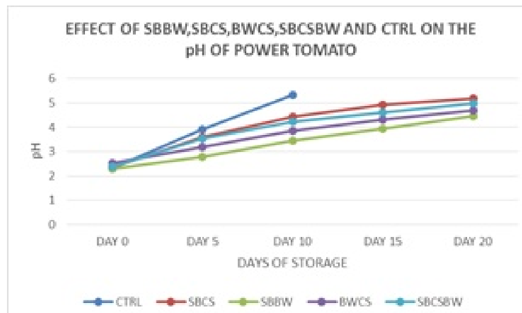

Figure 16. Changes in pH of Power following different waxing treatments.

3.6 Shelf life of tomato varieties following different Waxing treatment.

The storage life of the two tomato varieties following the different waxing treatment is depicted in the figure 17. The study revealed that the control for Pectomech and Power had a shelf life of 12 days and 10 days respectively. However, tomato fruits treated with different waxing material lasted for 20 days and above. In Pectomech, BW treatment had the longest shelf life of 34 days whiles CS treatment had the shortest shelf life of 23days for the treated samples. For the Power variety, the longest shelf life was recorded with BW treatment (28 days) whiles the shortest shelf life was recorded with CS treatment (22 days).

3.7 External colour of tomato varieties following different waxing treatment.

The study showed that there was significant increase in external colour as the days of storage progressed from day 0 to day 20. There was also significant differences ($p<0.05$) in waxing and varietal effect as well as their interactions.

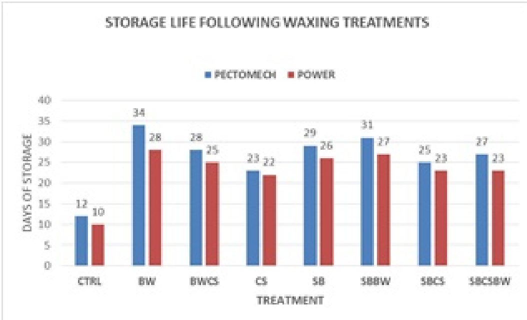

Figure 17. Shelf life of tomato varieties following different waxing treatments.

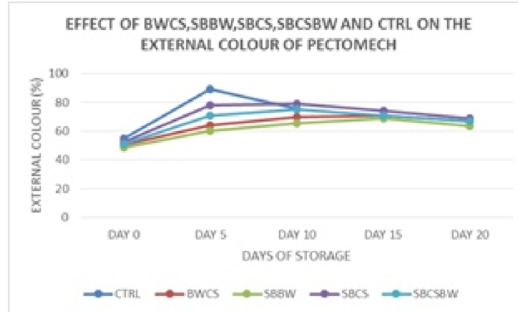

Figure 19. Changes in External Colour following different waxing treatments on Pectomech.

However, the control fruits for both varieties increased in colour sharply from day 0 to day 5 and dropped sharply from day 5 to day 10 but the treated fruit increased gradually from day 0 to day 5 and maintained a uniform colour up till day 20 when a change in the colour was observed (Figures 18 and 19). For Pectomech, the highest value for external colour from day 0 to day 10 was recorded with the control treatment (73.18) and it was statistically different ($p>0.05$) from the other treatments and their combinations. The BW treatment recorded the lowest value (57.54) and it was significantly different ($p<0.05$) from the other treatment and their combinations except SBBW treatment. There was no significant difference ($p<0.05$) between the external colour of CS, SBCS, and SBCSBW treatments (Appendix 1.9). However from day 15 to day 20, SBCS had the highest value for external colour (71.59). BW treatment recorded the lowest value for external colour (60.64) and was significantly different ($p<0.05$) from the other treatment and their combinations. There was no significance difference between BWCS, CS, SBCS, SBBW and SB treatments.

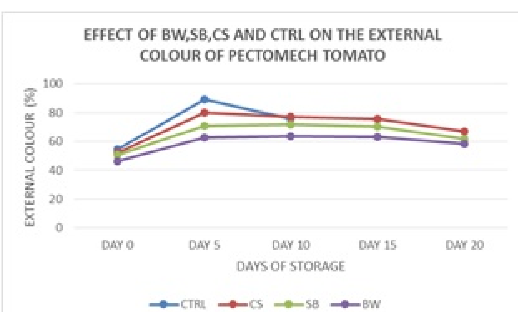

Figure 18. Changes in External Colour following different waxing treatments on Pectomech.

For Power, the highest value for external colour from day 0 to day 10 was recorded with the control fruits (74.52) and it was significantly different ($p<0.05$) from the other treatment and their combinations. The BW treatment recorded the lowest value for external colour (57.09). There was no significant difference ($p<0.05$) between BWCS, CS, SBCS and SBCSBW. However, from day 15 to day 20, the highest value for external colour was recorded with SBCS treatment (71.94) and was significantly different ($p<0.05$) from the other treatments. BW treatment recorded the lowest value for external colour and was not significantly different ($p<0.05$) from SBBW treatment (Figure 20 and 21). Generally, colour development was similar for both varieties. The results also suggest that waxing or edible coating delayed to a higher extent, the ripening process of tomato fruits during the storage period.

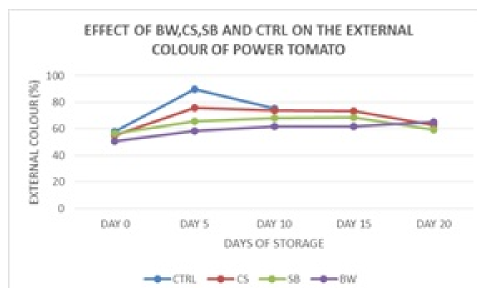

Figure 20. Changes in External Colour following different waxing treatments on Power.

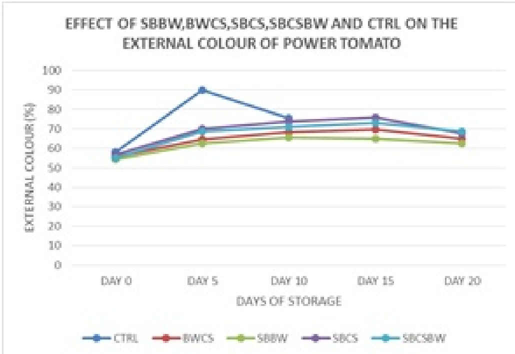

Figure 21. Changes in External Colour following different waxing treatments on Power.

4. DISCUSSION

Weight loss means the amount of water lost from fruits or vegetables over a period and it is related to the shelf life of produce. In this study the percentage weight loss of the two tomato varieties increased with the storage period. Fruits stored at ambient tropical conditions lose weight due to respiration and transpiration. The lower loss in weight compared to control that was seen in fruit coated with different waxing materials are consistent with the findings of several researchers. Olivas et al. (2003), concluded that wax application largely contributed to the reduction in the weight losses of tomatoes. Edible coatings act as water-loss barriers, causing high relative humidity in the surrounding atmosphere of the tomato fruit and thus reducing the moisture gradient to the exterior (Park et al., (1994) and El Ghaouth et al., (1992). Similar works by Mahajan et al. (2011), suggests that the percent weight loss in general, increased with advancement of the storage period rather slowly in the beginning, but at a faster pace as the storage period advanced. Mejia-Tores et al., (2009) also noted similar trends in weight loss when tomatoes were waxed. Firmness is a critical quality index because it determines whether or not a fruit can be transported or shipped to distant markets without deteriorating. Tomato fruit soften as they develop from immature green to full red colour (Hanson, 2001). This study showed that there was a significant decline in firmness from day 0 to day 20 and the control fruits were declined in firmness faster than the treated fruits. Mahajan et al., (2011), reported that fruit firmness declined with advancement in storage period and it was higher in the control fruit than the treated fruits. These results are in line with Gonzalez-Aguilar et al., (2010a) who suggested that the edible coatings significantly ($p < 0.05$) reduced water and increased firmness in tomato fruit during storage. The total soluble solids are the amount of sugar and soluble minerals present in fruits and vegetables. The results showed that, there was a significant ($p < 0.05$) increase in total soluble solids (TSS) from day 0 to day 10 and a gradual decline from day 10 to day 20 for both Power and Pectomech tomato varieties. The increase in TSS from day 0 to day 10 may be due to hydrolytic changes in the starch concentration during the postharvest period. These changes result in the conversion of starch to sugar, which is an important index of ripening process (Kays, 1997). Ladaniya and Sonker (1997) reported maximum retention of TSS when fruits were waxed and stored for up to 21 days. Gul et al., (1990) also found that TSS increased slowly in wax coated blood red orange fruits than control during storage. Syamal (1991) reported that the total soluble solids increase during ripening. During normal ripening, the total soluble solid tend to increase through the stages of maturity. Syamal (1991) indicated that the slow increase might be due to use of waxes which affect the activity of mitochondria and some enzymes. However the gradual decline of TSS from day 10 to day 20 for both varieties may be due to more utilization of sugars than conversion of complex carbohydrates into simple sugars by the fruit to fulfill energy demand. From the experiment it was observed that power variety retained significantly higher levels of TSS than the Pectomech variety. The test that measures all the acids present in a given fruit is referred to as total titratable acidity (TTA). The study showed that there was a significant ($p<0.05$) decrease in TTA from day 0 to day 20 for both varieties and the control fruits had lower levels of total titratable acids compared to the treated fruits According to Hu et al., (2011), wax treatment reduced titratable acidity of pineapple kept under cold storage conditions by approximately 6% and 5% compared with the control at 21 days of storage. Similar works by Jiang and Li (2001) showed that wax coating on longan fruit decreased titratable acidity during storage. Shahid et al. (2011) also reported that bee wax coatings of sweet orange decreased TTA during the storage period. In general, fruit acidity tends to decrease with maturation and a concomitant increase in sugar content (Raffo et al., 2002). pH of fruits and vegetables is the measure of the strength of the acids in them. Results from the experiments showed that there was a significant ($p<0.05$) increase in pH from day 0 to day 20. Padmini (2006) reported that the pH of the fruit increases throughout development. The increase in pH is in agreement with Oyeleke and Odedeji (2011) who discovered that pawpaw fruits treated with palm kernel oil retained a higher pH than bee waxing treatment and chemical waxing treatment. Similar works done by Shahid et al., (2011), revealed that increase in pH in wax treated fruits might be due to high rate of metabolic activities, hence acidity decreased but pH increased and result in high TSS contents. The change in pH during storage period might be due to a number of reasons. First, the alteration of biochemical condition of fruit due to wax treatments and secondly due to lower rate of respiration and metabolic activity. The study showed that there was significant ($p<0.05$) increase in external colour as the days of storage progressed from day 0 to day 20. The colour development was similar for both varieties. The waxing or edible coating delayed to a larger extent, the ripening process of tomato fruits during the storage period. These results are consistent with the findings of Zapata et al., (2008), who reported that one alternative to modify the ripening process is the use of edible coatings. The delay of red colour formation of coated tomatoes is related to the modification of the internal atmosphere of the fruit, which produces high CO2 and low O2 levels that affect the maturation process. Mejia-Torres et al., (2009), observed that Waxed fruits showed a delay in colour development and ripening and attributed it to a delay in chlorophyll degradation and lycopene synthesis. Storage life refers to the period between when fruits are harvested and the time the fruits become unfit for sale or consumption. The study revealed that the control for Pectomech and Power variety lasted for 12 days and 10 days, respectively. However, waxed tomato fruits irrespective of the waxing materials stored for more than 20 days. The shorter storage life of the control fruit may be due to the higher respiration rate than unwaxed fruits. On the other hand, the longer storage life of the treated fruit could mean that the waxing material slowed down the rate of respiration and did not encourage the rapid exchange of carbon dioxide and oxygen. This result is similar to the findings of Gonzalez-Aguilar et al., (2010a), who reported that the use of a mineral oil treatment preserved the quality of tomato fruit to the greatest extent and concluded that mineral oil wax could be a good alternative for preserving the quality and extending the shelf life of fresh tomato fruit. Shahid et al., (2011) reported that bee wax coating was very effective in improving the overall quality and extending the shelf life of sweet orange fruits at room temperature. Nurul (2012), also reported that cassava starch coating on fresh- cut pineapple delayed the change in colour, maintain quality of the pineapples and prolong the storage life.

5. Conclusion

The study showed that edible wax coatings were very effective in preserving the overall quality of the tomato fruits. All waxing treatments delayed the development of weight loss, firmness, pH, total soluble solids, and total titrable acidity of fruits. The results also suggest that the edible wax coatings delayed the ripening process and colour development of tomato fruits during the storage period and extended the shelf life. BW treatment and it combinations performed better than the other treatments. Thus, locally produced wax such as BW, SB, CS treatments and it combinations could be a good technology for preserving the quality and extending the shelf life of fresh tomato fruits as well as maintaining the physical and chemical properties. It is recommended that similar experiments should be carried out with the same locally produced wax under farmers' condition to verify the findings.

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