The Effect of Bee Wax Coating and Storage Temperatures on Shelf life and Quality of Nectarine

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Abstract

Fruit coating was performed by dipping method to cover whole surface of fruits and then air-dried. Physio-chemical data (weight loss, total soluble solids, titratable acidity and pH) and sensory attributes (color, taste, flavor, appearance and overall acceptability) were taken at five days interval. The experiment was carried out in control-randomized design at Holetta Research center. The results of statistical analysis t i p fe! i b ! i fs f! bt ! t ho g dbo ! e gg fs fod f! c f ffo! s fb n fo t !) ! !gps! c p i physio-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±0.91ºBrix). 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 where were recorded for uncoated fruits stored at room temperature (22°C). In general, the result of the shelf life of bee wax coated fruit was extended to 50 days while uncoated fruit stored at room temperature (control) deteriorated within three days. Therefore, it is recommended that coating nectarine fruits with bee wax and storage temperature between 1°C and 6°C would prolong the shelf life of the crop without affecting its nutritional quality.

Introduction

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

Materials and Methods

Experimental materials

Two hundred forty nectarine fruits were collected from Holetta Agricultural Research Center (HARC) research field. The fruits were carefully selected, based on uniformity at commercial maturity stage, color, shape and those free of physical damage and infection by biotic factors used for the experiment. Harvested fruits were transported to ANRL of the center and washed by 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 bees wax and edible oil were collected from Holetta Beekeeping Research Center and local super market, respectively. The wax emulsion was prepared, according to Hassan et al., (2013) 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 wax samples was dissolved in water. Then, 100 ml of edible oil was added to the molten wax and, finally, water was added to the solution until it reached of 1000 ml.

Treatments

The fruits were randomly divided into six treatments, each with 40 fruits involving: coated fruits stored at 6 °C, coated fruits stored at 1 °C, coated fruits stored at room temperature, uncoated fruits stored at 6 °C, uncoated fruits stored at 1 °C and uncoated fruits stored at room temperature. Fruit coating was performed by dipping method to cover whole surface of fruits and then by air-drying. Physio-chemical properties were ensured at five days interval for 50 days. However, fruit sensory attributes of data was taken depending on the shelf life of each treatment during the storage periods.

Physio-Chemical properties

Percentage of weight loss: All sample fruits were weighed on the first day to determine their initial weights. Then, Fruits were weighed (three samples per repetition) at five 5 days interval and percent weight loss was calculated by using the following formula (Wang et al., 2005)

$$\text{Weight loss (\%)} = \frac{\text{Initial - Final weight x 100}}{\text{Initial weight}}$$

Total soluble solid (ºBrix): The concentration of total soluble solid was determined by direct reading from sample juice drop in a refractometer. Small quantity of fruit juice (3-5 drops) was dropped on to fixed prism surface at 20 ºC and the result was expressed as ^{o} Brix (AOAC, 2006).

Titratable acidity and pH: Titratable acidity was measured according to standard procedures (AOAC, 2000). Ten gram of grinded nectarine juice samples were taken from each treatment. Then, the samples were diluted with 250 ml warm water. Ten ml of supernatant sample was titrated with 0.1 N NaOH and titration was continued until pH value of 8.2. Titratable acidity was expressed as percentage of citric acid/100 ml of

juice. The pH value of the samples was measured using a glass electrode pH meter, which was subsequently to calibrated by buffer solution at 7 and 4, according to described by the method (AOAC, 2005)

Sensory Evaluation

Sensory properties (flavor, texture, appearance, taste, and overall acceptability) were evaluated by ten semi-trained panelists composed of 6 females and 4 males. Panelists were selected based on their previous experience in sensory evaluation. Samples were given to each panelist in a completely randomized order, served on white saucers and labeled with three digit random numbers. Panelists were served water and unsalted crackers to clean their mouth before testing each sample. Using five point hedonic scale panelists 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 physio-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 $P \leq 0.05$ was considered statistically significant.

Results and Discussion

Fruit weight loss: Table 1 show the change in weight of coated and uncoated nectarine fruits, which were maintained at different temperatures during the storage period. The result indicated that percentage of weight loss increased steadily with prolonged storage period. There was a significant difference between the treatments ($P \leq 0.05$). The highest percentage of weight loss recorded for uncoated fruits stored at 22 ^{o}C (control), while, the lowest percent weight loss was recorded for coated nectarine fruits at stored 1° C (Table 1). This result was 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. The nectarine fruits, which were coated and stored at 1°C and 6°C, had lower weight loss percentage than those fruits coated and stored at room temperature. This indicates that, in addition to waxing, especially storage temperatures condition of coated fruits determines the shelf life of nectarine fruits. Hence, waxing and storage at room temperature may not act as moisture loss barrier for a long period as compared to waxing and preserving at cold storage. This might be, cracking of wax layer with increased with increased storage temperature its role covering the surface of nectarine fruits to minimize moisture loss through evaporation from the fruits. Similar findings were reported by Shein *et al.*, (2008) who stated 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 by to 30%.

The results of present study also indicated that coated nectarine fruits stored at cold temperatures (1°C and 6°C) had lower percentage of weight loss. Hence, coating and storing under cold conditions seems effective method to increase shelf life of nectarine fruits. This finding is less or more similar with the work of other researchers Patel and Goswami (1984), who showed that storage life of mango fruits was extended by wax coating and cold storage.

Titratable acidity: There was statistically significant difference ($P \leq 0.05$) among 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 room temperature (22ºC). 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°C and 1°C) to slow down the change in fruit acidity and the rate of breakdown acids into sugars during metabolic activities. Besides, coating fruits might have deprived intake of oxygen, retarding the rate of respiration and, thus metabolism. The decrease in acid content of incorporated 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; Willis *et al*., 1998).

Fruit juice pH: Table 1 show that there was a significant difference ($P \leq 0.05$) among the treatments for pH of fruit juice. The highest mean pH value (4.29) was observed for uncoated fruits stored at room 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 did uncoated fruits stored at higher temperatures. This might be due to combined effect of waxing and cold storage to slow down oxidation of acids found in nectarine fruits. The result of the present study was in agreement with the work of Diaz-Sobac *et al.*, (1996) who reported higher increases in pH of the control samples compared to pH of the mangoes coated with maltodextrin and methylcellulose. The result of the present study was also in line with previous findings Medlicott *et al.*, (1987), indicating that the rate of increase in pH of control samples were higher than in coated fruits.

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 (15.32ºBrix) TSS was observed for coated fruits stored at 6°C while the lowest value (0.93ºBrix) was for the control treatments. The reduction in TSS during of 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°C, coated fruit stored at 1°C, coated fruit stored at room temperature, uncoated fruit stored at 6°C, uncoated fruit stored at 1°C and uncoated fruits stored at room temperature (control).

Besides, at the end of the storage period were 15.32 ^{o}Brix, 15.23 ^{o}Brix, 13.82 ^{o}Brix, 10.73 ^{o}Brix, 10.46 ^{o}Brix and 0.93 ^{o}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 was in agreement with the findings of Patel *et al.,* (2008), who reported that changes in TSS content are natural phenomena that are correlated with hydrolytic changes in carbohydrates during storage.

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

Treatment	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}

SE= Standard error of the mean. Means followed by different letters within a column are significantly different at P 0.05 level.

Flavor and taste: It was observed that there was significant differences ($P \leq 0.05$) between the treatments for mean score value of flavor and taste (Table 2). The highest mean score (4.23) of flavor was observed for coated fruits stored at 6°C, while the lowest value (0.77) was for the control treatment fruits (uncoated) stored at room temperature throughout storage time (Fig.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 (Fig.3). In line with this Karakurt *et al.,* (2000) reported that none melting flesh peach cultivars which were evaluated as low flavored 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 ($P>0.05$) between coated fruits stored in cold storage flavor and taste during the experiments period. The mean score for flavor was positively correlated with the mean score of taste. This could be due to the same biochemical constitutes contribution to both flavor and taste of the fruits.

In agreement with results of the present study, Rapaille *et al.,* (2003) have 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). Moreover, 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, resulting in only a small reduction in flavor quality (Abad *et al*., 2003).

Sourness and texture: Highest mean score values of sourness (4.12) and texture (4.22) were observed for coated fruits stored at 6°C and at 1°C, respectively (Table 2), while the lowest mean score parameters were recorded for the control fruits (uncoated and stored at room temperature). The result indicated that coated fruits stored at 1°C and 6°C exhibited highest mean scores of sourness and texture as compared to other treatments. But, the mean score values of coated fruits stored at room temperature were higher than those over all mean values of uncoated fruits (Fig .4 and 5) stored at (22°C, 1°C and 6°C). Hence, the result of the present study indicates that coating by bee wax and storing cold temperature (1°C and 6°C) may help to maintain the sensory quality of nectarine fruits. The study also indicated that coating alone might not help much, as shelf life of coated nectarine fruits depends on storage temperature. In agreement with this, Patricia *et al.,* (2005) have reported that refrigerated strawberry coated with gluten based films had better firmness retention than the control. Similarly, coated apple 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 room 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 higher and maintained for longer period for coated fruits stored at 1 ºC and 6 ºC than for the other treatments (Fig.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.

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

Treatment	Flavor	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 22ºC	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]

SE= Standard error of the mean. Means followed by different letters within a column are significantly different at ! 0.05 level using Least Significance Difference

Shelf life essay: ten semi- trained panelists evaluated sensory attributes (flavor, taste, appearance, sourness and overall acceptability) at five days interval during the storage period. Treatments, which failed in acceptability during the storage periods, were discontinued from further sensory evaluation.

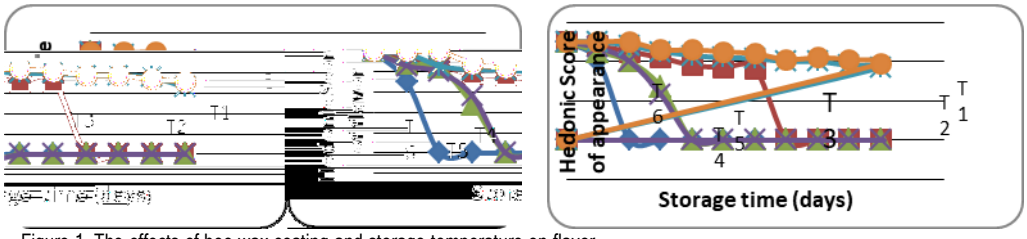

Figure 1. The effects of bee wax coating and storage temperature on flavor

Figure 2. The effect of bee wax coating and storage temperature on of the nectarine fruits the during storage period.
Appearance of the nectarine fruits during the storage period

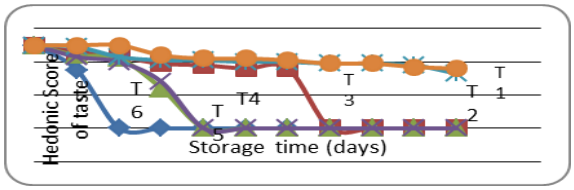

Figure 3: The effect of bee wax coating and storage temperature coating and storage temperature

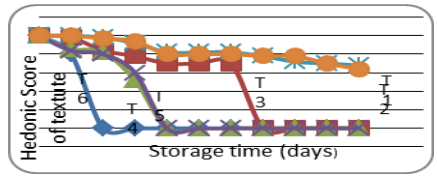

Figure 4: The effect of bee wax

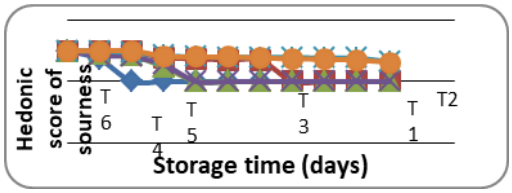

Figure 5: The effect of beeswax coating and storage temperatures on sourness of nectarine during storage period

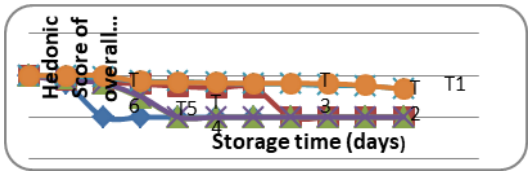

Figure 6: The effect of beeswax coating and storage temperatures on overall acceptability of nectarine during storage period

***Note**: T1=Coated fruits stored at 6°C, T2= Coated fruits at 1°C, T3=Coated fruits stored room temperature, T4=Uncoated fruits stored at 6°C T5=Uncoated fruits stored at 1°C and T6=Uncoated fruits stored at room temperature (22ºC)*

Results of the present study indicated that, there were significant variations between the treatments for all sensory attributes during the storage period. There was sharp decrease in mean value of flavor in T6 (uncoated fruits stored at room temperature) at fifth day after storage when other treatments had acceptable values (Fig.1). However, mean flavor coated fruits stored both at 6°C and 1°C was not much affected and gradually declined during the storage periods. This might be due to the influence of low storage temperature and coating on flavor enhancer compounds by depressing the activity of enzymes facilitating biochemical reactions in the fruit.

Hence, this shows that storing nectarine fruits at room temperature (22°C) had detrimental effect on flavor through its effects on biochemical constituents of the fruit. 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-flavor if over-abundant in the fruit. Similarly, there was a sharp decline in appearance of uncoated fruit stored at room temperature (22ºC) decrease in coated fruits stored at 6ºC and 1°C was slight and gradual during storage period (Fig.2). In general, flavor and appearance of fruits in all treatments decreased with prolonged time of storage though coating nectarine fruit by bee wax and storing in cold temperature (1°C and 6°C) significantly retained the appearance and flavor as well as sensory attributes of the fruits for longer duration. In agreements with this results David *et al.*, (2013) reported that holding mandarins at warm temperatures such as 22°C could be very harmful to flavor 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 decreased with the time of storage (Fig.3 and Fig.4) and showed the same trend of response to the treatments as did flavor and appearance values. Retention of taste and texture was by far better for coated nectarine fruits than for uncoated fruits and for cold (1°C and 6°C) than for room temperature (22ºC) during 50 days of storage As with other sensory attributes mean values of texture and taste significantly decreased with prolonged storage time, particularly for uncoated fruits. . These results were in agreement with the finding of Ladaniya and Sonker (1997) who reported that, maximum retention of natural freshness and firmness was recorded when *Nagpur mandrin* fruits were waxed and stored for up to 21 days. At the initial stages, texture of the fruits becomes more palatable, but eventually the fruit structure disintegrates, probably because of physiological and biochemical changed. In line with this, it has been reported that, during ripening and maturation, prospecting (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 been also reported for sweet orange by Muhammad, (2007) indicating that the scores values of taste decreased during fruit storage time from zero days to 56 days. The hedonic score values of overall acceptability (Fig.6 and sourness (Fig.5) decreased with prolonged storage time, though the rate decline was not the same within all treatments. Both parameters had values decreasing at a fastest rate in uncoated nectarine fruits while slowly decreasing exhibited values those fruits stored at 1°C 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 combination of 12% wax coating and storage at 5°C was the best treatment for maintaining the quality and extending the shelf-life of tangerine citrus var. Siam Banjar, , as it exhibited 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°C and 6°C) was superior over uncoating 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 bee wax 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 room temperature exhibited the highest percentage of weight loss and pH value and lowest mean score values of sensory parameters. Furthermore, the shelf life coated nectarine fruits stored at room temperature was extended to 30 days, compared to uncoated fruit stored at the same temperature which deteriorated within three to five days while the shelf life of coated

nectarines fruits stored at 1°C and 6°C was extended to 50 days. Hence, coating nectarine fruits by bee wax 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 post-harvest losses and increase the income of nectarine growing small-scale farmers.

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