ASSESSMENT OF LOCALLY PRODUCED WAXING MATERIALS ON THE SHELF LIFE AND QUALITY OF TOMATO FRUITS (*SOLANUM LYCOPERSICUM*)

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ABSTRACT: *The work was done to assess the effectiveness of locally produced waxing materials on the quality of tomato fruits. The experiment was performed in the Chemistry Laboratory of the Department of Food and Postharvest Technology, in the Koforidua Technical University. Materials that were used for the experiment is the Power Rano variety of tomato and four (4) waxing materials (shea butter, cassava starch, beeswax, and a combination of the three (shea butter + cassava starch + beeswax) and a control. Data on randomly selected fruits in each treatment per replication was recorded at four different days: 7, 14, 21 and 28 days of storage during the experiment. The following quality indices were measured: Weight loss (%), Total soluble solids (TSS), Total titrable acidity (TTA), and Shelf life of fruit. The data collected on the laboratory experiments and sensory evaluation were subjected to analysis of variance (ANOVA) using Statistical Package for the Social Sciences (SPSS) and the means were separated using Duncan multiple range of test at 5%. Results from the work indicated that, treating tomato fruit with wax was effective in preserving the fruit. All waxing treatments delayed the development of weight loss, firmness, pH, total soluble solids, and total titrable acidity of fruits. It was concluded that edible wax coatings delayed the ripening process and colour development of tomato fruits during the storage period and extended the shelf life. However, it is recommended that there should be sensitization on the use of locally produced wax to extend the shelf life of tomato for consumers and further work should be done on the economics analysis of waxing tomatoes*.

KEYWORDS: tomato, waxing, weight loss, total soluble solids, total titrable acidity, shelf life

INTRODUCTION

Tomato (*Solanum l*

ycopersicum.) is a key horticultural crop with a projected global production of above 129 million metric tons (FAO, 2008). Tomato is a vegetable of high economic importance in many countries as it is a somewhat short duration vegetable and gives a high outcome (Obeng-Ofori, *et al.*, 2007). It is economically attractive and the area under cultivation is growing daily in Ghana. Tomato is the most significant 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 justly

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important cash crop in the peripheries of urban areas in the forest zone (Obeng-Ofori, *et al.*, 2007).

Tomato of the nightshade family is consumed in different ways, including raw, as an ingredient in many dishes and sauces and in drinks. The tomato fruit, categorised as a vegetable in trade, is a prominent "protective food" (Alam *et al.*, 2007). Tomatoes and tomato-based foods provide an expedient matrix by which nutrients and other health-related food constituents are supplied to the body. Tomato forms a very important component of food consumed in Ghana and this is obvious in the fact that many Ghanaian dishes have tomatoes as a component ingredient (Tambo and Gbemu, 2010). Tomato is a rich source of vitamin B and phytonutrients, the most abundant in tomatoes are the carotenoids, lycopene being the most prominent, followed by beta-carotene and gamma-carotene, as well as several minor carotenoids (Beecher, 1998). In spite of the modest levels of beta-carotene and gamma-carotene in tomato products, due to their provitamin activity, a high consumption of the vegetable and its products result in a rich supply of vitamin A in the body. Lycopene, an antioxidant, purportedly fights the free radicals that can interfere with normal cell growth and activity. These free radicals according to Filippone (2006), can potentially lead to cancer, heart disease and premature aging.

Tomato fruits still live and respire after harvesting, however their quality and appearance change during handling. Shelf life is defined as the period in which a product should maintain a predetermined level of quality under specified storage conditions (Ball, 1997). Post-harvest weight change in vegetables is usually due to loss of water through transpiration. This loss of water can lead to wilting and shrivelling, which both reduce market value and consumer acceptability (Ball, 1997). A number of chemical and physical processes take place in vegetables during storage. The quality of most fruits and vegetables is affected by water loss during storage, which depends on the temperature and relative humidity conditions of storage (Perez et al., 2003). Consumers judge the quality of fresh tomatoes by their firmness, colour and taste, which are related to ripeness and shelf life. Major losses in the quality and quantity of fresh vegetable and fruit products occur between harvest and consumption (Brooks *et al*., 2008).These are critically dependent upon three factors: desiccation, physiological process of maturation and senescence and the onset and rate of microbial growth. The effect of storage temperature on physiochemical quality and quantity changes in tomatoes varies with cultivars. 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*., 2010).

The unavailability of preservation techniques in the tomato production areas contributes to the large amounts of tomatoes lost after harvest. These scenarios are most obviously diminishing the income of tomato farmers at the same time when foreign producers are indirectly financed by the government of Ghana and entrepreneurs through the importation of tomato and tomato products from the foreign market.

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Considering that Ghana experiences annual gluts during the major seasons when high percentage of the harvested produce is lost, there is the need to identify causes of such losses and develop better storage techniques to reduce them to improve food security in the country. Therefore, the application of different waxing materials to extend postharvest life of tomato fruit is needed to delay or reduce post-harvest losses. Mineral oil coating could be a good alternative to preserve the quality and extend the postharvest life of tomato fruit (Gonzalez-Aguilar *et al*., 2010).

To combat postharvest loss, there is a need to develop simple, cost effective and easily adaptable preservation techniques to prolong the shelf life of tomatoes. This study therefore seeks to identify the various waxing materials and their effect on tomato fruit shelf life and quality indices.

MATERIALS AND METHODS

Materials used and Source of Materials

The materials that were used for the experiment is the Power Rano variety of tomato and four (4) waxing materials (shea butter, cassava starch, beeswax, and a combination of the three (shea butter + cassava starch + beeswax) and a control. All the materials were obtained from the market retailers in the Koforidua Central Market.

Experimental Design

A 1 x 5 factorial experiment layout in complete randomized design with five (5) treatment combination and 3 replications each was adopted. The tomato variety was obtained from the market retailers in the Koforidua Central Market. The fruits were obtained at the physiological stage of maturity and transported to the laboratory. 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 five (5) lots each containing 15 fruits. Each treatment was replicated three times.

Table 1: Description of Materials

	TREATMENTS	*RATIOS*
T_0	Control	0:0:0
T_1	Shea butter	1:0:0
T_2	Cassava starch	1:0:0
T_3	Beeswax	1:0:0
T_4	Shea butter + Cassava starch + Beeswax	1:1:1

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Wax Application Method

The tomato fruits were briefly dipped or submerged completely in a bath of melted wax of beeswax and shea butter at a temperature of 45^{o}C. The tomato fruits were ready for packing within few minutes after dipping. The cassava starch slurry was prepared by mixing 400g of cassava starch with 1.5 litres of water. This solution was heated up to 50^{o}C while continuously stirring until the starch was gelatinized. The cooked starch was allowed to cool and the fruits were dipped in it completely for some few seconds to ensure that the fruits were completely covered with the starch. The coated fruits were allowed to air dry after the wax application. All lots of fruits were packed according to the experimental layout and stored at room temperature in the laboratory. The concentrations of wax used a ratio of 1:1:1 for the treatment combination.

Data Collection

Data on randomly selected fruits in each treatment per replication was recorded at 7, 14, 21 and 28 days of storage during the experiment on the following quality indices: Weight loss (%), Total soluble solids, Total titrable acidity and Shelf life of fruits.

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:

$$Percentage\ weight\ loss = \frac{Weight\ of\ fresh\ fruits\ (g) - Weight\ after\ interval\ x\ 100}{Weight\ of\ fresh\ fruits\ (g)}$$

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 3 drops 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 in ^{o}Brix.

Total Titrable Acidity (TTA)

Three fruits from each treatment were homogenized in 100mls of distilled water with a mortar and pestle. The homogenized solution was filtered through a muslin cloth. Ten millilitres of the filtrate were transferred into a 125mls conical flask and 100mls of distilled water was added to the filtrate. Three drops of phenolphthalein indicator were 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 (AOAC, 1990).

$$\%\ TTA = \frac{Mls\ NaOH\ x\ Normality\ (NaOH)\ x\ 0.064\ \ x\ 100}{Volume\ of\ sample\ (ml)}$$

Where 0.064*= acid milliequivalent factor.

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Shelf Life of fruits

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

Sensory Analysis

Assessors were selected from the Department of Food and Postharvest Technology in the Koforidua Technical University and asked to assess the visual quality of tomatoes that had been treated with different waxing materials. Coded samples per treatment were assessed by each of the 10-member panel. A Seven-point Hedonic scale was used to score samples for skin colour, attractiveness, firmness, smell, and overall acceptability.

Data Analysis

The data collected on the laboratory experiments and sensory evaluation were subjected to Analysis of Variance (ANOVA) using Statistical Package for the Social Sciences (SPSS) and the means were separated using Duncan multiple range test at 5%. The data collected on consumer acceptability and perception with the questionnaire was analysed using SPSS.

RESULTS AND DISCUSSION

Table 2: Effect of Different Waxing Materials on the %WL of Tomato

	DAY 7	DAY 14	DAY 21	DAY 28	MEANS
CTRL	3.22	10.17	18.24	26.67	14.75a
SB	3.21	10.14	18.33	27.34	14.75a
CS	6.30	13.21	21.23	30.87	17.90c
BW	3.43	9.73	17.45	26.75	14.34b
SBCSBW	4.32	10.34	17.12	26.34	14.53b

CTRL= Control, SB= Shea butter, CS= Cassava starch, BW= Bee wax, SBCSBW= Shea butter + Cassava starch + Bee wax. All means sharing same letters (a, b) are statistically non-significant at 0.05 probability level.

Percentage Weight Loss (% WL)

The percentage weight loss of the tomato increased with the storage period and was higher for the cassava starch (CS) fruits than the other treated fruits and the control from day 7 to day 28 (Table 2). The maximum weight loss (17.90%) from day 7 to 28 was recorded for the cassava starch (CS)

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fruit and this figure was statistically different ($p<0.05$) from the weight loss of the other treatments and their combinations. The minimum weight loss (14.34%) was recorded with Beewax (BW) treatment. Beewax (BW) treatment was statistically different ($p<0.05$) from Shea Butter (SB) and Cassava Starch (CS) (Table 2), but was not significantly different from the combination of all the waxes (SBCSBW). Shea butter recorded a weight loss of 14.75%, control had weight loss of 14.75% and the combination (beeswax +shea butter +cassava starch) recorded a weight loss of 14.53%.

Weight loss can be attributed to the fact that a quantity of water is lost from fresh produce over a period of time. In the study the percentage weight loss of the tomato 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 in line 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). Similar works by Mahajan *et al.* (2011), also 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.

Table 3: Results of Different Waxing Materials on the Total Soluble Solids (TSS) of Tomato.

	DAY 7	DAY 14	DAY 21	DAY 28	MEANS
CTRL	5.13	5.65	4.44	4.73	4.99c
SB	4.77	3.76	4.65	5.22	4.60b
CS	5.13	4.12	8.54	4.78	5.64a
BW	5.23	3.76	7.88	5.86	5.68a
SBCSBW	4.32	6.65	8.45	7.56	6.75d

CTRL= Control, SB= Shea butter, CS= Cassava starch, BW= Bee wax, SBCSBW= Shea butter + Cassava starch + Bee wax. All means sharing same letters (a, b) are statistically non-significant at 0.05 probability level.

Total Soluble Solids (TSS) of Tomato

With regards to the total soluble solids, the results showed that, there was no consistency in the TSS from day 7 to day 28 (Table 3). The wax combination coated fruit had maximum TSS (6.75) which was statistically different ($p<0.05$) from fruits of the other treatments. Shea Butter (SB) treatment fruits had the lowest total soluble solids TSS (4.60) which was statistically

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different ($p<0.05$) from those of Bee wax (BW) (5.68) and Cassava Starch (CS) (5.64) treatments.

The total soluble solids are the amount of sugar and soluble minerals present in fruits and vegetables. From the study, it was seen that there were inconsistencies (increase and decrease) in the TSS from day 7 to day 28. This may be due to some chemical reactions and changes over the storage period and also changes in the starch concentration during the post-harvest period (Kays, 1997). 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.

Table 4: Outcome of Different Waxing Material on the Total Titrable Acidity (TTA) of Tomato

	DAY 7	DAY 14	DAY 21	DAY 28	MEANS
CTRL	0.56	0.45	0.40	0.38	0.45a
SB	0.61	0.56	0.46	0.33	0.49b
CS	0.53	0.49	0.42	0.31	0.44a
BW	0.64	0.55	0.49	0.40	0.52b
SBCSBW	0.59	0.50	0.39	0.30	0.45a

CTRL= Control, SB= Shea butter, CS= Cassava starch, BW= Bee wax, SBCSBW= Shea butter + Cassava starch + Bee wax. All means sharing same letters (a, b) are statistically non-significant at 0.05 probability level.

Total Titrable Acidity (TTA) of Tomato.

The study showed that there was a significant ($p<0.05$) decrease in Total Titrable Acidity (TTA) from day 7 to 28 as well as a significant difference in waxing effect and their interactions.

Bee wax (BW) treatment recorded the highest TTA (0.52). The CS fruits recorded the lowest TTA (0.44). However, Bee wax (BW) treatment was not significantly different ($p>0.05$) from Shea Butter (SB). Cassava Starch (CS) was also not significantly different from control (CTRL) and the combination of all the waxes (SBCSBW).

Total Titrable Acidity (TTA) is the test that measures all the acid present in a fruit or vegetable. The study showed that there was a significant decrease in TTA from day 7 to day 28 for both the control and the waxed fruit. CS fruits had lower levels of total titrable acids compared to

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the other treated fruits and the control. According to Hu *et al.*, (2011), wax treatment reduced titrable acidity of pineapple kept under cold storage conditions by approximately 6% and 5 % compared with the control at 21 days of storage. Lim-Buying *et al.*, (1998) also observed that Prowax F coating on apples during room storage decrease titrable acidity faster in control fruits than in wax coated fruits. The decrease in acidity was due to the accumulation of CO_2 internally in the fruits tissue which causes acidosis after dissolving and forming carbonic acid (Carrillo *et al.*, 1995). Disappearance of malic and citric acid during ripening process may be the main factor responsible for the reduction in titrable acidity during the storage. Similar works by Jiang and Li (2001) showed that wax coating on longan fruit decreased titrable 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).

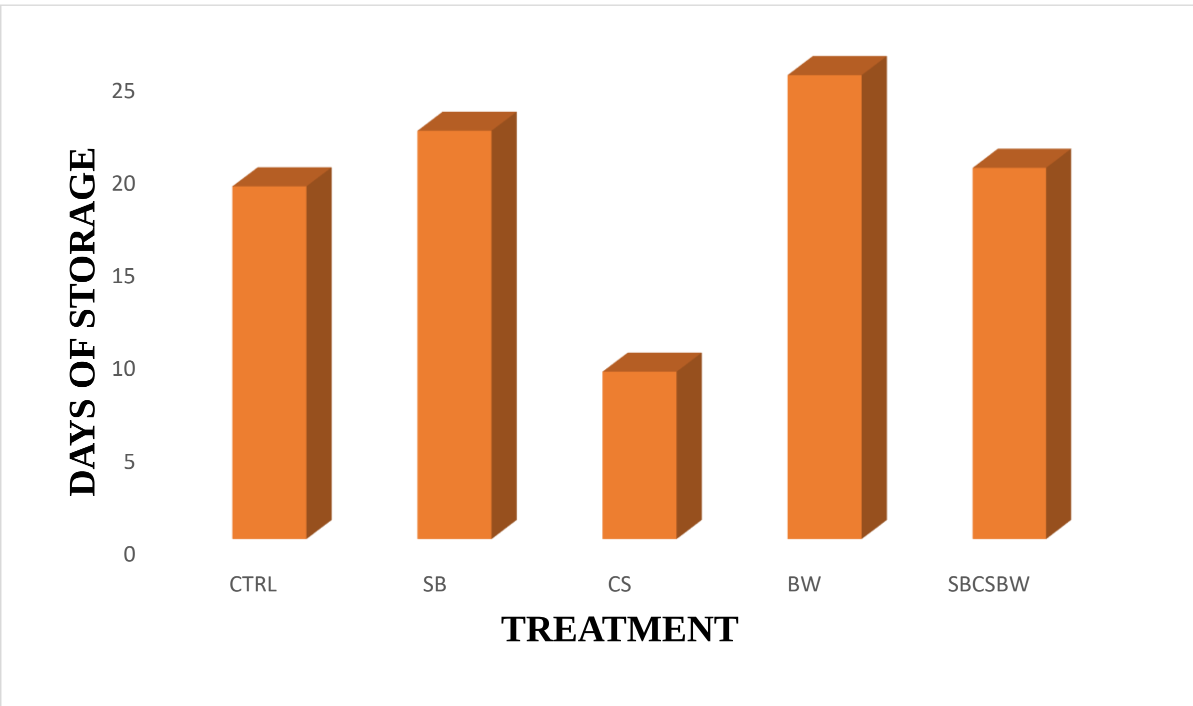

Figure 1: Graph of shelf life of different waxed tomato fruit

Shelf Life of fruits

The storage life of the tomato following the different waxing treatment is shown in Figure 1 above. The study revealed that the control treatment had a storage life of 19 days, SB treated tomato had a storage life of 22 days, CS waxed tomato had a storage life of 9 days, BW waxed tomato had a storage life of 25 and wax combination tomato had a storage life of 20 days. It was also seen that BW treatment had the longest shelf life of 25 days while the control had the shortest storage life of 9 days.

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Storage life refers to the period between which fruits are harvested and the time the fruits become unfit for sale or consumption. The study revealed that the CS fruit lasted for 9 days. However, other waxed tomato fruits irrespective of the waxing materials stored for 19 or more days. The shorter storage life of the CS fruit may be due to heat absorption by the starch molecules. The heat caused higher temperature around the fruit. On the other hand, the longer storage life of the other 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. Sugri *et al.* (2010) also noted that shea butter as a food-grade wax on plantain varieties prolong the shelf life and maintain their sensory qualities.

Table 5: Reaction on Different Waxing Material on the Sensory Attributes of Tomato

WAX	ATTRACTIVENESS	FIRMNESS	SKIN COLOUR	SMELL	OVERALL ACCEPTABILITY
BW	3.41a	4.20a	4.00a	3.93a	3.63a
SB	2.76b	3.19b	3.00b	3.40b	3.00b
SBCSBW	2.38c	3.86c	2.80c	3.66c	3.30c
CS	2.04d	1.70e	2.60d	2.13d	1.97d
CTRL	2.26e	2.77d	2.77e	3.17e	2.80e

CTRL= Control, SB= Shea butter, CS= Cassava starch, BW= Bee wax, SBCSBW= Shea butter + Cassava starch + Bee wax. All means sharing same letters (a, b) are statistically non-significant at 0.05 probability level.

Sensory Attributes of Tomato

The study revealed that there were significant effects of waxing interaction on all the sensory attributes of tomato fruits (Table 5). The BW treatment had a significantly higher effect on all the sensory attributes of the tomato fruits, whilst the CS fruits had the lowest effect on all the sensory attributes. In terms of attractiveness, BW treatment was preferred by majority of the panelist to the other treatments. Similarly, there were no difference in effect on smell between treatments except control which was preferred to the CS fruits. The effect of waxing on firmness was significantly higher in BW treatment than other treatments. Effect on overall acceptability showed that there were differences between fruits coated with CS and the control but there were no differences between the remaining treatments (Table 5).

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Results from sensory evaluation showed that waxed fruits (except CS) had better sensory attributes than the control fruits. The panellist preferred treated fruits than the untreated fruits considering all the sensory attributes. As far as the panellists were concerned, wax treatment did not affect skin colour except for CS treatment. Fruit coated with BW treatment and its combinations (cs+bw+sb) were the most accepted over the other treatment.

CONCLUSION

Fruit quality covers a number of different characteristics among which more attention has been paid to fruit grade. Results from the work indicated that, treating tomato fruit with wax was effective in preserving the fruit. All waxing treatments delayed the development of weight loss, firmness, pH, total soluble solids, and total titrable acidity of fruits except for the tomato coated with cassava starch. 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. Beewax treatment was more effective compared with other treatments. The study also indicated that, locally produced wax such as Beewax, Shea butter, cassava starch, treatments 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.

With regards to the sensory properties of the waxed fruit, it can be concluded from the study that consumers would be willing to buy and use waxed tomatoes because waxing had no bad effect on the quality of tomato. It can be concluded from the study that consumers would be willing to buy and use waxed tomatoes. Additionally, the locally produced waxes such Beewax, Shea butter, Cassava starch and their combinations improved some organoleptic properties such as attractiveness, firmness, smell and overall acceptability of waxed fruits.

Generally, for stored tomatoes, consumers preferred waxed fruits to unwaxed fruits. Farmers and traders should be encouraged to use locally available wax materials to coat their produce in order to maintain the quality. It is recommended that there should be sensitization on the use locally produced wax to extent the shelf life of tomato for consumers and locally produced wax such as bee wax could be a good technology for preserving the quality and extending the shelf life of fresh tomatoes as well as maintaining the physical and chemical properties.

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