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Research Article

Coconut Oil and Beeswax Edible Coating for Postharvest Quality Maintenance of BARI Malta-1 at Ambient Storage

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Abstract

An experiment was conducted to assess the influence of coconut oil and beeswax edible coating on postharvest storage quality of BARI Malta-1 (*Citrus sinensis*) at ambient condition (27±4°C and 65±5% RH). Sorted fruits were washed with drinking water; after removing surface water, fruits were coated with coconut oil and beeswax mixture (9:1 or 8:2 or 7:3 w/w basis) or only coconut oil. After coating, fruits were kept in plastic crates and stored at 27±4°C and 65±5% RH. Weight loss, firmness, external colour (hue angle and lightness), TSS, pH, ascorbic acid, total sugar and reducing sugar were analyzed periodically during storage. After 18 days of storage, uncoated BARI Malta-1 had lost 45.6% of its firmness, while only coconut oil coated Malta had lost 32.7%, and combinations of coconut oil and beeswax Malta had lost just about 20% of its firmness. The maximum weight loss of 16% was recorded in the uncoated BARI Malta-1, whereas only 6% was lost in the Malta coated with a mixtures of coconut oil beeswax (7:3) at the last day of storage. During the eighteenth day of storage, uncoated BARI Malta-1 retained 44.00 mg/100g of ascorbic acid, indicating a significant loss during storage. The levels of ascorbic acid in coated BARI Malta-1 that had either been coated with coconut oil alone or with coconut oil and beeswax at the final day (18) of storage ranged from 54 to 58 mg/100g. The findings showed that using coconut oil alone or in combination with a beeswax coating was effective in maintaining the ascorbic acid content, preventing weight loss, and maintaining the firmness of the BARI Malta-1 throughout storage.

Keyword: Ascorbic acid, Beeswax, Edible coating, Firmness, Hue angle

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Introduction

The major citrus fruits are sweet orange (Malta, mandarin), lime, lemon, pomelo, and other exotic citrus fruits. In this sub-continent, juicy sweet oranges were locally introduced with the name of Malta fruit. This fruit is very popular in Asian countries including Bangladesh. Malta is one of the major commercial fruit crops that is widely consumed both as fresh fruit or juice attributed to its high vitamin C content and its antioxidant potential (Kiong et al., 2008). Home production increased in the last 15 years and growers are interested in producing more quality sweet oranges because of consumer preference and the market price. Bangladesh Agricultural Research Institute has developed a sweet orange variety named BARI Malta-1. It produces a lot of fruit (20 t/ha) and is a regular fruit-bearing variety. The round, medium-sized (146g) BARI Malta-1 fruits are juicy (33.7%) and delicious (TSS 7.8% and total acid 0.36%) and are collected between October and December (DHCP, 2017). It is the good source of vitamin C and minerals as well as people prefer it because of its sweet-sour test and pleasant flavor. Proper time and method of harvesting along with transportation, storage, and proper packaging materials determines the postharvest losses of sweet orange (Arun and Ghimire, 2019). Physical weight loss and quality deterioration are the main causes of postharvest losses.

Lack of adequate postharvest technology and handling practices to maintain the quality and shelf life of these fruit are now the main concern for growers, handlers and processors. After harvest, growers are forced to sell their fruit at undesirable prices due to insufficient storage technology and fruit decay. Farmers are not able to cool the fruit or maintain low temperatures during storage and marketing or utilize controlled atmosphere storage facility because of insufficient and expensive electrical equipment. Therefore, affordable technologies are needed to support the fresh citrus industry to ensure delivery of quality fruit. One way other than temperature control that may be used to slow down the respiration rate and fruit metabolism is to modify the fruit internal atmosphere. Modified atmosphere within the fruit can be created by either modification of the atmosphere surrounding the fruit, as in modified atmosphere packaging (MAP), or by applying a semipermeable coating on the fruit surface.

Pure coconut oil as edible coating of fruits has gaining interest for its anti-senescence property by controlling respiration rate, transpiration rate and binding of the ethylene biosynthesis process. Coconut oil is a natural well-being food product rich in lauric acid. There is evidence that a part of this acid converts endogenously to monolaurin that is known to possess a broad spectrum of antiviral, antibacterial and antifungal activities (Liberman et al, 2006). Coconut oil coating closed the opening of stomata and lenticels thereby, reducing the transpiration and respiration rate and also reduce microbial activity (Bisen et al., 2012). Nasrin et al., (2020) observed that uncoated open lemon was acceptable up to 6 days, coconut oil-beeswax (90:10 and 80:20) coated lemon kept open was acceptable up to 15 days and coconut oil-beeswax (both formulations) or only coconut oil coated lemon in MAP was acceptable more than 18

days retaining fresh like appearance and quality at ambient storage.

Citrus commercial coatings are generically known as waxes due to the fact that composition of initial formulations was based on paraffin wax or a combination of various other waxes such as beeswax or carnauba. Their main purpose is to reduce fruit weight loss, shrinkage and improve appearance, but they can also reduce the incidence of chilling injury or other citrus rind disorders (Porat, et al., 2004; Bajwa and Anjum, 2007). Thus, the objective of this research was to evaluate the performance of edible coating (coconut oil-beeswax coating and only coconut oil) on physico-chemical quality of fresh BARI Malta-1 during storing in open crates at ambient condition.

Materials and Methods

Material

BARI Malta-1 (*Citrus sinensis*) was collected from the field of one progressive farmer of Tangail district, Bangladesh. BARI Malta-1 was harvested in the month of October, based on maturity, uniformity of size and absence of physical damage. Chemicals that were used in this study as a treatment or for chemical analysis were chemical grade.

Edible Coating Formulations

To prepare 100 ml of three different mixtures of coconut oil-beeswax edible coating (9:1, 8:2 and 7:3 w/w basis) 90, 80 & 70 g coconut oil was mixed with 10, 20 & 30 g of beeswax respectively in three separates beakers by stirring on a low flame in order to obtain a homogenous mass that would become viscous upon cooling (Nasrin et al., 2020). Fruits were divided into 5 lots, i. 1st lot fruits were without coating, ii. 2nd lot fruits were coated with 100% coconut oil, iii. 3rd lot fruits were coated with coconut oil-beeswax mixture edible coating (9:1), iv. 4th lot fruits were coated with coconut oil-beeswax edible coating (8:2), and v. 5th lot fruits were coated with coconut oil-beeswax mixture edible coating (7:3). Upon cooling, the coating was applied carefully on the fruit skin by a soft and clean brush. Each fruits lot were kept in plastic crates and stored at ambient condition (27±4°C and 65±5% RH). Each lot was acted as treatments and each treatment consisted of 5 replications. Measurements on various physical and chemical attributes were done at the day of experiment setting and on 3 days interval up to 18 days of storage.

Measurement of Whole Fruit Firmness

Firmness of BARI Malta-1 was analyzed by Fruit Texture Analyzer (GUSS, Model Number: GS-25, SA). An 8 mm dia. flat end probe was pushed to a depth of 3 mm into BARI Malta-1 (same position of each sample) at 5 mm per sec speed. The utmost penetration force was used as firmness value of BARI Malta-1in Newton. Three BARI Malta-1 (two opposite locations for each) from each replication were analyzed and the mean value was used (Nasrin et al., 2018a).

Measurement of Weight Loss

Initial weight of 10 fruits from each replication was taken after treatment and then 3 days interval throughout storage time. It was calculated by the weight difference

between initial and specific time interval divided by initial weight and finally denoted by percent.

Measurement of Surface Colour

External colour of BARI Malta-1 was evaluated with a Chroma Meter (Model CR-400, Minolta Corp., Japan) based on CIE (L*a*b*). L* is lightness whereas a* and b* values were transformed to chroma (c) and hue angle (h°) automatically in this Chroma meter. Before measurement, calibration was done using supplied white plate (Nasrin et al., 2017).

Determination of Ascorbic Acid, pH, Total Sugar, Reducing Sugar and Total Soluble Solids (TSS)

The ascorbic acid content, total sugar and reducing sugar of BARI Malta-1 juice were analyzed according to AOAC (1994). TSS of BARI Malta-1 juice was determined by using refractometer. pH of BARI Malta-1 juice was assessed by pH meter (HANNA Instrument Inc, pH-211; Microprocessor, pH Meter, Italy).

Statistical Analysis

A completely randomized design (CRD) was done with three replications for each experiment and mean ± standard deviation was shown. Analysis of variance (ANOVA) was done according to the procedures of MSTAT-C software. Comparison among data was performed using Duncan's Multiple Range Test (DMRT) ($p<0.05$).

Results and Discussion

Firmness

Firmness or texture is an important quality parameter of fresh fruits for consumer preference. Degradation of insoluble protopectin to the more soluble pectic acid and pectin contribute to a decrease of firmness in many fruits. These changes occur relatively slowly and are less pronounced to citrus fruits as compared to climacteric fruits (Ladaniya, 2004). However, some softening of fruits also occurs due to the change of turgor pressure and or respiratory loss of dry matters during growth development and senescence. Figure 1 illustrates the effect of edible coating during storage at ambient temperature (27±4) °C on the firmness of BARI Malta-1. Initially the firmness value of BARI Malta-1 was 2.69N and it was decreased gradually with time but the rate was different for different treatments. Among the treatment, BARI Malta-1 coated with all three mixtures of coconut oil-beeswax edible coating retained their firmness effectively throughout the storage period. Uncoated BARI Malta-1 had lost 45.6% firmness while only coconut oil coated BARI Malta-1 lost 32.7% and mixtures of coconut oil- beeswax BARI Malta-1 had lost only around 20% at 18 days of storage.

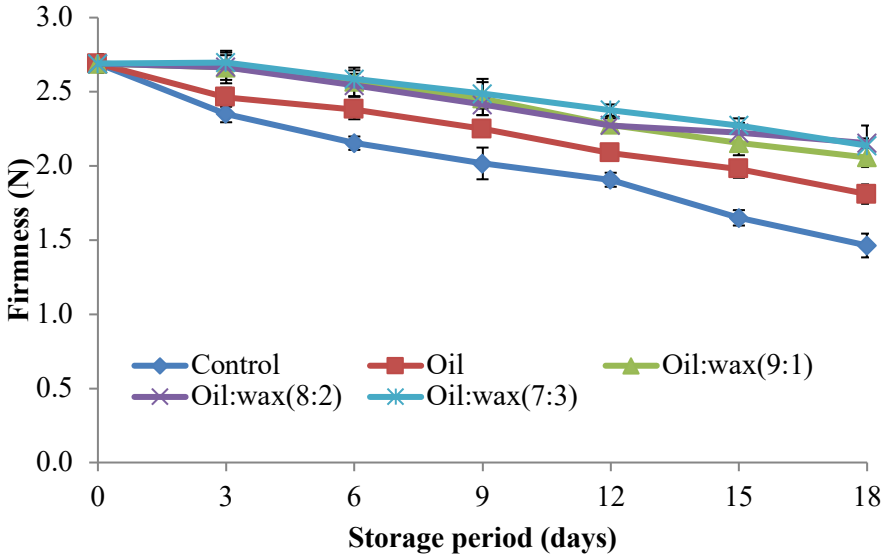

Fig. 1. Firmness of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C. Note: Control=Uncoated; Oil=Coated with only coconut oil; Oil: wax (9:1)=Coated with coconut oil and beeswax (9:1); Oil: wax (8:2)=Coated with coconut oil and beeswax (8:2); Oil: wax (7:3)=Coated with coconut oil and beeswax (7:3). Vertical bars indicate standard deviation.

Nasrin et al., (2020) reported that the firmness value of fresh lemon was 5.43N and uncoated open lemons stored at ambient condition had lost 62.62% firmness at 6th day of storage while MAP lemon was as firm as initial up to 12th day during storage. Nasrin et al., (2018b) also observed in another study that among the treatment, coconut oil coated mandarin was most firm during ambient storage and it lost about 38% firmness while uncoated or control fruits had lost 68% firmness at 16 days of storage period. When applying the beeswax edible coating to sweet orange Shahid and Abbasim (2011) discovered that the coatings not only prevented the moisture loss but improved the texture and the general appearance of the fruits for a long period of storage.

Weight Loss

Figure 2 illustrates the effect of edible coating on the weight loss of BARI Malta-1 during storage at ambient temperature (27±4) °C. Weight loss of fruits, in general, increased with the advancement in storage period. Maximum weight loss around 16% occurred in uncoated BARI Malta-1 whereas it was only around 6% in BARI Malta-1 coated with coconut oil and beeswax (7:3) during18 days of storage at 27±4°C. Nasrin et al (2023) stated that maximum weight loss, around 33% occurred in uncoated lemon kept open whereas it was only 4% in coated (only coconut oil or coconut oil-beeswax)

lemon packaged in MAP at 6th week of storage at 12±1 °C. Moreover, they reported that lemon coated with coconut oil-beeswax and kept open had lost 5.96% weight at 4th week of storage period. Shahid and Abbasim (2011) speculated that the beeswax coatings decreased the respiration rate of the fruits, thus reducing the weight loss and increased the shelf life of sweet orange. Weight loss is a consequence of fruit dehydration due to changes in surface transfer resistance to water vapour, in respiration rate, and the occurrence of small fissures connecting the internal and external atmospheres (Woods, 1990). Coating on fruits creates a barrier between fruit skin and outer atmosphere which controls movement of O_2, CO_2, moisture, and solute movement, thereby reducing respiration, water loss, and oxidation rates. Sakhale and Kapse (2012) found that dipping of sweet orange in the solution (150 ppm GA3 + 500 ppm Bavistin) and further wrapping resulted in lowest weight loss (3.9%) as against 25.7% in the fruits were given only a plain water dipping treatment (control) stored for 24 days at ambient condition (27±2°C).

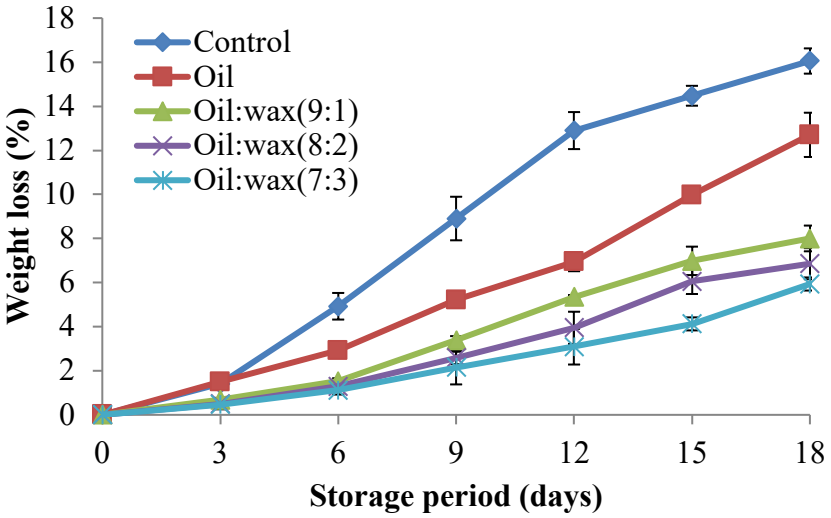

Fig. 2. Weight loss of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C. Note: Control=Uncoated; Oil=Coated with only coconut oil; Oil: wax (9:1) =Coated with coconut oil and beeswax (9:1); Oil: wax (8:2)=Coated with coconut oil and beeswax (8:2); Oil: wax (7:3)=Coated with coconut oil and beeswax (7:3). Vertical bars indicate standard deviation.

External Fruit Colour (Hue angle)

Colour is an important factor in the perception of fruit quality. Figure 3 illustrates the changes in surface colour in terms of hue angle of BARI Malta-1 influenced by edible

coating during storage at ambient temperature (27±4) °C. Initial hue angle value of BARI Malta-1 was 120.26 that mean, fruits were dark green colour. It is clear from the figure 3 that hue angle value is decreasing gradually with storage period as BARI Malta-1 turns from green to yellow skin colour with storage period. The reason is there, after this period, ethylene production and respiration rate were increased that stimulate to degreening BARI Malta-1.

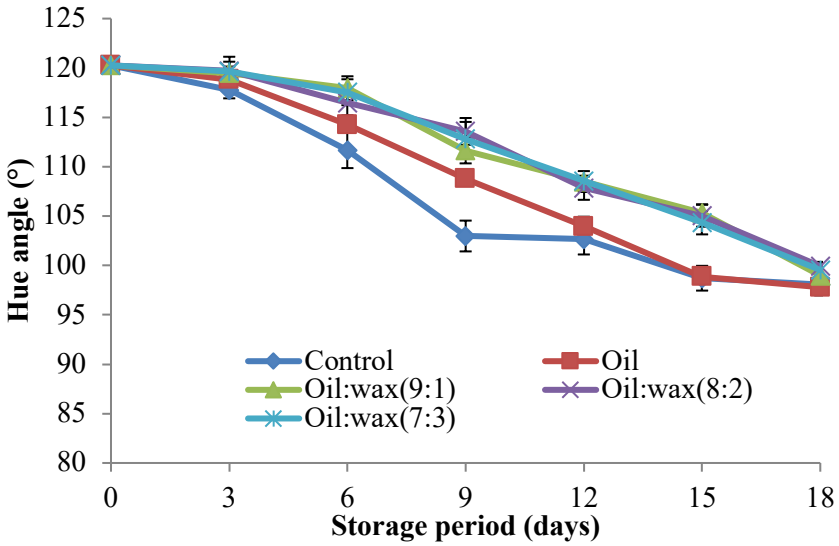

Fig. 3. External colour (hue angle) of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C. Note: Control=Uncoated; Oil=Coated with only coconut oil; Oil: wax (9:1)=Coated with coconut oil and beeswax (9:1); Oil: wax (8:2)=Coated with coconut oil and beeswax (8:2); Oil: wax (7:3)=Coated with coconut oil and beeswax (7:3). Vertical bars indicate standard deviation.

Figure 3 illustrates those changes of colour (from green to yellow) was significantly less in BARI Malta-1 coated with all three mixtures of coconut oil-beeswax edible coating throughout the storage period. Hue angle value was 102.98 in uncoated BARI Malta-1 while, it was around 113 in all coconut oil-beeswax coated BARI Malta-1 and 108.77 in coconut oil coated BARI Malta-1 at 9th day of storage. But this value was similar around 99 in all coated and uncoated BARI Malta-1 at last day (18th day) of storage period. Obeed and Harhash (2006) found the similar results like our findings, changes of skin colour from green to yellow in "Mexican" lime during storage. Initially hue angle value of lime had 106.57, after 4 weeks of storage, it was 97.45 when fruits were treated with hot water containing calcium chloride 2% and stored at 12°C.

External Fruit Colour (Lightness)

Figure 4 illustrates the changes in surface colour in terms of lightness of BARI Malta-

1 influenced by edible coating during storage at ambient temperature (27±4) °C. The L* parameter is an indicator of darkening. Initial lightness value of BARI Malta-1 was 37.88 and it is increasing gradually with storage period as BARI Malta-1 turns from green to yellow skin colour with storage period. Green colour reflects less light than yellow/orange colour. Lightness value was 60.67 in uncoated BARI Malta-1 while, it was between the range of 46 to 48 in all coconut oil-beeswax or only coconut oil coated BARI Malta-1 at 9th day of ambient storage. However, on the last day (18th day) of the storage period, these values were close to one another and varied from 58 to 63 in all coated and uncoated BARI Malta-1. Pure coconut oil coating helps to delay in ripening of fruits and uniform colour development of Kagzi lime in later period of storage (Besin et al., 2012). When applying the beeswax edible coating to sweet orange Shahid and Abbasim (2011) discovered that the coatings not only prevented the moisture loss but improved the texture and the general appearance of the fruits for a long period of storage.

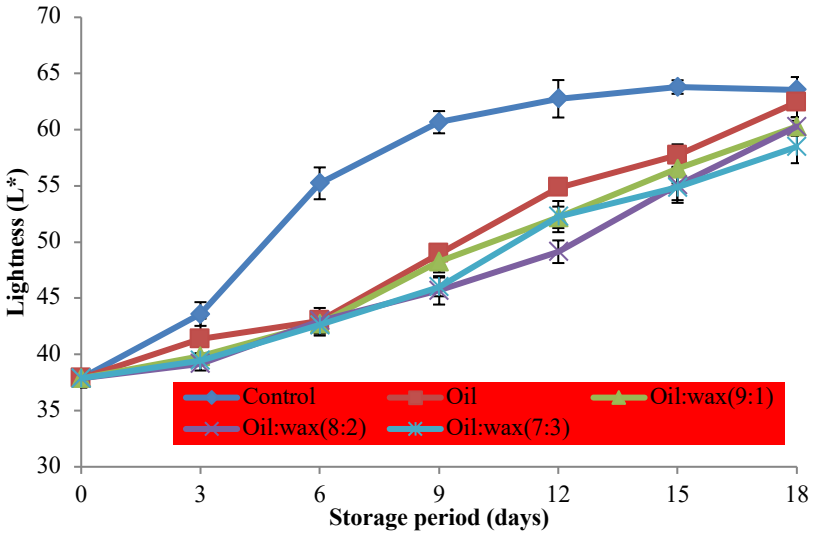

Fig. 4. External colour (lightness) of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C. Note: Control=Uncoated; Oil=Coated with only coconut oil; Oil: wax (9:1)=Coated with coconut oil and beeswax (9:1); Oil: wax (8:2)=Coated with coconut oil and beeswax (8:2); Oil: wax (7:3)=Coated with coconut oil and beeswax (7:3). Vertical bars indicate standard deviation.

Ascorbic Acid, TSS, pH, Total Sugar, Reducing Sugar and Non-Reducing Sugar

Ascorbic acid, TSS and pH content of fresh BARI Malta-1 was 60.67 mg/100g, 6.1(° Brix) and 4.67 respectively as shown in Table 1. During storage uncoated BARI Malta-1 lost ascorbic acid severely and retained 44.00 mg/100g at 18th day of storage. While

coated BARI Malta-1 with only coconut oil or coconut oil-beeswax preserved ascorbic acid (ranged from 54 to 58 mg/100g) up to the last day (18) of storage. Unlike ascorbic acid, TSS content was increased moderately throughout the storage period and maximum (7.9° Brix) TSS was observed in uncoated BARI Malta-1 at 18th day of storage. pH content was also increased slightly irrespective to the treatments throughout the storage. But, there were no significant differences ($p < 0.05$) in case of TSS and pH among different treatments during storage period.

Table 1. Ascorbic acid, TSS and pH content of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C.

Treatment	Ascorbic acid (mg/100g)			TSS (°Brix)			pH		
	0 day	9 days	18 days	0 day	9 days	18 days	0 day	9 days	18 days
Control	60.67	49.00^{b}	44.00^{b}	8.17	8.30	8.87	4.67	4.89	4.89
Oil	60.67	55.00^{a}	54.33^{a}	8.17	8.27	8.73	4.67	4.82	4.88
Oil:wax(9:1)	60.67	54.67^{a}	56.67^{a}	8.17	8.00	8.25	4.67	4.77	4.84
Oil:wax(8:2)	60.67	56.00^{a}	55.00^{a}	8.17	7.90	8.17	4.67	4.73	4.86
Oil:wax(7:3)	60.67	57.67^{a}	58.00^{a}	8.17	7.97	8.20	4.67	4.69	4.85

Control=Uncoated; Oil=Coated with only coconut oil; Oil: wax (9:1)=Coated with coconut oil and beeswax (9:1); Oil: wax (8:2)=Coated with coconut oil and beeswax (8:2); Oil: wax (7:3)=Coated with coconut oil and beeswax (7:3). Means with different letters within each column are significantly different ($p < 0.05$).

Nasrin et al., (2018b) reported that ascorbic acid, TSS and pH content in fresh mandarin were 31.39 mg/100g, 4.1 % and 9.1%, respectively and during 16 days of storage, ascorbic acid content reduced severely to 14.3 mg/100g in control or uncoated fruits, while 22.4 mg/100g in the fruits coated with coconut oil. Pure coconut oil and castor oil helped in reducing the rate of ripening in Kagzi lime which results in dissolution of ascorbic acid to dehydro ascorbic acid during storage (Bisen et al., 2012). Porras et al., (2015) found that ascorbic acid content in fresh Verna lemon was 47.2 mg/100g in his study. Piga et al., (1997) found that after harvest "libson" lemon retained pH 2.55, acidity 7.33 (%) and TSS 6.4 (°Brix) and during storage acidity value was decreased slightly.

Table 2 represents the changes of total sugar, non-reducing sugar and reducing sugar content of BARI Malta-1throughout the storage period. Initial value of total sugar, non-reducing sugar and reducing sugar of BARI Malta-1 was 7.77%, 4.94% and 2.83%, respectively and during storage all sugar values were increased slightly but there were no significant differences ($p < 0.05$). Nasrin et al (2018b) reported that total sugar and reducing sugar of mandarin was 10.78% and 4.17%, respectively at initial stage, but these values were increased slightly with storage period. Initial value of ascorbic acid,

total sugar and reducing sugar of Nagpur mandarin was 30.8 mg/100 ml, 8.1% and 3.7%, respectively found by Ladaniya (2011). Figure 5 depicts the visual perspectives of BARI Malta-1 as impacted by edible coating during experimental investigations conducted at room temperature (27±4) °C.

Table 2. Sugar contents of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C.

Treatment	Reducing sugar (%)			Non-reducing sugar (%)			Total sugar (%)		
	0 day	9 days	18 days	0 day	9 days	18 days	0 day	9 days	18 days
Control	2.83	2.89	3.05	4.94	6.43	7.1	7.77	9.34	10.15
Oil	2.83	2.98	3.88	4.94	5.70	6.14	7.77	8.68	10.02
Oil:wax(9:1)	2.83	3.11	3.24	4.94	5.51	6.99	7.77	8.62	10.23
Oil:wax(8:2)	2.83	2.73	3.19	4.94	5.84	6.81	7.77	8.57	10.00
Oil:wax(7:3)	2.83	2.69	3.28	4.94	6.04	6.79	7.77	8.73	10.07

Control=Uncoated; Oil = Coated with only coconut oil; Oil: wax (9:1) = Coated with coconut oil and beeswax (9:1); Oil: wax (8:2) = Coated with coconut oil and beeswax (8:2); Oil: wax (7:3) = Coated with coconut oil and beeswax (7:3).

Fresh BARI Malta-1 at the day of harvest

Uncoated BARI Malta-1 at 18 days of storage

Coconut oil coated BARI Malta-1 at 18 days of storage

Coconut oil & beeswax (7:3) coated BARI Malta-1 at 18 days of storage

Coconut oil & beeswax (8:2) coated BARI Malta-1 at 18 days of storage

Coconut oil & beeswax (9:1) coated BARI Malta-1 at 18 days of storage

Fig. 5. Pictorial view of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C.

Conclusion

Coconut oil and 3 different mixtures of coconut oil and beeswax (9:1, 8:2 and 7:3 w/w basis) are a natural, low cost, healthy edible coating and also very easy to apply any fruits like BARI Malta-1. The physico-chemical parameters of BARI Malta-1 were positively influenced by coconut oil beeswax or only coconut oil coating up to 18 days during storage at ambient temperature (27±4) °C**.** Mixtures of coconut oil, beeswax or even only coconut oil coating assisted to preserve weight, firmness, appearance and

ascorbic acid content of BARI Malta-1 very efficiently than uncoated BARI Malta-1 throughout the storage period. In future, similar study can be carried out using these edible coatings in BARI Malta-1 at recommended low temperature or these coating can be applied in other fruits.

Acknowledgement

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References

AOAC, (1994). Official Methods of Analysis. Association of Official Analytical Chemists. 1111. North 19th Street, Suite 20, 16th Edi. Arlington, Virginia, USA. 22209.

Arun, G.C. and Ghimire, K. (2019). Estimating post-harvest loss at the farm level to enhance Food Security: A Case of Nepal. *International Journal of Agriculture, Environment and Food Sciences*, 3:127–136.

Bajwa, B.E. and Anjum, F.M. (2007). Improving storage performance of *Citrus reticulata* Blanco mandarins by controlling some physiological disorders. *International Journal of Food Science and Technology*, 42: 459–501.

Bisen, A., Pandey, S. K. and Patel, N. (2012). Effect of skin coatings on prolonging shelf life of kagzi lime fruits (Citrus aurantifolia Swingle). *Journal of Food Science and Technology*, 49(6):753–759. DOI 10.1007/s13197-010-0214-y.

DHCP. (2017). Digital herbarium of crop plants, Department of crop botany, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU). https://dhcrop.bsmrau.net/references/

Kiong, A.L.P., Wan, L.S., Hussein, S. and Ibrahim, R. (2008). Induction of somatic embryos from explants different of *Citrus sinensis*. *Journal of plant Science,* 3(1): 18-32. DOI: 10.3923/jps.2008.18.32

Ladaniya, M.S. (2011). Physico-chemical, respiratory and fungicide residue changes in wax coated mandarin fruit stored at chilling temperature with intermittent warming. *Journal of Food Science and Technology*, 48(2): 150–158.

Ladaniya, M.S., (2004). Citrus: Postharvest Cold Chain, Pp. 239-276.

Liberman, S., Enig, M.G. and Preuss, H.G. (2006). A review on monolaurin and lauric acid: natural virucidal and bactericidal agents. *Alternative and Complementary Therapy*, 12(6): 310-314. https://doi.org/10.1089/act.2006.12.310

Nasrin, T.A.A., Arfin, M.S., Rahman, M.A., Molla, M.M. Sabuz, A.A. and Matin, M.A. (2023). Influence of novel coconut oil and beeswax edible coating and MAP on postharvest shelf life and quality attributes of lemon at low temperatures. *Measurement: Food*, 10:100084. https://doi.org/10.1016/j.meafoo.2023.100084

Nasrin, T.A.A., Rahman, M.A., Arfin, M.S., Islam, M.N., and Ullah, M.A. (2020). Effect of novel coconut oil and beeswax edible coating on postharvest quality of lemon at ambient storage. *Journal of Agriculture and Food Research*, 2:100019. https://doi.org/10.1016/j.jafr.2019.100019

Nasrin, T. A. A., Rahman, M. A., Hossain, M. A., Islam, M. N., and Arfin, M. S. (2018a). Effect of edible coating on postharvest quality of bell pepper at ambient storage. *Bulletin, Institute of Tropical Agriculture, Kyushu University*, 41:73-83. https://doi.org/10.11189/bita.41.73. 4.

Nasrin, T.A.A., Islam, M.N., Rahman, M.A., Arfin, M.S., Ullah, M.A. (2018b). Evaluation of postharvest quality of edible coated mandarin at ambient storage. *International journal of agricultural research innovation and technology.* 8 (1):18-25.

Nasrin, T.A.A., Rahman, M.A., Hossain, M.A., Islam, M.N., and Arfin, M.S. (2017). Postharvest quality response of strawberries with aloe vera coating during refrigerated storage. *Journal of Horticultural Science and Biotechnology*, 92:6, 598-605. https://doi.org/10.1080/14620316.2017.1324326

Obeed, R.S. and M.M. Harhash (2006). Impact of postharvest treatments on storage life and quality of "Mexican" Lime. *Journal of the Advances in Agricultural Researches*,11 (3):189-193.

Piga, A., Daquino, S., Agabbio, M., and Piergiovanni, L. (1997). Polyethylene film packaging affects quality of 'libson' lemons during long-term storage. *Italian Journal of Food Science*,1(9):25-34.

Porat, R., Weiss, B., Cohen, L., Daus, A. and Aharoni, N. (2004). Reduction of postharvest rind disorder in citrus fruit by modified atmosphere packing. *Postharvest Biology and Technology*, 33: 35-43.

Porras, J.M., Brotons, A., Conesa, R., Castaner, O., Perez-Tornero1, F. J., Manera. (2015). Quality and fruit colour change in Verna lemon. *Journal of Applied Botany and Food Quality*, 88: 215 -221.

Sakhale, B.K. and Kapse, B.M. (2012). Studies on shelf-life extension of sweet oranges (Citrus sinensis L.). *International Food Research Journal*, 19(2): 779-781.

Shahid, M.N. and Abbasim, N.A. (2011). Effect of bee wax coatings on physiological changes in fruits of sweet orange Cv. "Blood re". *Sarhad Journal of Agriculture*, 27(3): 385-394.

Woods, J. L. (1990). Moisture loss from fruits and vegetables. *Postharvest News Information*, 1: 195 - 199.