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Improving shelf life of nectarine fruit (*Prunus persica*) by beeswax coating and cold storage application

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This study was carried out to determine the effect of beeswax coating and cold storage condition on the shelf life of nectarine fruit. A total of 240 nectarine fruits were collected and divided into six treatments, each with 40 fruits. The treatments consisted of coated fruits stored at 6°C (T1), coated fruits stored at 1°C (T2), coated fruits stored at ambient temperature (T3), uncoated fruits stored at 6°C (T4), uncoated fruits stored at 1°C (T5) and uncoated fruits stored at ambient temperature (T6). Physico-chemical data and sensory attributes were taken at five days interval. The results showed that there was a significant difference between treatments ($p \leq 0.05$) for both physico-chemical properties and sensory attributes during the storage time (50 days). The result showed that the highest percentage of titratable acidity (1.45± 0.06) and total soluble solids (15.32±0.91°Brix) as well as highest mean scores of sensory parameters such as flavor (4.23±0.06), sourness (4.12±0.07), appearance (4.49±0.05), taste (4.27±0.06), texture (4.19±0.07) and overall acceptability (4.25±0.05) were recorded for coated nectarine fruits stored at 6°C followed by coating and storage at 1°C. On the other hand, the highest weight loss percentage (25.27±3.67) and pH value (4.29±0.16) and the lowest mean scores values for sensory evaluation were recorded for uncoated fruits stored at ambient temperature (22°C). The shelf life of beeswax coated fruit stored at cold storage was extended by 50 days following the deterioration of uncoated fruit stored at ambient temperature after three days. Therefore, nectarine fruits coated with beeswax and stored at temperatures of 1 and 6°C had prolonged shelf life without affecting its nutritional quality.

Key words: Attributes, bee, coating, nectarine, physico-chemical, properties, sensory, wax.

INTRODUCTION

Despite the remarkable progress made in increased food production at the global level approximately half of the population in the third world does not have access to adequate food supplies. There are many reasons for this, one of which is food losses occurring in the postharvest and marketing system. Postharvest losses of fruits and vegetables are estimated to be 5-20% in developed countries and 20-50% in developing countries (Mashav, 2010). On farm losses occur during storage, when the crop is being stored for auto-consumption or while the farmer awaits a selling opportunity or arise in prices (Shepherd, 2012).

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Agriculture is the mainstay of Ethiopian economy and it provides all the necessary dietary foods, raw materials for food industries and quality products for export market. From a total of 39.7 million tonnes of total crops produced in Ethiopia, 23.1 million tonnes are not highly perishable whereas 6.6 million tonnes are highly perishable (CSA, 2012).

Horticultural crops, such as fruits are perishable products and, therefore, sensitive to greater losses than do non-perishable crops (Parfitt et al., 2010). Their post-harvest life depends on the rate at which they use up their stored food reserves and their rate of water loss. When food and water reserves are exhausted, the produce dies and decays. Perishable commodities need careful handling during harvesting and post-harvest handling; this would make deterioration of produces minimized as much as possible during the period between harvest and consumption. For instance scientists reported total post-harvest loss of banana as 26.5% where 56% of the loss occurred at the retail level due to rot before reaching consumers in Ethiopia. Furthermore, climate and weather conditions, harvesting and handling techniques, packaging, storage and transportation facility, market situation, disease and pest were major causes of post-harvest loss in Dirre Dewa where postharvest loss ranging from 20 to 50% was recorded between marketing and consumption (Mohammed and Afework, 2016).

Even though the horticultural sector in Ethiopia is growing there is low and insufficient support for the improvement and reduction of post-harvest loss; quality deterioration of horticultural crops was reported. An estimate of 15 to 70% of post-harvest losses of horticultural crops in Ethiopia was reported. Thus, such losses during harvest are a major source of food loss and could be seen from food security and poverty reduction aspects in the country because losses have direct effect on people’s livelihood and the economy of the country as whole (Misrak et al., 2014).

To increase food availability, it is therefore not enough to increase productivity of agricultural commodities but there is also a need to lower the losses. According to Boxall (1998), farmers growing horticultural crops, especially fruits are facing high economic losses, due to lack of methods to increase the shelf life of those crops. Peaches are extremely perishable fruits and do not lend themselves to prolonged storage; if held too long at or near 0°C they are subjected to chilling injury. The onset of these symptoms determines the postharvest storage potential, because chilling injury development reduces consumers’ acceptance (Crisosto et al., 1997).

Application of surface coating on fruits is considered as one the several treatments developed to reduce postharvest losses and to prolong the shelf life of fruits and vegetables (Baldwin et al., 1995). Preserving fresh fruits after harvest and maintaining their quality for longer periods until processing, marketing or consumption is one of the major problems in the value chains of most fruits including peach or nectarine. This situation necessitates the use of proper preservation and optimum storage conditions. Hence, the aim of the study was, therefore to evaluate the potential of beeswax coating and storage temperature to extend the shelf life of nectarine fruits as determined by their physico-chemical properties and sensory attributes.

MATERIALS AND METHODS

Experimental materials:

A total of 240 nectarine fruits were collected from Holetta Agricultural Research Centre located at Holetta, Ethiopia. The fruits were carefully selected, based on uniformity at the commercial maturity stage, colour, shape and those free of physical damage and infection by biotic factors used for the experiment. Harvested fruits were transported to the laboratory and washed in tap cold water to lower the temperature and, after a while, washed again with warm water (45-50°C) to minimize surface load of microorganisms. Then, fruit samples were surface dried by muslin cloth and randomly assigned to six groups. Purified beeswax and DANA edible oil were collected from the Holetta Beekeeping Research Centre, Holetta, Ethiopia and the local super market, respectively. The wax emulsion was prepared, according to Hassan et al. (2014) with little modification, using 120 g of wax dissolved in 200 ml of pure water and heated to 80-90°C. The solution was mixed gently until all the wax was dissolved in hot water. Then, 100 ml of the edible oil was added to the molten wax and, finally, hot water (50-55°C) was added to the solution until it reached 1000 ml.

Treatments

The fruits were randomly divided into six groups of 40 fruits each and treated in the following way: coated fruits stored at 6°C, coated fruits stored at 1°C, coated fruits stored at ambient temperature, uncoated fruits stored at 6°C, uncoated fruits stored at 1°C and uncoated fruits stored at ambient temperature. Fruit coating was performed by the dipping method to cover whole surface of fruits and then by air drying. Physico-chemical properties were measured at 5 days interval for 50 days. However, fruit sensory attributes of the samples were determined based on the shelf-life of each treatment during the storage periods.

Physico-chemical properties

Percentage of weight loss

All sample fruits were weighed on the first day to determine their initial weights. Then, fruits were weighed in triplicates at five 5 days interval and percentweight loss was calculated by using the following formula (Wang et al., 2005).

Total soluble solid (°Brix)

The concentration of total soluble solid was determined by direct reading from sample juice dropped on a refractometer sample platform. A small quantity of fruit juice (3-5 drops) was placed onto a fixed prism surface of the refractometer at 20°C and the result was expressed as o Brix (AOAC, 2006).

Table 1. Effect of beeswax coating and storage temperature on physico-chemical properties of nectarine fruits.

Treatments	pH	TA (%)	TSS (%)	Weight Loss (%)
Coated fruits stored at 6°C	3.42±0.06[c]	1.45± 0.06[a]	15.32±0.91[a]	8.20±1.48[c]
Coated fruit stored at 1°C	3.62± 0.07[bc]	1.37± 0.05[ab]	15.23±0.83[a]	7.97±1.15[c]
Coated fruit stored at 22ºC	3.91±0.17[abc]	1.19±0.11[abc]	13.82±0.91[ab]	14.06±3.04[bc]
Uncoated fruit stored at 6°C	3.99±0.13[ab]	1.03± 0.11[bc]	10.73±0.95[bc]	20.39±3.19[ab]
Uncoated fruit stored at 1°C	4.01±0.15[ab]	1.01±0.09[bc]	10.46±1.15[bc]	19.78±3.00[ab]
Uncoated fruit stored (control) at 22ºC	4.29±0.16[a]	0.93±0.11[c]	9.36±1.20[c]	25.27±3.67[a]

Values are Means ± Standard Error. Valuesfollowed by different letters within a column are significantly different (p≤ 0.05) using Least Significance Difference (LSD).

Titratable acidity and pH

Titratable acidity was measured according to standard procedures (AOAC, 2000). Ten grams of ground nectarine fruit samples were taken from each treatment. Then, the samples were diluted with 250 ml warm water. Ten milliters of the supernatant was titrated with 0.1N NaOH until a pH value of 8.2 was reached. The titratable acidity was expressed asa percentage of citric acid/100 ml of juice. The pH value of the samples were measured using a glass electrode pH meter, which was calibrated by buffer solution at pH 7 and 4, according to the method described by AOAC (2005).

Sensory evaluation

Sensory properties (flavour, texture, appearance, taste, and overall acceptability) were evaluated by ten semi-trained panellists composed of 6 females and 4 males. Panellists were selected based on their previous experience in sensory evaluation.Samples were given to each panellist in a completely randomized order, served on white saucers and labelled with three digit random numbers. Panellists were served water and unsalted crackers to cleanse their palettes in between samples. Using the five point hedonic scale panellists were asked to rank or to score sensory attributes based on preference where; 1= for dislike very much, 2= for dislike moderately, 3= for neither like nor dislike, 4= for like moderately and 5= for like extremely. An average score above 3.5 was considered a limit of acceptability for all sensory attributes.

Statistical analysis

Statistical analysis of the physico-chemical and sensory data was performed by SPSS software version 20 (SPSS, Inc., Chicago, IL, USA). Analysis of variance was performed using two-way ANOVA at 95% confidence interval and 5% level of significance. For comparison of treatments, sensory data were subjected to analysis by Kruskal Wallis test and value of P ≤0.05 was considered statistically significant.

RESULTS AND DISCUSSION

Fruit weight loss

Table 1 shows the change in weight of coated and uncoated nectarine fruits, which were stored at different temperatures. The results indicated that weight loss increased steadily with prolonged storage. There was a significant (p ≤0.05) difference between the treatments. The highest percentage of weight loss recorded for uncoated fruits stored at 22°C (control), while, the lowest percent weight loss was recorded for coated nectarine fruits at 1°C (Table 1). These results were similar with the findings of Joyce et al. (1995), who reported that waxing extended storage life of avocado through the reduction of moisture loss and modification of internal storage, as well as to observations reported by Shein et al. (2008) who concluded that the use of 18% teva wax coating in combination with cold storage can reduce the percentage of weight loss of ‘Sai Nam Peung’ mandarin orange (*Citrus reticulata* Blanco) up to 30%, and to Patel and Goswami (1984), who reported that storage life of mango fruits was extended by wax coating and co1d storage.The nectarine fruits which were coated and stored at 1 and 6°C had lower weight loss percentage than those fruits coated and stored at ambient temperature. This indicates that, in addition to waxing, especially storage temperatures of the coated fruits determine the shelf life of nectarine fruits. Hence, waxing and storage at ambient temperature might not be act as moisture loss protective as compared to waxing and cold storage. This might be, the ambient temperature affects moisture content of the wax and the wax may not help moisture loss barrier from surface of the nectarines fruit.

Titratable acidity

There was statistically significant difference (p≤ 0.05) amongst the treatments for titratable acidity. The highest mean value of titratable acidity (1.452%) was recorded for coated fruits maintained at 6ºC during the storage periods, while uncoated fruits stored at ambient temperature (22°C). Relatively higher values of titratable acidity were observed for coated fruits as compared to those uncoated and stored at higher temperatures. This could probably be due to the effect of waxing and lower storage temperatures (6 and 1°C) to slow down the change in fruit acidity and fruit starch hydrolyzed to simple sugars during metabolic activities. The decrease in acid content of fruits stored at high temperature could also be caused by the use of acids in the fruit as a source of energy and conversion of organic acids to form sugars (Burton, 1985; Wills et al., 1998).

Table 2. Mean score values of sensory attributes as affected by beeswax coating and storage temperature of nectarine fruits.

Treatments	Flavour	Sourness	Appearance	Taste	Texture	Overall acceptability
Coated fruits stored at 6°C	4.23±0.06[a]	4.12±0.07[a]	4.49±0.05[a]	4.27±0.06[a]	4.19±0.07[a]	4.25±0.05[a]
Coated fruit stored at 1°C	4.16±0.04[a]	4.01±0.06[a]	4.31±0.06[a]	4.15±0.05[a]	4.22±0.07[a]	4.19±0.04[a]
Coated fruit stored at 22ºC	2.67±0.18[b]	2.62±0.17[b]	2.61±0.18[b]	2.61±0.18[b]	2.48±0.17[b]	2.59±0.17[b]
Uncoated fruit stored at 6°C	1.43±0.20[c]	1.46±0.20[c]	1.47±0.20[c]	1.45±0.20[c]	1.47±0.20[c]	1.45±0.20[c]
Uncoated fruit stored at 1°C	1.42±0.20[c]	1.45±0.20[cd]	1.46±0.20[cd]	1.45±0.20[c]	1.47±0.20[c]	1.45±0.20[c]
Uncoated fruit stored (control) at 22°C	0.77±0.16[d]	0.82±0.16[d]	0.82±0.16[d]	0.81±0.16[d]	0.81±0.17[d]	0.81±0.16[d]

Values are Means ± Standard error. Values

Fruit juice pH

Table 1 shows that there was a significant difference ($p \leq 0.05$) amongst the treatments for pH of fruit juice. The highest mean pH value (4.29) was observed for uncoated fruits stored at ambient temperature (control), while the lowest value (3.42) was recorded for coated fruits stored at 6°C (Table 1). The result indicated that coated fruits stored at low temperatures had lower mean pH values than the uncoated fruits stored at higher temperatures. This might be due to combined effect of waxing and cold storage slowing down oxidation of acids found in nectarine fruits. The result of the present study was in agreement with the work of Diaz et al. (1996) who reported increases in pH of the control samples compared to pH of the mangoes coated with malto dextrin and methyl cellulose. The result of the present study is also in line with previous findings by Medlicott et al. (1987), who observed that the rate of increase in pH of control samples was higher than in coated mango fruits stored at 25°C

Total soluble solids (TSS)

The result presented in Table 1 shows the difference in TSS of the coated and uncoated nectarine fruits which was significant ($p \leq 0.05$) during storage period. The result indicated that the highest mean (15.32°Brix) TSS was observed for coated fruits stored at 6°C while the lowest value (0.93°Brix) was for the control treatments. The reduction in TSS in uncoated fruits stored at higher temperature could be faster gas exchange metabolic rates (Mahajan et al., 2006). The mean TSS content for coated fruit stored at 6 and 1°C, at ambient temperature, and uncoated fruit stored at 6 and 1°C and at ambient temperature (control) at the end of the storage period were 15.32, 15.23, 13.82, 10.73, 10.46 and 0.93°Brix, respectively (Table 1). The increase in mean TSS with prolonged storage time could be probably due to the effect of waxing and cold storage, as waxing and cold storage condition slows down the rate of respiration and, thus percentage of TSS increased slowly with storage period. This result is in agreement with the findings of Patel et al. (2008), who reported that changes in TSS content are natural phenomena that correlate with hydrolytic changes in carbohydrates during storage.

Flavour and taste

It was observed that there were significant differences ($p \leq 0.05$) between the treatments for mean score value of flavour and taste (Table 2). The highest mean score (4.23) of flavour was observed for coated fruits stored at 6°C, while the lowest value (0.77) was for the control treatment fruits (uncoated) stored at ambient temperature throughout the storage time (Figure 1). The overall mean score for coated fruits stored at different temperatures was higher than the corresponding value for uncoated fruits. The same trend was observed for mean scores of taste with the highest value (4.27) for coated fruits stored at 6°C, and the lowest (0.81) for the control treatments (Figure 3). In line with this Karakurt et al. (2000) reported that none melting flesh peach cultivars which were evaluated as low flavoured had reduced soluble sugars and total soluble solids. Hence, results of the present study indicate that waxing and storing fruits under cold condition maintain sensory attributes without significant changes for longer period, as there were no significant differences ($p > 0.05$) in flavour and taste between coated fruits stored in cold storage during the experimental period. The mean score for flavour had similarity with the mean score of taste. This could be due to the fact that the same biochemical constituents contribute to both flavour and taste of the fruits.

In agreement with results of the present study, Rapaille et al. (2003) reported that sorbitol as one of alcohol sugars is more beneficial than other sugars with regard to diet control and dental health (reducing caloric intake) and it improves the fruit's taste and texture, as texture and physical properties of a fruit have, in turn, influence on fruit taste. Similarly, it has been reported that fruit quality can be properly preserved under cold conditions for long periods of time, resulting in only a small reduction in flavour quality (Abad et al., 2003).

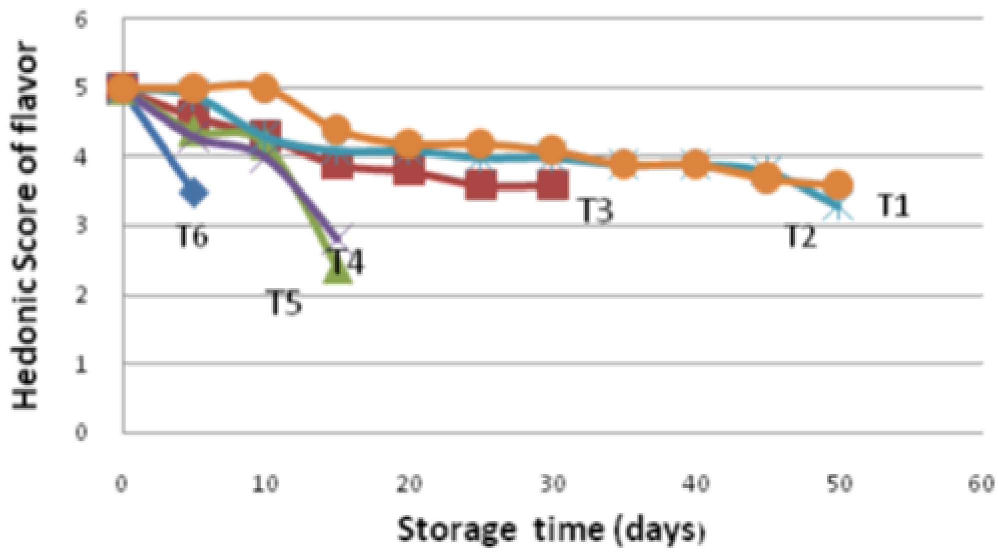

Figure 1. The effects of beeswax coating and storage temperature on the flavor nectarine fruits during storage period.

Sourness and texture

Highest mean score values of sourness (4.12) and texture (4.22) were observed for coated fruits stored at 6 and 1°C, respectively (Table 2), while the lowest mean score parameters were recorded for the control fruits (uncoated and stored at ambient temperature). The result indicated that coated fruits stored at 1 and 6°C exhibited the highest mean scores of sourness and texture as compared to other treatments. But, the mean score values of coated fruits stored at ambient temperature were higher than the overall mean values of uncoated fruits (Figures 4 and 5) stored at 22, 1 and 6°C. Hence, the result of the present study indicates that coating by beeswax and storing cold temperature (1 and 6°C) may help to maintain the sensory quality of nectarine fruits. The study also indicated that coating alone may not help much, as shelf life of coated nectarine fruits depends on storage temperature. In agreement with this, Patricia et al. (2005) reported that refrigerated strawberry coated with gluten based films had better firmness retention than the control. Similarly, apple coated with paraffin oil and jojoba was found to have higher mean scores for visual appearance, texture and overall acceptability; while the control apple sample had the lowest mean scores values for those parameters (EL-Anany et al., 2009).

Appearance and overall acceptability

Table 2 shows that there was statistically significant difference ($p \leq 0.05$) among the treatments for appearance and overall acceptability. The highest means score values of appearance and overall acceptability were observed for coated nectarine fruits stored at 6°C, while the lowest mean value was recorded for control treatments (uncoated) stored at ambient temperature (22ºC). The mean scores of appearance and overall acceptability for coated fruits stored at 6°C were 4.49 and 4.25, respectively (Table 2). Furthermore, overall acceptability values were consistently higher and maintained for longer period for coated fruits stored at 1 and 6°C than for the other treatments (Figure 6).

This result was in agreement with the findings of Hassan et al. (2014) who found that the highest score of sensory attributes (colour, texture, odor, freshness, appearance, fruit firmness, taste, and overall acceptability) was observed for 12% wax coated tangerine citrus var. Siam Banjar fruit stored at 5°C.

Shelf life determination (acceptability assessment)

Sensory attributes (flavour, taste, appearance, sourness and overall acceptability) were evaluated by ten semi-trained panellists at 5 days intervals during the storage period. Treatments which failed the acceptability assessment during the storage periods were discontinued from further sensory evaluation.

Results of the present study indicated that, there were significant variations between the treatments for all sensory attributes during the storage period. There was a sharp decrease in the mean value of flavour in T6 (uncoated fruits stored at ambient temperature) on the 5th day of storage when other treatments had acceptable

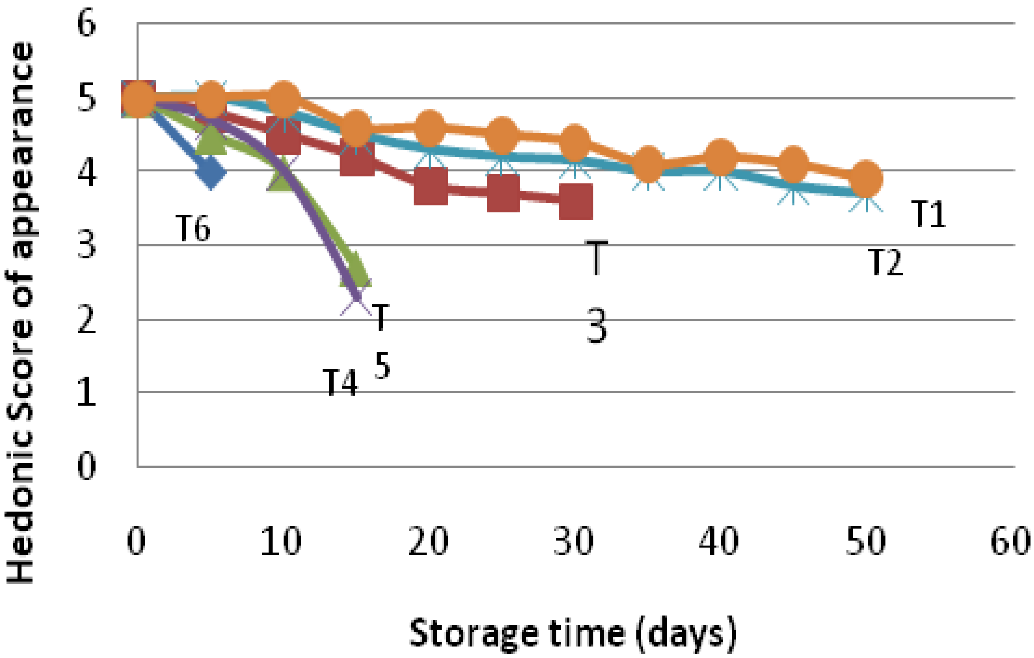

Figure 2. The effect of beeswax coating and storage temperatures on the appearance of the nectarine fruits during the storage period.

values (Figure 1). However, the mean flavour of the coated fruits stored both at 6 and 1°C was not much affected and gradually declined during the storage period. This indicates low temperature and coating can maintain flavour and slow down the rate of biochemical reaction of fruit.

Hence, this shows that storing nectarine fruits at ambient temperature (22°C) had a detrimental effect on flavour through its effects on biochemical constituents of the fruits. In line with this, David et al. (2013) reported that though ethyl-based esters were most typical in sweet and aroma, their presence might lead to off-flavour if over-abundant in the fruit. Similarly, there was a sharp decline in the “appearance” of uncoated fruit stored at ambient temperature (22°C); the decrease observed in the coated fruits stored at 6 and 1°C was not significant ($p<0.05$) and gradual during the storage period (Figure 2). In general, flavour and appearance of fruits in all treatments decreased with prolonged storage though coating nectarine fruit with beeswax and storing in cold temperature (1 and 6°C) significantly retained the appearance and flavour as well as other sensory attributes of the fruits for longer periods. In agreements with this result David et al. (2013) reported that holding mandarins at warm temperatures such as 20°C could be very harmful to flavour quality. The combined effect of waxing and storage temperature on fruit internal atmosphere and citrus quality has also been shown in some previous works (Eaks and Ludi, 1960; Baldwin et al., 1995; Chun et al., 1998).

The score values of taste and texture also decreased with the time of storage (Figures 3 and 4) and showed the same trend of response to the treatments as did flavour and appearance values. Retention of taste and texture was by far better for coated nectarine fruits than for uncoated fruits and for cold (1 and 6°C) than for ambient temperature (22°C) during 50 days of storage. Similar results were also reported by Alam and Paul (2001) who studied the effects of cellulose-based coating (carboxyl methyl cellulose) on the shelf life of Kinnow fruits and found that carboxyl methyl cellulose coating (0.5%) extended shelf life up to 40 days without adversely affecting the quality but taste scores were lowered when storage life increased.

At the initial stages texture of the fruits was firm but eventually the fruit structure disintegrated. It was, probably because of physiological and biochemical changes. In line with this, it has been reported that, during ripening and maturation, protopectin (insoluble form of pectin substances) is gradually broken down to lower molecular weight fractions, which are more soluble in water and cause softening of fruits (Wills et al., 1981). Similar results have also been reported for sweet orange by Muhammad (2007) indicating that the scores values of taste decreased during fruit storage time from 0 to 56 days.

The hedonic score values of overall acceptability (Figure 6) and sourness (Figure 5) decreased with prolonged storage. However, mean score of overall acceptability and sourness decreased rapidly for

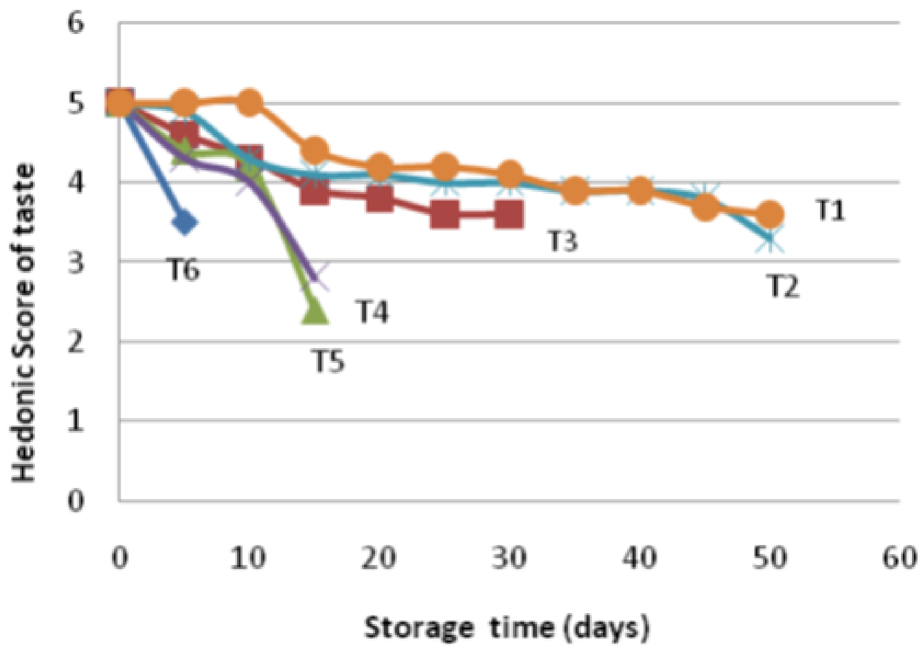

Figure 3. The effect of beeswax coating and storage temperatures on the taste of nectarine during storage period.

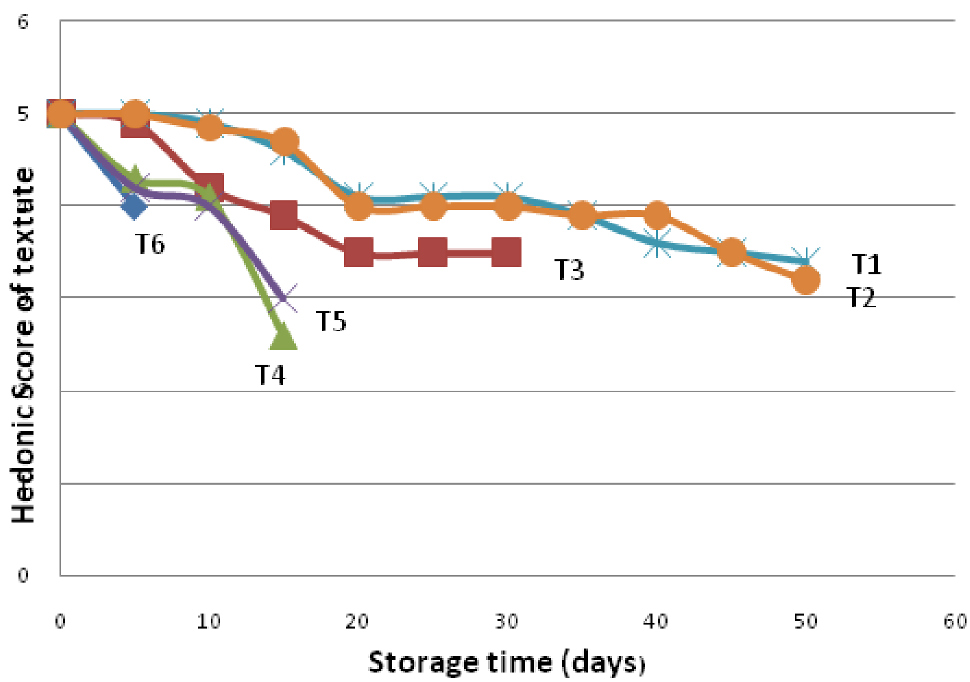

Figure 4. The effect of beeswax coating and storage temperatures on the texture of nectarine fruits during the storage period.

uncoated nectarine fruits while slowly decreasing exhibited values those fruits stored at 1 and 6°C temperatures. Hence, such a rapid decline in sourness and overall acceptability values may indicate shorter shelf life while slowly decreasing values show longer shelf life nectarine fruits. In line with this, it has been reported that

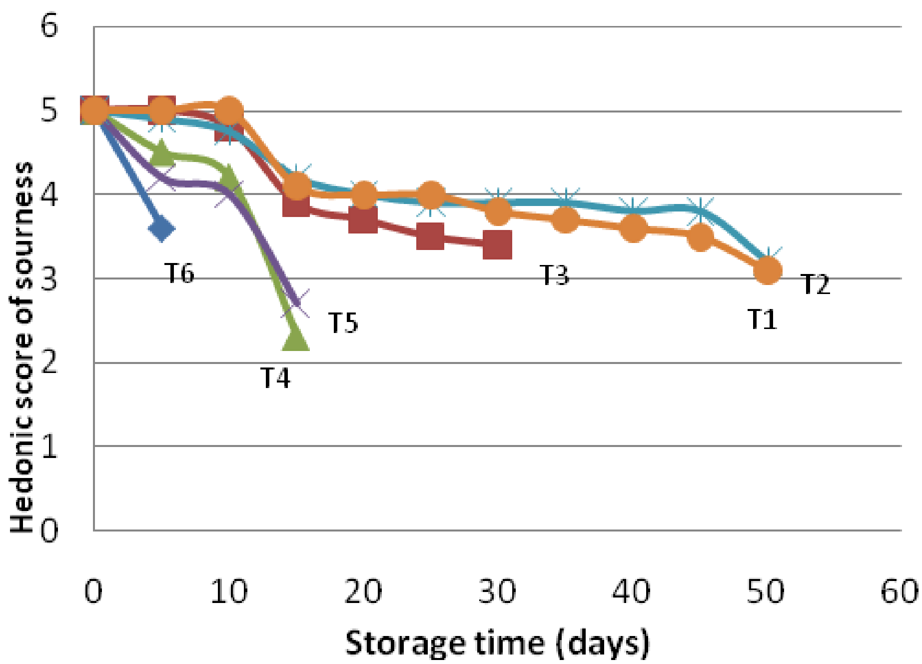

Figure 5. The effect of beeswax coating and storage temperatureson sourness of nectarine during storage period.
Note: T1=Coated fruits stored at 6°C, T2= Coated fruits at 1°C, T3=Coated fruits stored ambient temperature, T4=Uncoated fruits stored at 6°C T5=Uncoated fruits stored at 1°C and T6=Uncoated fruits stored at ambient temperature (22°C)

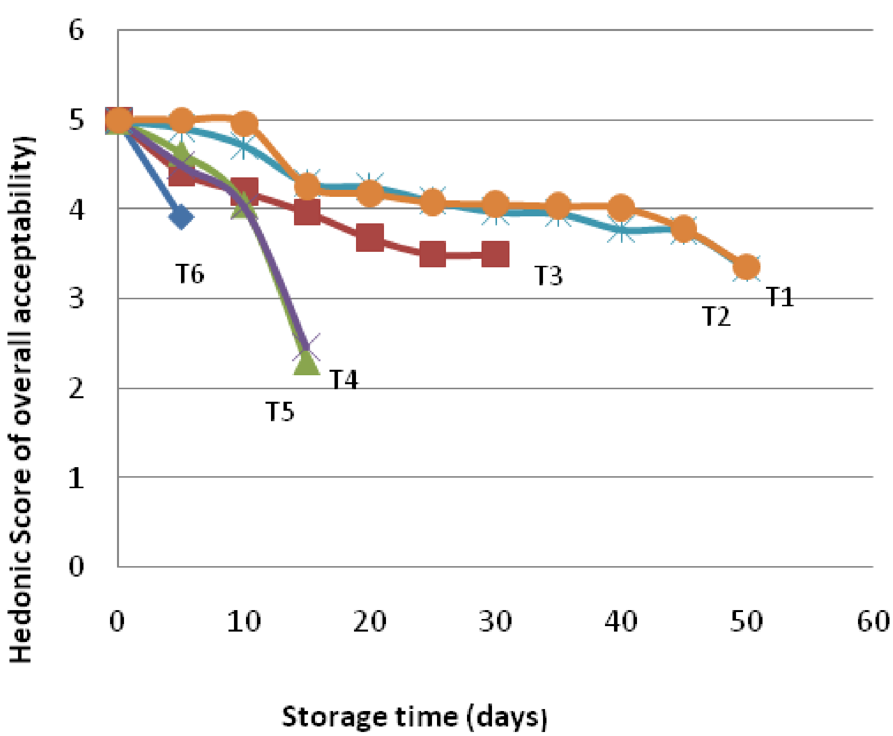

Figure 6. The effect of beeswax coating and storage temperatures on overall acceptability of nectarine during storage period.
Note: T1=Coated fruits stored at 6°C, T2= Coated fruits at 1°C, T3=Coated fruits stored ambient temperature, T4=Uncoated fruits stored at 6°C T5=Uncoated fruits stored at 1°C and T6=Uncoated fruits stored at ambient temperature (22°C)

combination of 12% wax coating and storage at 5°C was the best treatment for maintaining the quality and extending the shelf-life of the tangerine citrus var. Siam Banjar, as it exhibited a higher overall sensory acceptability value than did the other treatments or the control (Hassan et al., 2014). In general, the present study revealed that, waxing and storage under cold condition (1 and 6°C) was superior to the control and keeping nectarine fruits at room temperature in terms of all most all fruit quality attributes, including shelf life.

CONCLUSION AND RECOMMENDATION

Results of the present study showed that beeswax coating and storage temperature have a significant role to extend shelf life and maintain the quality of nectarine fruit. The highest percentage of titratable acidity and total soluble solids (TSS), as well as highest score values of sensory attributes were recorded for coated nectarine fruits stored at 6°C, while uncoated nectarine fruits stored at ambient temperature exhibited the highest percentage of weight loss and pH value and lowest mean score values of sensory parameters. Furthermore, the shelf life of the coated nectarine fruits stored at ambient temperature was extended to 30 days, compared to uncoated fruits stored at the same temperature which deteriorated within three to five days while life of coated nectarines fruits stored at 1 and 6°C was extended to 50 days. Hence, coating nectarine fruits by beeswax and storing at 6°C was found to be the most effective method in maintaining quality and extending shelf-life of the fruits. This finding also indicates waxing fruits and storing under cold conditions can be the option to reduce postharvest losses and increase the income of nectarine growing small scale farmers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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