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# Effect of bee wax and linseed oil coatings and frequency of dipping on the biochemical and organoleptic quality of fresh orange juice (*Citrus sinensis* cv. Valencia)

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## ABSTRACT

An investigation was carried out to study the effects of bee wax and linseed oil coatings and frequency of application on the quality of juice extracts during ambient storage for 28 days. It was found that the results of both wax coating and oil dipping were significantly ($p < 0.05$) different from and better than that of control in many of the parameters. Fruit from BW3 (bee wax emulsion three time dip) treatment had the lowest weight losses during storage periods. The ascorbic acid content and titratable acidity decreased while the total soluble solids and pH increased for all treatments, the rate being significantly ($p < 0.05$) slower for coated samples. Linseed oil at all levels of application and BW3treatments had significantly ($P < 0.05$) lower total aerobic bacteria and total mold and yeast counts than control samples on 28th day and were able to inhibit microbial growth for 21 storage days. The color score of coated fruits was generally better than control fruits. The flavor, generally, was reducing in acceptability as storage days increased. It can be concluded that bee wax emulsion is promising than linseed oil, especially in three times application level, as a coating material for Valencia oranges.

**Keywords:** Bee wax emulsion, coating, linseed oil, orange juice, quality.

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## INTRODUCTION

Kenya's Fresh citrus fruits are highly perishable due to release of heat from respiration, consequently losing moisture. If they are kept without any treatment at ordinary condition they may spoil mainly due to water vapor loss, decay and respiration (Ladaniya, 2008). In developing countries like Ethiopia, where the proper handling of fresh fruits is inadequate, losses during storage, marketing and transit have been reported to be as high as 50% (Mekbib, 2006). Very little emphasis has been laid on the post-harvest handling (Seifu, 2010). Orange juice quality depends on the raw material, processing conditions, storage conditions and packaging materials. For example, the usual practice of washing of citrus fruits after harvest

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was an effective method for removing spores from the surface of fruits, but it leads to removal of the natural wax that acts as a barrier to moisture and gases (Wissanee and Renu, 2007).

Wax coatings are made of natural or synthetic waxes and fatty acids (beeswax, carnauba, polyethylene, stearic acid, and oleic acid), oils, shellac, emulsifier, plasticizers, antifoam agents, and surfactants (Salman et al., 2008). Coatings form a semi-permeable barrier to water vapor and gas exchange, leading to weight loss reduction, respiration rate modification, and senescence delay of coated produce. Edible films and coatings are alternative, non-polluting methods that have been developed to extend produce post harvest shelf-life (Thirupathiet al., 2006; Silvia et al., 2009; Trevor, 2009). Thus the combination of effective and indigenous surface coating material with proper post-harvest treatments would increase marketability by maintaining market weight and appearance, and conserve juice quality by reducing water loss, respiration and microbial load (by reducing infection) in the juice.

The influence of different coatings on the physicochemical parameters of citrus fruit has been widely studied (Marcillaet al., 2009). But there is no report of the specific physical, chemical, microbiological and sensory properties of the fresh orange juice in relation to coating treatments and shelf life of the raw material. In addition, basic information on film-coating methods of application for food surfaces and demonstration of effectiveness are lacking (Sirisha, 2003). In Ethiopia, no study has been done and there is a lack of information dealing with locally available edible coating application, with sufficient thickness, to sweet oranges.

Therefore, the purpose of this research was to assess the potential effects of bee wax and linseed oil coatings on the quality of orange juice extracts, and also to investigate the influence of frequency of applying bee wax and linseed oil coatings on the quality attributes of juice extracts during ambient storage.

## MATERIALS AND METHODS

### Experimental materials

Orange fruits were obtained from a Tony citrus farm in Dire Dawa, Ethiopia. The treatment materials used for coating the orange fruits consisted of bee wax and linseed oil. Pure bee wax and linseed oil were purchased from the Merkato market in Addis Ababa.

### Experimental procedures

Sample preparation. Orange fruits were harvested at proper maturity in the morning only from the peripheral parts of the trees in the same orchard. Fruits were hand harvested and lots for different treatments were prepared following the procedures described in Mazumdar and Majumder (2003).

Orange fruits were sorted and graded by size for uniformity purpose. Then the sorted ones were surface washed with tap water to remove field heat, dust, soil, and insect excreta and to reduce microbial load at the fruit and vegetable packing house of Tony Farm. Then the surface-adhered water was removed from the fruits by rubbing lightly with a clean piece of dry soft cloth before packing.

The surface cleaned fruits were packed in slotted plastic crates and covered with a moist cloth. Then the crates were carefully loaded on a truck. The load was transported early in the morning; it was unloaded with care from the truck and moved to the Food Science and Post-harvest Technology laboratory of Haramaya University.

*Application of disinfecting solution*. All orange fruits were disinfected by soaking in a 100 ml/L sodium hypochlorite/water solution for 2 min and rinsed in water (Gustavo et al., 2003). Then the fruits were dried at ambient air before subsequent waxing and oil dipping treatments.

*Waxing materials and their formulation*. In general quantity of wax used for coating of fruits/vegetables estimated to be 50mg/kg, because usually one kilogram of coating compound was used for one ton of fruits/vegetables (FAO, 2002).

*Emulsions preparation*. Emulsions were prepared as described previously in Salman et al. (2008). Bee wax (315 g) was placed in 25 L container and melted at 70 °C, heated continuously to attain a temperature of 80–90 °C. Oleic acid (144 g) was added to the melted wax followed by the addition of 86 g triethanolamine with a constant stirring. Then, 5.2 L of distilled water (which was pre-heated at the same temperature of 80 – 90 °C) was added slowly and with continued stirring for 5-7 minutes. Prepared emulsion was cooled down and stored at ambient temperature in a covered container before use.

**Treatments and sampling method**

*Treatments design*. Seven coating treatments (bee wax emulsion one time dip (BW1), bee wax emulsion two time dip (BW2), bee wax emulsion three time dip (BW3), linseed oil one time dip (LO1), linseed oil two time dip (LO2), linseed oil three time dip (LO3) and control) and five storage durations (day1, day 7, day14, day21, and day28) with three replications were used in the study.

*Application of bee wax and linseed oil*. The previously disinfected fruits were sub-divided randomly into seven groups with equal numbers of orange fruits. Prepared oil/water wax emulsion was applied manually by immersion to respective replicates (about 15 s at ambient condition) and then the treated fruits were drained and allowed to air-dry at room temperature prior to ambient storage (Silvia et al., 2009). Similarly, for treatment with linseed oil, the respective replicates were dipped in pure linseed oil for one hour (Syed et al., 2004). The remaining group was subdivided into three replicates and left as treatment control.

*Sampling method*. All quality parameters were investigated at 7 days interval for 1 month. At 1, 7, 14, 21, and 28 days of storage, 5 fruits were taken randomly from each replicate for chemical and microbial analysis and 10 fruits for sensory analysis. For physiological analysis, the same marked oranges consisting of 5 per replicate were weighed at the beginning and at the end of each storage period.

**Juice extraction**

Juice was extracted by hand-peeling, cutting oranges into slices and then squeezing using an electric juice extractor (Waring Commercial, type 6001X, No. 31JE35 6X-00777 USA) at ambient condition.

**Data collection**

*Physiological weight loss*. The physiological weight loss (PWL) was determined following the method described by Waskaret al. (1999). Orange fruits from each treatment and from each labelled container were removed and weighed on a sensitive balance (type DT 2K model Lark® 511214 USA).

*Total soluble solids*. Total soluble solids (TSS) were determined following the procedures described by Waskar et al. (1999).

*Titratable acidity and pH*. The pH value of the orange juice was measured with a pH meter. The titratable acidity (TA) of orange juice was determined according to the methods described by Maul et al. (2000).

*Ascorbic acid*. The ascorbic acid content of the juice was determined by the 2, 6-dichlorophenol indophenol method (AOAC, 2000).

*Microbiological changes*. Microbiological estimation was carried out on every sampling date. The total microbial population was estimated using the procedure followed by Bracket (1990).

The presence of total aerobic bacteria was determined using plate count agar (TPC). For estimation of total molds and yeasts, potato dextrose agar (PDA) was used, which has been prepared and kept in a controlled area to cool enough. In all cases pour plate method was used as described in Askar and Treptow (1993).

Microbial analysis was performed in duplicates from 102 and 103 dilutions and the results were the average of the four determinants for both TPC and PDA. Results were presented as the logarithm of colony forming units per gram (log CFU/mL) of the product.

Secondly; number of microorganisms was determined by the total count method. In each fruit juice dilution, the number of microorganisms was calculated in accordance to between 30 – 300 microorganisms using formula described in Franco (2005).

**Sensory evaluation**

Organoleptic evaluation of juice color and flavor for all the samples was carried out by rating method of Ranganna (1979). An effective test was done for determination of the quality attributes (color and flavor as organoleptic parameter) of extracting juice for each storage time; 10 fruits were taken randomly for juice extraction from each replicate. The sessions were established for taste evaluation of juices by volunteer untrained panelists of 30 people with age between 18 and 65.Samples were presented to panelists in transparent cups labeled with 3-digit random codes for identification and served to them at room temperature. All samples of one treatment were tested using juice spoons in one session at room temperature. The panelists were told to rinse their mouth with a tap water in between tastes so as to avoid sensory bias. Juice color was evaluated visually. The sensory evaluation was conducted using a 7-point hedonic scale (where 1=dislike extremely and 7=like extremely), rating of juice color and flavor.

**Data analysis**

The data were subjected to analysis of variance (ANOVA) for factorial experiment in completely randomized design (CRD) with 3 replications using the SAS system for windows 9.0 version statistical software (SAS Institute, 2002). Treatment means were compared by applying least significant difference (LSD) test at the 5 % level of significance.

**RESULTS AND DISCUSSION**

**Effect of coating on weight loss**

The results regarding the effect of different treatments on percent loss in weight of Valencia oranges were given in Table 1. All treatments were significantly ($p < 0.05$) different from each other. After 7 days of storage a maximum weight loss of 7.78% was recorded in the control while the lowest value of 3.56% was recorded in BW3 treatment. A similar situation existed in the data of other storage periods. After 28 days of storage, the lowest value of 17.49% was recorded for BW3 while the maximum values of 21.03% and 23.04% were recorded for LO1 and control samples, respectively. Maximum weight loss in control is due to the high rate of transpiration. Minimum weight loss in treatment BW3 might be due to wax coating. Hence coating applications retained weight in fruits throughout the storage period. These results are in line with the findings of Syed et al. (2004) on banky apple.

There was a decrease in weight loss when oranges were coated with a bee wax emulsion compared to linseed oil coated and control samples. This is in accordance with the reports of Sirisha (2003). The reason why bee wax micro emulsion was able to be significantly effective in reducing moisture loss may be that it forms more uniform and stable coating than the linseed oil due to its compositional property (i.e. due to the existence of a continuous hydrophobic phase, which is highly repellent to moisture).

Weight loss significantly ($P<0.05$) decreased as the level of treatment application is increased both in bee wax emulsion and linseed oil dipped fruits. This is in agreement with the work of Shahid and Abbasi (2011). Similar results were also reported by Dorriaet al. (2007) on Valencia oranges. This was due to the reason that repeated dips increases the barrier property of the coating material by providing thicker layer leading to more physical blocking to transpire from the skin of orange.

The weight loss continued throughout the storage period for all the samples, but the rate of losses decreased as storage period increased. These results further affirmed the findings of Attia (1995), who reported that with the passage of time weight loss increased.

**Table 1. Effect of coating treatments on weight loss (%) of *Valencia* oranges during storage time (n=3)**

| Treatments | Storage days | | | |
|---|---|---|---|---|
| | 7 | 14 | 21 | 28 |
| Control | $7.78^{Aa}$ | $17.03^{Ab}$ | $20.97^{Ac}$ | $23.04^{Ad}$ |
| BW1 | $4.54^{Be}$ | $13.63^{Bf}$ | $16.73^{Bg}$ | $19.58^{Bh}$ |
| BW2 | $4.02^{BCi}$ | $11.69^{Cj}$ | $15.33^{Ck}$ | $18.63^{Cl}$ |
| BW3 | $3.56^{Cm}$ | $10.94^{Cn}$ | $14.73^{Co}$ | $17.49^{Dp}$ |
| LO1 | $7.27^{Aq}$ | $15.13^{Dr}$ | $17.13^{Bs}$ | $21.03^{Et}$ |
| LO2 | $6.57^{Du}$ | $13.29^{Ev}$ | $16.50^{Cw}$ | $20.23^{Bx}$ |
| LO3 | $6.26^{Dy}$ | $11.61^{Cz}$ | $16.06^{Cw}$ | $19.75^{By}$ |

Mean values sharing same small letters in a row are not significantly ($p > 0.05$) different from each other.
Mean values sharing same capital letters in a column are not significantly ($p > 0.05$) different from each other.

**Table 2. Effect of coating treatments on total soluble solid (°Brix) of orange juice during storage (n=3)**

| Treatments | Storage days | | | |
|---|---|---|---|---|
| | 7 | 14 | 21 | 28 |
| Control | $10.25^{Aa}$ | $11.73^{Ab}$ | $11.86^{Acb}$ | $12.88^{Acd}$ |
| BW1 | $10.23^{Aa}$ | $11.70^{Af}$ | $11.23^{Bgf}$ | $12.10^{Bhg}$ |
| BW2 | $10.23^{Aa}$ | $11.56^{Aj}$ | $11.16^{Bk}$ | $11.66^{Blk}$ |
| BW3 | $10.26^{Aa}$ | $11.53^{Bo}$ | $10.80^{Bpa}$ | $10.93^{Cqp}$ |
| LO1 | $10.33^{Aa}$ | $11.63^{Bt}$ | $11.10^{Bua}$ | $12.83^{Av}$ |
| LO2 | $10.23^{Aa}$ | $11.55^{By}$ | $10.83^{Bza}$ | $11.83^{By}$ |
| LO3 | $10.26^{Aa}$ | $11.43^{Bb}$ | $10.26^{Ca}$ | $11.50^{Cb}$ |

Mean values sharing same small letters in a row are not significantly ($p > 0.05$) different from each other.
Mean values sharing same capital letters in a column are not significantly ($p > 0.05$) different from each other

**Effect of coating on biochemical quality of juice**

*Total soluble solids*. The data of total soluble solids are presented in Table 2. The initial TSS value was in the range of 10.23 °Brix to 10.26 °Brix and in the following storage days it increased progressively. The general trend is that those treated with wax and oil had showed lower levels of TSS relative to the control. After 28 days of storage, maximum TSS recorded in the control (13.33 °Brix) and next maximum for LO1 (13.16 °Brix) while the least TSS value was recorded for BW3 (11.63 °Brix) and the next minimum for BW2 (12.26 °Brix). Most of the differences were statistically significant ($p < 0.05$). Increased TSS in control may be due to accumulation of different solutes in vacuoles of cells as fruits goes ripen and starch is hydrolyzed into sugars.

A possible reason in reduction of TSS in coated samples were due to the fact that these retard the hydrolysis of starch into sugars and also the conversion of polysaccharides into disaccharides and monosaccharides by slowing the biochemical activities. These results are in line with the findings of Sirisha (2003), Babar (2007), Daniel and Yanyun (2007), Dorria et al. (2007) and Maria et al. (2007).

Furthermore, for those treated with coating materials, the higher the number of coatings the lower the TSS values at all storage periods. The reason BW3 has significantly reduced TSS change as compared to all other treatments is that wax emulsions have superior moisture barrier property than oils (Daniel and Yanyun, 2007) and the fact that more concentration of coating formed a more layer on the surface of fruits, thus delaying degradative processes. A similar trend was reported by Shahid and Abbasi (2011).

**Table 3. Effect of coating treatments on titratable acidity (%) of *Valencia* oranges during storage time (n=3)**

| Treatments | Storage days | | | |
|---|---|---|---|---|
| | 7 | 14 | 21 | 28 |
| Control | $0.73^{Aa}$ | $0.30^{Ab}$ | $0.21^{Ac}$ | $0.17^{Ad}$ |
| BW1 | $0.74^{Aa}$ | $0.31^{Ab}$ | $0.29^{Bhb}$ | $0.19^{Bi}$ |
| BW2 | $0.76^{Aa}$ | $0.31^{Ab}$ | $0.27^{Bmb}$ | $0.21^{Cn}$ |
| BW3 | $0.72^{Aa}$ | $0.30^{Ab}$ | $0.26^{Brt}$ | $0.25^{Cs}$ |
| LO1 | $0.76^{Aa}$ | $0.31^{Ab}$ | $0.32^{Cwhb}$ | $0.25^{Cx}$ |
| LO2 | $0.74^{Aa}$ | $0.33^{Ab}$ | $0.32^{Cb}$ | $0.26^{Dn}$ |
| LO3 | $0.74^{Aa}$ | $0.35^{Ab}$ | $0.33^{Cc}$ | $0.28^{Dd}$ |

Mean values sharing same small letters in a row are not significantly ($p > 0.05$) different from each other.
Mean values sharing same capital letters in a column are not significantly ($p > 0.05$) different from each other.

*Titratable acidity*. Table 3 shows that all treatments resulted in significant ($P<0.05$) difference in TA to each other. The initial value of TA ranged from 0.72% to 0.76% and starting from day 14, it showed a decreasing trend throughout the storage period for all treatments. By day 28 values ranged from 0.12% of the control sample to 0.23% of the LO3. The reduction of TA in all treatments during the storage period might be due to the fact that acidity decreases on ripening of fruit (Habib et al., 2007; Shahid and Abbasi, 2011) by conversion into sugars and their further utilization in metabolic process in the fruit. These results are in line with the study of Babar (2007).

Oil treatment has preserved significantly ($p < 0.05$) higher TA than wax at all levels of application for storage periods of 14 days and above. This may be due to the reason that oil treatment forms less permeable layer to $O_2$ gas than wax

emulsion (Daniel and Yanyun, 2007) which may lead to less metabolic activity due to reduced respiration rate. Higher level of coating material caused lower metabolic changes inside dipped fruits by retarding respiration and reducing moisture loss (Sirisha, 2003).

*pH value*. Table 4 shows the pH data of the orange fruits which underwent various treatments. The fresh fruit at harvest had a pH value in the range of 3.80 to 3.86. The pH value increased for all treatments as storage period increased and after 28 days of storage it was in the range of 4.28 to 4.58. This is expected since the acidity of fruits decreases as fruits ripen and/or over ripen as the age increased. The pH value of the control sample remained the highest at all storage periods showing that the physiological change taking place in the fruit led to further ripening thus reducing the acidity and increasing the sugar content of the fruits. This result is in line with the study of Habib et al. (2009).

In most cases, for those subjected to wax and oil coating, those with single dipping resulted in significantly ($p < 0.05$) higher pH than that of the other two groups. This is because thinner coating could allow higher respiration rate than thicker one and that this enabled the former to respire more and convert the acid content to sugar thereby raising the pH. Fruits with a triple layer of wax or oil had very limited respiration and therefore slowest change of organic acids to sugar, thus the pH remains significant ($p < 0.05$) the lowest.

**Table 4. Effect of coating treatments on pH of orange juice during storage (n=3)**

| Treatments | Storage days | | | |
|---|---|---|---|---|
| | 7 | 14 | 21 | 28 |
| Control | $3.83^{Aa}$ | $4.30^{Ab}$ | $4.32^{Ac}$ | $4.40^{Ad}$ |
| BW1 | $3.80^{Aa}$ | $4.15^{Af}$ | $4.23^{Agf}$ | $4.36^{Bhg}$ |
| BW2 | $3.86^{Aa}$ | $4.05^{Ajr}$ | $4.20^{Akj}$ | $4.27^{Blk}$ |
| BW3 | $3.83^{Aa}$ | $3.95^{Bn}$ | $4.11^{Bol}$ | $4.15^{Cp}$ |
| LO1 | $3.80^{Aa}$ | $4.23^{Cr}$ | $4.26^{Asr}$ | $4.38^{Atsrh}$ |
| LO2 | $3.86^{Aa}$ | $4.17^{Cv}$ | $4.22^{Awv}$ | $4.36^{Bxp}$ |
| LO3 | $3.80^{Aa}$ | $4.12^{Cz}$ | $4.18^{Bz}$ | $4.23^{Dz}$ |

Mean values sharing same small letters in a row are not significantly ($p > 0.05$) different from each other.
Mean values sharing same capital letters in a column are not significantly ($p > 0.05$) different from each other

*Ascorbic acid content*. The ascorbic acid content of the fresh orange fruits was in the range of 48.0 mg/100 mL to 51.0 mg/100 mL (Table 5). The ascorbic acid content of juice from fruits subject to different treatments decreased with increasing storage period, but at a lower rate as compared to that of the control. The control samples did show that their values are significantly ($p < 0.05$) lower than all the values belonging to the treated fruits at all storage periods. After 28 days of storage, maximum ascorbic acid retention was recorded for LO3 (15.83 mg/100 mL), next maximum for LO2 (15.50 mg/100 mL) and BW3 (14.50 mg/100 mL) and least for the control (9.83 mg/100 mL). The higher unrestricted respiration of the control fruits might have resulted in higher change of the organic acids to TSS or other components and the fact that oils are more effective as a barrier to respiratory gases than wax emulsions (Daniel and Yanyun, 2007) might have caused more ascorbic acid retention in oil treated samples than in wax treated samples. These results are comparable with that of Dorria et al. (2007).

Fruits subjected to single dip, be it bee wax or oil, exhibited lowest ascorbic acid content. This could be due to higher respiration that resulted in greater change of ascorbic acid to other compounds, hence the lowest ascorbic acid content. Fruits

with tripple dipping exhibited the highest ascorbic acid for both bee wax and oil treatments. These results are in line with those of Dhaka et al. (2001).

**Table 5. Effect of coating treatments on ascorbic acid (mg/100 ml) of orange juice during storage (n=3)**

| Treatments | Storage days | | | |
|---|---|---|---|---|
| | 7 | 14 | 21 | 28 |
| Control | $48.25^{Aa}$ | $31.33^{Ab}$ | $13.08^{Ac}$ | $10.83^{Adc}$ |
| BW1 | $48.50^{Aa}$ | $37.33^{Bf}$ | $17.50^{Bg}$ | $16.00^{Bhg}$ |
| BW2 | $48.66^{Aa}$ | $40.33^{Cj}$ | $23.33^{Ck}$ | $21.66^{Clk}$ |
| BW3 | $48.33^{Aa}$ | $44.00^{Dn}$ | $25.83^{Do}$ | $25.00^{Dpo}$ |
| LO1 | $48.00^{Aa}$ | $35.66^{Er}$ | $15.83^{Es}$ | $14.66^{Ets}$ |
| LO2 | $51.00^{Aa}$ | $38.33^{Fv}$ | $20.00^{Fw}$ | $16.33^{Fxw}$ |
| LO3 | $48.33^{Aa}$ | $41.00^{Gz}$ | $24.16^{Gb}$ | $23.00^{Gcb}$ |

Mean values sharing same small letters in a row are not significantly ($p > 0.05$) different from each other.
Mean values sharing same capital letters in a column are not significantly ($p > 0.05$) different from each other

*Total aerobic bacteria (TPC)*. The values for total plate count for all the treatments ranged from non-detectable (ND) during the three earlier storage times to 4.40 log CFU/mL for BW1 samples at the final storage time. During the first 14 days, there was no bacterial growth. This could be due to the initial disinfection of Valencia orange fruits which inhibited spore germination and bacterial infection till the $14^{th}$ day in all the samples.

The reason that linseed oil dipping at all levels of application significantly ($p < 0.05$) inhibited bacterial growth for seven more days may be that oils have high oxygen barrier property (Babar, 2007). On the other hand, BW1 and BW2 treatments had significantly ($p < 0.05$) allowed bacterial growth in the later days. This could be due to the inefficient barrier property of wax emulsions to respiratory gases (Daniel and Yanyun, 2007; Ladaniya, 2008). This is also in accordance with the study by Waks et al. (1985). But BW3 had ND on day 21 and only 1.20 log CFU/mL after that which is significantly ($p < 0.05$) different and lowest of all treatments. This may be due to the combination of reduced O2 sufficient to retard respiration and increased level of CO2 that can effectively inhibit microbial growth (Myrna et al., 1991). This is also in accordance with the reports by Sirisha (2003), Babar (2007) and Daniel and Yanyun (2007).

*Total molds and yeasts (PDA)*. The PDA count was significantly ($P < 0.05$) lower for BW3 treated fruits and for linseed oil at all levels of application than control samples and BW1 and BW2 on last day of storage. The different effects of bee wax emulsion and linseed oil on mold and yeast development may be related to the differences in their composition or physical properties. The significantly ($p < 0.05$) lower microbial load in the oil treated samples at all levels of application and that of BW3 on day 28 may be due to similar reasons as for TPC. These results are in agreement with the results of Wakset al. (1985).

**Organoleptic quality of juice**

*Color evaluation*. The data of color acceptance of the orange fruits are shown in Table 6. The readings of day 7 appear to be higher showing more acceptability than the color on day 1 but are not statistically different. This increase in color score during storage might be due to a series of physico-chemical changes like the breakdown of chlorophyll and increase in carotenoid pigments of the pulp caused by enzymatic oxidation and photodegradation (Ladaniya, 2008). However the color acceptability of fruits stored for 14 and 21 days does not seem to have any trend. Color acceptance values on day 28 were all significantly

($p < 0.05$) lower than the acceptability values observed on any other storage period. It clearly showed that respondents had reduced liking for the color of the fruits on that day. Similar results were found by Shahid (2007).

**Table 6. Effect of coating treatments on color of orange juice during storage (n=3)**

| Treatments | Storage days | | | |
|---|---|---|---|---|
| | 7 | 14 | 21 | 28 |
| Control | $5.84^{Aa}$ | $6.01^{Aba}$ | $4.81^{Ac}$ | $5.48^{Ad}$ |
| BW1 | $5.80^{Aa}$ | $5.78^{Bfa}$ | $5.05^{Bg}$ | $5.65^{Bhaf}$ |
| BW2 | $5.94^{Aa}$ | $6.15^{Cjna}$ | $5.62^{Ck}$ | $5.66^{Blk}$ |
| BW3 | $5.92^{Aa}$ | $6.15^{Dna}$ | $5.75^{Co}$ | $5.70^{Bp}$ |
| LO1 | $5.94^{Aa}$ | $6.02^{Cra}$ | $5.06^{Bs}$ | $5.55^{At}$ |
| LO2 | $5.92^{Aa}$ | $5.86^{Bva}$ | $5.13^{Bw}$ | $5.55^{Axw}$ |
| LO3 | $5.94^{Aa}$ | $5.94^{Bza}$ | $5.56^{Cbk}$ | $5.36^{cd}$ |

Mean values sharing same small letters in a row are not significantly ($p > 0.05$) different from each other.
Mean values sharing same capital letters in a column are not significantly ($p > 0.05$) different from each other

**Table 7. Effect of coating treatments on flavor of orange juice during storage (n=3)**

| Treatments | Storage days | | | |
|---|---|---|---|---|
| | 7 | 14 | 21 | 28 |
| Control | $6.11^{Aa}$ | $5.75^{Abd}$ | $4.18^{Ac}$ | $6.00^{Ada}$ |
| BW1 | $6.07^{Aa}$ | $5.55^{Afn}$ | $4.47^{Bg}$ | $5.72^{Bhf}$ |
| BW2 | $6.06^{Aa}$ | $5.77^{Aj}$ | $4.91^{Ck}$ | $4.93^{Clk}$ |
| BW3 | $6.04^{Aa}$ | $5.92^{Bna}$ | $5.56^{Do}$ | $4.50^{Dp}$ |
| LO1 | $6.01^{Aa}$ | $5.54^{Ar}$ | $4.77^{Cs}$ | $4.96^{Cts}$ |
| LO2 | $5.96^{Aa}$ | $5.44^{Av}$ | $4.97^{Cw}$ | $4.70^{Dx}$ |
| LO3 | $5.88^{Aba}$ | $5.23^{Az}$ | $5.42^{Dz}$ | $3.74^{Eb}$ |

Mean values sharing same small letters in a row are not significantly ($p > 0.05$) different from each other.
Mean values sharing same capital letters in a column are not significantly ($p > 0.05$) different from each other

As the number of dips increased, acceptability scores became larger for all storage periods. On day 14 and 28 the differences were statistically significant ($p < 0.05$) while those on the remaining storage periods showed largely no significant difference. The main factors that increased color score as the number of dips increased in both wax and oil coated samples may be due to increased $CO_2$ levels and decreased $O_2$ levels which reduce respiration rates and hence the metabolic changes. Significantly appreciable retention of color score was noted in bee wax emulsion treated samples after the $28^{th}$ day of storage period as compared to linseed oil treated ones. This may be the result of more efficient barrier property of wax than oil in moisture loss (Daniel and Yanyun, 2007). These findings generally coincide with Habib et al. (2007).

*Flavor evaluation*. The scores in the subsequent taste days showed that the flavor, generally, was decreasing in acceptability as storage days increased reaching the lowest level on day 28 (Table 7). This might be due to conversion of complex organic

compounds into esters, aldehydes, acids, alcohols, ketones and ethers that contribute significantly to the flavor (Ladaniya, 2008).

The fruits coated with bee wax performed better by getting significantly ($p < 0.05$) higher scores on day 7, 21 and 28 exhibiting the excellence of the bee wax treatment over that of the linseed oil.

Of the three levels of wax treatment the BW3 had statistically ($p < 0.05$) higher scores in the three out of five taste days. Generally, the larger the number of dips the better the acceptability scores attained. Similar results were reported by Shahid (2007).

The data from the linseed oil treated fruits did not show a clear pattern regarding the influence of the number of dips. It could probably be due to the insignificant impact of the number of dips on fruit flavor. Moreover, the flavor score of linseed oil treated samples were significantly ($p < 0.05$) lower than the control (4.57) at all levels of applications after 28 days of storage. This may be due to the high gas barrier property of oil, which will cause anaerobic/fermentative environment in the fruit, resulting in high ethanol content which is linked with off flavor (Daniel and Yanyun, 2007).

The overall generalization from the data indicates is that given the 6 point out of 7 scores of the fresh fruit juice the scores obtained up to the 21st day were 4.5 and above, except one of the LO3, and showed that the samples treated with both wax and oil coatings had acceptable flavor. The acceptability of the linseed oil treated fruits did not go beyond 21 days.

## CONCLUSION

The utilization of bee wax emulsion coating on Valencia orange fruit is promising than the linseed oil coating, especially in three times application level. Fruits coated with bee wax emulsion three times dip stored in a good physicochemical, microbial and sensory quality up to 28 days, which was long enough storage period for domestic market display at ambient condition. It can substitute or be alternative to commercial wax used in handling citrus fruit for domestic market and export. In order to satisfy the primary goal of reducing quality loss of Valencia orange fruits with the use of bee wax emulsion and linseed oil based edible coatings, continued efforts are necessary to develop more stable bee wax emulsion and linseed oil with modified coating characteristics of moisture, oxygen and microbial barrier capabilities. The same research should be conducted under cold temperatures as low as 10 °C to exploit the potential of the bee wax emulsion and linseed oil coatings to prolong shelf life even longer than 28 days. These coating materials should also be tested on Valencia oranges combined with different packaging materials such as high density polyethylene bags.

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