Journal of Tropical Crop Science Vol. 4 No. 1, February 2017
www.j-tropical-crops.com

Improvement of Shelf Life and Sensory Quality of Pummelos by Fruit Waxing and Wrapping

Titistyas Gusti Aji, Slamet Susanto*, Dewi Sukma, Sintho Wahyuning Ardie

Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University.
Jl. Meranti, Kampus IPB Dramaga, Bogor 16680, Indonesia

*Corresponding author; email: slmtsanto@gmail.com

Abstract

The aims of this study were to evaluate the physical and chemical change of pummelo fruit during storage with waxing and wrapping, and to determine the effect of waxing and wrapping and its interaction in affecting shelf life of pummelo fruits. This research was arranged in a randomized complete block design with two factors and three replications. The first factor was waxing consisted of without waxing, 10% beeswax, 5% beeswax, and chitosan. The second factor was wrapping consisted of without wrapping and wrapping using either transparent yellow or white plastic wrap. Pummelo fruits experience weight loss, reduced total soluble solid (TSS), decrease in firmness and total acidity during 48 days of storage in room temperature. Waxing using beeswax or wrapping using plastic wraps significantly suppressed weight loss and maintained fruit firmness compared to those without waxing and wrapping. However, waxing and wrapping did not significantly affect the quality of pummelo fruits. Based on the fruit's weight loss, firmness, and panelist preferences, 5% or 10% bees wax can be used as waxing. Both transparent yellow and white plastic wraps can be used to maintain fruit weight, firmness, and appearances during storage.

Keywords: *Citrus grandis* (L.) Osbeck, coating, internal quality, plastic packaging

Introduction

Pummelo (*Citrus grandis* (L.) Osbeck) is one of 60 fruits that is aprioritized commodity to be developed according to Indonesian Directorate General of Agriculture. Pummelo has potentials to be developed in Indonesia because of its unique characteristics, including its large size, good flavor, and a relatively long shelf life (Susanto, 2004). In addition to these advantages, pummelo also contains substances that are beneficial to the human health (Tsai et al., 2007; Oyedepo, 2012). Amongst the wide varieties of pummelo accessions in Indonesia there are seeded, potentially seedless, and seedless accessions. “Cikoneng”, “Jawa 2”, “Magetan”, “Sri Nyonya”, “Adas Duku”, “Bali Putih”, and “Muria Merah 2” have seeds. The potentially seedless accessions are “Bali Merah 1” and “Nambangan”, whereas “Jawa 1”, “Bali Merah 2”, “Bageng Taji”, and “Muria Merah 1” are seedless (Rahayu, 2012).

Lack of quality, quantity, and continuous supply is one of the main problems of Indonesian horticultural production in general. The seasonal nature of pummelo causes abundant amount of fruits available in the market during harvest seasons that resulting in a significant price drop. One of the strategies to have a continuous supply of pummelo in the market is to increase its shelf life after harvest so the period of fruit availability could be extended. Pummelo has a relatively long shelf life and methods to keep fruit quality during storage needs to be improved.One of the methods that can be used to extend the shelf life of fruits is by fruit coating. Beeswax and chitosan are edible coatings and widely used as coating materials. According to Pavlath and Orts (2009), edible coatings are all kinds of material used as a coating on various foods that aim to extend the shelf life of the products, which can be consumed together with the food, both with and without the disposal of the coating. Wax coating was able to maintain the physical and chemical quality of Nambangan pummelo (Siahaan, 1998) and Blood Red sweet orange (Shahid and Abbasi, 2011). The use of chitosan as a coating was able to reduce fungal infection while maintaining the fruit quality of tangor (Chien et al., 2007) and grapefruit (Abdel-Kader et al*.,* 2011) during storage.

In addition to coating, plastic packaging can also be applied to maintain fruit quality during storage. Packaging with a polymer film that has a permeability to certain gases creates a modified atmosphere conditions around the product. This allows control of gas and in turn can affect physiological processes in fruit (Lange, 2000). Rusmono (1999) reported that the white stretch plastic and stretch plastic have a different permeability to oxygen and carbon dioxide gas which then affect the shelf life of fruits. Wrapping applied to tangelo was able to provide a beneficial effect not only maintain but also improve the organoleptic quality of fruit (D'Aquino et al*.,* 1998). Sonkar and Ladaniya (1999) reported that wrapping using either heat-shrinkable (LDPE) or stretch-cling (LLDPE) in mandarin were able to reduce the rate of water loss, respiration, fruit softening, and total acidity of fruit.

Knowledge about postharvest characteristics and handling methods is required to maintain fruit quality and extend fruit shelf life. Various postharvest technologies to slow deterioration can be developed by understanding the natural characteristics of the fruits and quality deterioration that occurs after harvest. Until now, the study of postharvest handling of pummelo in Indonesia is still limited, one of them is the coating and packaging for pummelo during storage. The purpose of this study were to: 1) evaluate the changes in physical and chemical characteristics of pummelo that is affected by coating and wrapping during storage, and 2) identify the effect of coating,wrapping, and its interaction on the shelf life of pummelo.

Materials and Methods

This research was conducted in Postharvest Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University from May to August 2014. Fruit used were seeded pummelo cultivar of "Muria Merah 2". Coating materials used were beeswax and chitosan. Transparent yellow plastic wrap and transparent white plastic wrap were used for wrapping. Fruit quality analysis performed using 0.01 N iodine solution, 0.1 N NaOH solution, distilled water, phenolphthalein, and 1% starch solution. Penetrometer was used to measure fruit firmness, a refractometer to determine the total soluble solids, and titration apparatus to measure total acidity and total soluble solids.

Pummelo fruits were harvested from the farmers orchard in Kudus, Central Java, Indonesia. The fruits were transported by road to Postharvest Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University in Bogor, West Java. Upon arrival, fruits were sorted for peel color, weight, and fruit defects. Once sorted, the fruits were washed with water and air dried overnight. Coating was conducted by soaking the fruits in a coating solution for 60 seconds, air dried for ± 24 hours, and wrapped. Fruits were stored in a room with a range temperature of 24 to 27 °C and humidity of 70 to 80%.

The research design used in this experiment was factorial randomized complete block design with two factors, waxing and wrapping. There were four levels of coating; without coating (W0), coating using 10% beeswax (W1), coating using 5% beeswax (W2), and coating using a 1.5% chitosan (W3); and three levels of wrapping; without wrapping (P0), wrapping using transparent yellow plastic wrap (P1), and wraping using transparent white plastic wrap (P2). Experiments were carried out in three replications so that there were 36 experimental units in total. There were 11 fruits in each experimental unit, in which three fruits were used for non-destructive analysis, and eight fruits were used for destructive analysis, totalling 396 fruits.

Observations were carried out on external, internal, and sensory characters. External characters consisted of weight loss, firmness, and visual appearance of fruit. Internal character consisted of total soluble solids (TSS) and total acidity (TA). In sensory character observation, hedonic test were conducted where panelists determined preferences for fruit taste and appearance. Observations were conducted every two weeks, from week 0 to 12 weeks after treatment (WAT). Weight loss was determined by weighing the fruit during storage and calculating the weight loss in relation to fruit weight at the beginning of storage. The results were expressed as percentage (%). Fruit firmness was determined using penetrometer. Firmness values of the fruits (mm per 50 g per 5 second) were obtained from an average of three measurements at the end, middle, and base of the fruits. Visual observation was conducted by scoring the fruit appearance including peel smoothness and peel color during storage. The scale used for peel smoothness was one to four, where 1 = smooth, 2 = somewhat smooth, 3 = somewhat shriveled, and 4 = shriveled. The scale used for peel color was one to six, where 1 = dark green, 2 = light green, 3 = yellowish green, 4 = greenish yellow, 5 = light yellow, and 6 = dark yellow. The content of TSS and TA were determined using standard procedures as described in AOAC (1995). Total soluble solids (°Brix) was measured by direct reading of fruit juice on the refractometer lens. Total acidity (%) was measured by titration with 0.1 N NaOH. The hedonic test was conducted by 20 panelists, where panelists were asked to express their personal preferences using hedonic scale, where 1 = extremely dislike, 2 = dislike, 3 = somewhat like, 4 = like, and 5 = extremely like.

Parametric data was tested using the F test at significance level (α) = 0.05. If the F test results showed significant effects, data were further analysed by Duncan's Multiple Range Test (DMRT).

Results and Discussion

Non-coated fruits, non-wrapped fruits, and fruits coated with chitosan were only able to be stored up to 8 WAT, while fruits coated with beeswax, either 10% or 5%, and wrapped fruits, either with transparent yellow or transparent white plastic wrap, were able to be stored up to 12 WAT. According to Pascall and Lin (2013), chitosan is a polysaccharide based edible film that has good oxygen but poor moisture barrier properties, while beeswax is a lipid based edible film and has good moisture barrier. The poor ability to retain moisture of chitosan coating caused a great loss of water which could result in a reduced fruit shelf life.

Fruit Weight Loss

Weight loss associated with the shelf life of fruit is mainly caused by the loss of moisture from the fruit through transpiration process. The results of this experiment showed that weight loss increased throughout the storage period (Figure 1). Coating and wrapping were generally able to sustain the weight of the fruit during storage period (Table 1). Similar results were also found in grapefruit (Rodov et al., 2000), sweet orange (Shahid and Abbasi, 2011), and tangerne (Boonyakiat et al., 2012; Hassan et al., 2014) where coated fruits have lower weight loss percentage than non-coated ones. Application of plastic packaging in lemon (Cohen et al., 1990; Piga et al., 1997), mandarin (Tariq et al., 2004), and sweet orange (D'Aquino et al., 2001; Rab et al., 2010; Tabatabaekoloor, 2012) also demonstrated a similar effect on the inhibition of fruit weight loss.

Weight loss is considered as one the main causes of declining visual quality in agricultural products, which is mainly caused by water loss through transpiration. The high rate of transpiration causes desiccation, wilting, decreasing fruit firmness, and lowering the visual quality of the fruit due to shrinkage. Coating and wrapping suppressed fruit transpiration rate so that the rate of water loss can be reduced, thus keeping the aesthetic value of the fruit. Coating and wrapping function as a barrier between fruit and its environment. This barrier inhibits water loss and reduces fruit weight loss.

Fruit Firmness

Fruit firmness declined during storage (Figure 2). Coating and wrapping kept the fruit firmness at 2, 4, 6, and 8 WAT as compared to non-coated and non-wrapped fruits. There was significant increase in softness in the non-coated fruits, and fruits coated with either beeswax or chitosan at of 103.54%, 49.08%, and 81.96%, respectively, at 8 WAT. Meanwhile, the softness increase in non-wrapped fruits and wrapped fruits were 91.49% and 52.39%, respectively. Similar results were reported by Shahid and Abbasi (2011) that beeswax coating on sweet oranges was able to maintain fruit hardness during storage. Fruits wrapped either with transparent yellow or transparent white plastic wrap had lower fruit softening compared to non-wrapped fruits. These results are consistent with research on lemon (Cohen et al., 1990), grapefruit (Rodov et al., 2000), and sweet orange (D'Aquino et al., 2001; Tabatabaekoloor, 2012), in which packed fruits were firmer compared to non-packed fruits.

The integrity of cell wall decreased as storage period increased. As fruit firmness decreases, pectin and hemicellulose undergo a depolymerization process that resulted in cell wall softening and disintegration (Vicente et al., 2007). Coating and wrapping maintained fruit firmness by a mechanism similar

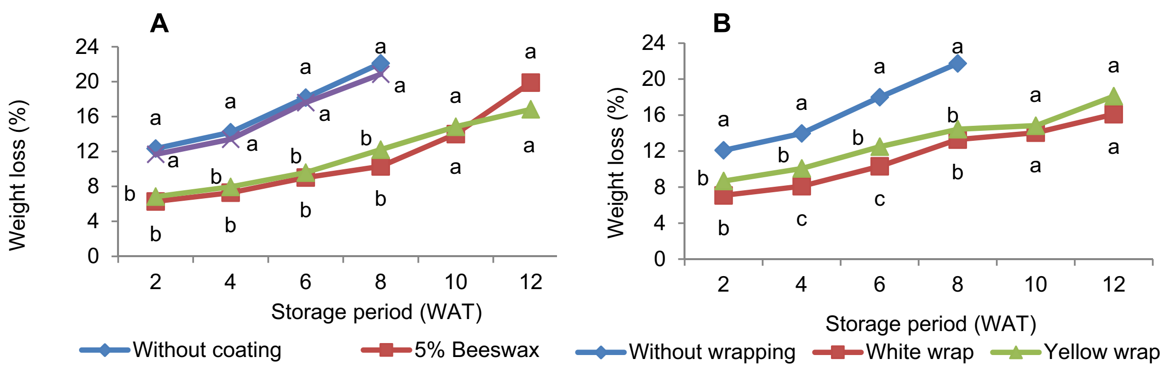


Figure 1. Effect of coating (A) and wrapping (B) on weight loss of pummelo "Muria Merah 2"

to controlled atmosphere packaging, by reducing the rate of respiration and transpiration, supressing senescence, and reducing the rate of cell wall degradation. Coated and wrapped fruits tend to be firmer than non-coated and non-wrapped fruits due

Table 1. Effect of coating and wrapping on weight loss and fruit firmness at eight week after treatment

Treatments	Without wrapping	Yellow plastic wrap	White plastic wrap
	Fruit weight loss (%)		
Without coating	35.69 a	19.60 b	17.92 bc
10% Beeswax	13.45 bc	10.12 c	13.50 bc
5% Beeswax	16.97 bc	11.84 bc	14.63 bc
Chitosan	30.75 a	17.83 bc	19.46 b
	Fruit firmness (mm per 50 g per 5 s)		
Without Coating	22.33 a	16.18 cde	19.00 bc
10% Beeswax	15.72 defg	13.00 fg	13.22 efg
5% Beeswax	15.81 defg	12.93 g	13.04 fg
Chitosan	19.22 b	16.00 def	16.33 cd

Note: values followed by different letters within the same column are significantly different at α = 0.05.

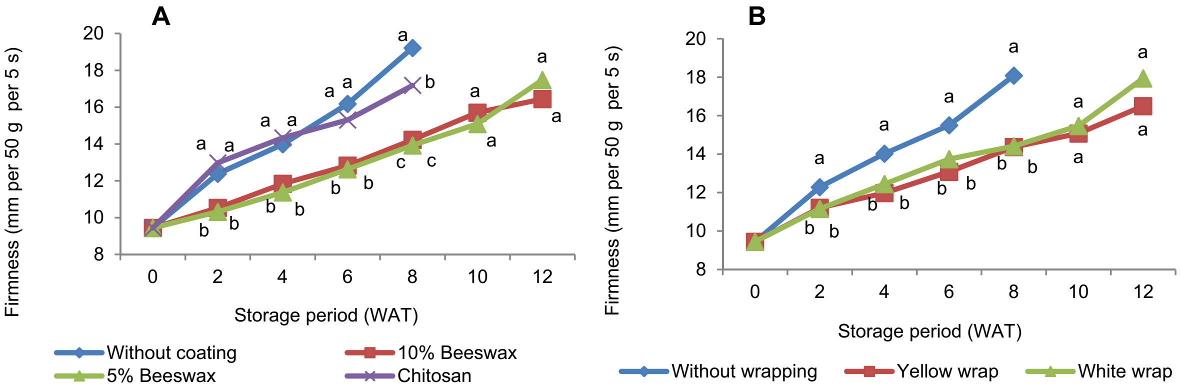


Figure 2. Effect of coating (A) and wrapping (B) on fruit firmness of pummelo “Muria Merah 2”

to the low rate of pectin depolymerization of the cell wall. Fruit firmness is also closely related to decrease in water potential. Coating and wrapping can reduce water loss and maintain fruit turgor. In this study, the combination of beeswax coating, either 10% or 5%, either with transparent yellow or transparent white plastic wrapping, was able to reduce the rate of weight loss and fruit softening during storage (Table 1).

Fruit Appearance

Peel shriveled and its color changed as storage period increased (Table 2). Water loss is a major cause of declining quality of fruit after harvest. The decreasing turgidity due to water loss causes cell shrinkage and decreases the visual quality of the fruit. In this experiment, coated fruits and fruits wrapped with transparent yellow plastic wrap had lower score of shrinkage level at 8 WAT compared to non-coated fruits and non-wrapped fruits. Coating and wrapping were used to suppress water loss from the fruit, prevent shrinkage, and delay ripening which resulted in maintaining the quality of fruit (Tabatabaekoloor, 2012; Hassan et al*.*, 2014).

Other changes that occur during storage is peel discoloration. At the beginning of storage, peel color was dark green to light green and greenish-yellow to light yellow at the end of storage (Figure 3). Discoloration occurs because of chlorophyll degradation and an increase in carotenoid during storage period (Boonyakiat et al*.*, 2012; Machado et al*.*, 2012). Coating with beeswax and wrapping were able to slow down the metabolism and chlorophyll degradation which in turn maintain the greenish color of peel until the end of the storage.

Total Acidity (TA) and Total Soluble Solid (TSS)

Coating and wrapping did not affect the TA and TSS content of the fruits throughout the storage period. In addition, there was no interaction between treatments during storage period (Figure 3). Similar results were reported on other citrus fruits such as lemon (Piga et al., 1997); grapefruit (Rodov et al., 2000) and orange (Tariq et al., 2004).

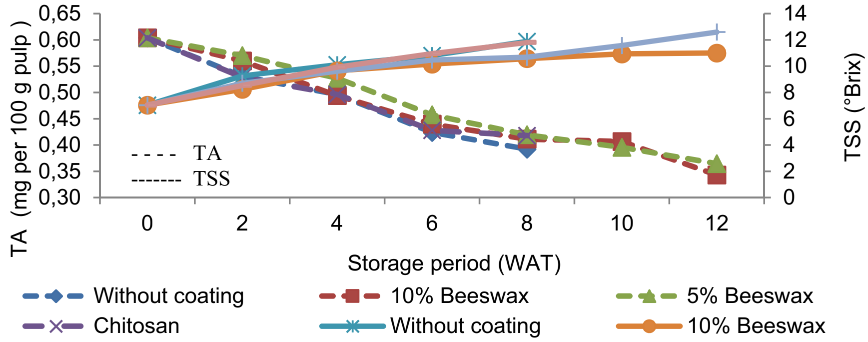
The acid content of pummelo fruit decreased during storage while TSS increased (Susanto et al*.*, 2010). Changes in TA and TSS content of fruit throughout

Table 2. Effect of fruit coating and wrapping on peel color and peel smoothness at eight weeks after treatment

Treatment	Storage period (weeks after treatment)					
	Peel color			Peel smoothness		
	4	8	12	4	8	12
Fruit coating						
Without coating	3.89 a	5.11 a	-	2.67 a	3.33 a	-
10% Beeswax	2.89 b	3.78 b	4.00	1.44 b	2.44 b	3.33
5% Beeswax	2.78 b	3.78 b	4.00	1.67 b	2.44 b	3.33
Chitosan	3.11 ab	4.44 ab	-	1.89 ab	2.44 b	-
Fruit wrapping						
Without wrapping	3.92 a	5.33 a	-	2.42 a	3.08 a	-
Yellow wrap	2.92 b	3.83 b	4.33	1.67 b	2.33 b	3.00
White wrap	2.67 b	3.67 b	3.67	1.67 b	2.58 ab	3.67
Interaction	*	*	ns	*	*	ns

Note: values followed by different letters within the same column are significantly different at α = 0.05.

A



B

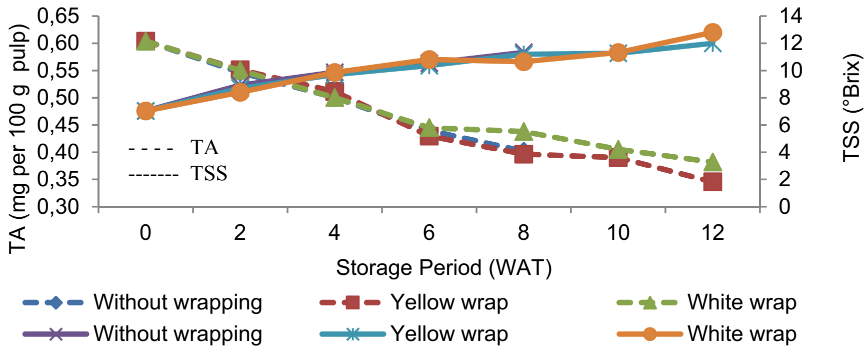


Figure 3. Effect of coating (A) and wrapping (B) on total acidity (TA) and total soluble solid (TSS) of pummelo "Muria Merah2"

the storage period were caused by breakdown of polysaccharides and organic acids into sugars through the respiration process. Pummelo is a non-climacteric fruit that does not experience a dramatic increase in respiration rate during maturation process. Hence, the content of sugars and acids in all treatments tend to be similar throughout the storage period. Similar results were observed in vitamin C content which decreased due to oxidation of organic acids as part of respiration process, but the vitamin C levels were similar between treatments (data not shown).

Sensory Characters

Evaluation on the sensory characteristics of pummelo fruits demonstrated that coating and wrapping

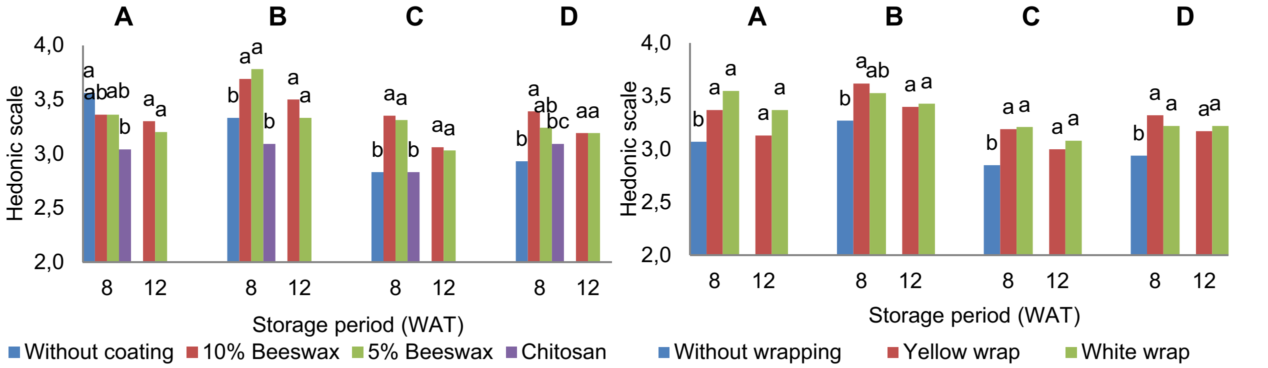


Figure 4. Effect of coating (left) and wrapping (right) on sweetness (A), acidity (B), peel color (C) and peel smoothness (D) of pummelo 'Muria Merah 2' during storage

can maintain the fruit taste and appearance during storage (Figure 4). Control fruits were the sweetest, but it was not significantly different from fruits coated with 5% or 10% beeswax. Fruit wrapping either with transparent yellow or transparent white plastic wrap resulted in the sweeteest fruits after eight weeks in storage. Fruits coated with beeswax had the most acceptable fruit acidity. Fruits wrapped with yellow or white plastic had similar levels of acidity.

Coating and wrapping also affected the panelist preferences on the appearence of pummelo. At 8 WAT, fruits coated with 10% beeswax had the highest score on peel smoothness but not significantly different from fruits coated with 5% beeswax. Furthermore, fruits coated with beeswax had the highest score on peel color. Fruits wrapped either with transparent yellow or transparent white plastic wrap had the most preferred smoothness and peel color (Figure 4). Overall, combination of beeswax coating, either 10% or 5%, with wrapping, either with transparent yellow or transparent white plastic wrap, had the best score on the taste and appearance of fruit (Table 3).

Coatings and wrapping also affect the appearance of fruit pummelo. Coating with 10% beeswax had the highest value on peel smoothness but not significantly different from the coating of 5% beeswax, while for the peel color, panelists showed the highest value on the beeswax treatments on the storage of 8 weeks. Fruits wrapped either with transparent yellow or transparent white plastic wrap had the most preferred

Table 3. Interaction between coating and wrapping on pummelo sensory characteristics at eight weeks after treatment

Treatments	Sweetness			Peel color		
	Without wrapping	Yellow wrap	White wrap	Without wrapping	Yellow wrap	White wrap
Without coating	3.33 abc	3.73 a	3.60 ab	2.67 ef	2.89 def	2.94 def
10% Beeswax	3.00 cd	3.20 bc	3.87 a	3.06 cde	3.56 a	3.44 ab
5% Beeswax	3.40 abc	3.13 bc	3.53 abc	3.11 bcd	3.33 abc	3.50 a
Chitosan	2.53 d	3.53 ab	3.20 bc	2.56 f	3.00 cde	2.94 def
	Acidity			Peel smoothness		
Without coating	3.73 ab	3.93 ab	2.80 de	2.72 d	3.06 cd	3.00 cd
10% Beeswax	3.40 bcde	3.87 ab	3.87 ab	3.06 cd	3.44 ab	3.67 a
5% Beeswax	4.00 a	3.53 abc	3.60 abc	3.06 cd	3.50 ab	3.17 bc
Chitosan	2.73 e	3.40 abcd	3.07 cde	2.94 cd	3.28 bc	3.06 cd

Note: values followed by different letters in the same column are significantly different at α = 0.05

peel smoothness and peel color (Figure 4). In general, the combination of beewax coating, either 10% or 5%, with wrapping either with transparent yellow or transparent white plastic wrap was the most preferred due to the fruit taste and appearance (Table 3).

Conclusion

Fruit weight and fruit firmness decreased whereas TSS increased during storage. Fruit color changed from green to yellow. Fruit shriveling results in decreased hedonic scores in taste and appearance. Waxing and wrapping suppressed weight loss and maintained firmness of pummelo fruits; however, these treatments did not significantly affect pummelo sensory quality during storage. Beeswaxing at 5 or 10%, combined with yellow or white transparent plastic wrap is recommended to extend the pummelo fruit shelf life.

Acknowledgement

This research was funded by the Directorate General of Higher Education of Ministry Education and Culture, through the National Competitive Research Grants in 2014 on behalf of Prof. Dr. Ir. Slamet Susanto, M.Sc.

References

Abdel-Kader, M., El-Mougy, N., and Lashin, S. (2011). Evaluation of grapefruit coating with chemical preservatives as control measure against postharvest decay. *Pytopathologia* **59**, 25-38.

AOAC. (1995). “Official Methods of Analysis of AOAC International, 16th Edition”. 1141 pp. Washington DC, USA.

Boonyakiat, D., Seehanam, P., and Rattanapanone, N. (2012). Effect of fruit size and coating material on quality of tangerine fruit cv. Sai Nam Phueng. *Chiang Mai University Journal of Natural Sciences* **11**, 213-230.

Chien, P.J., Sheu, F., and Lin, H.R. (2007). Coating citrus (*Murcott tangor*) fruit with low molecular weight chitosan increases postharvest quality and shelf life. *Food Chemistry* **100**, 1160-1164.

Cohen, E., Lurie, S., Shapiro, B. Ben-Yehoshua, S. Shalom, Y., and Rosenberger, I. (1990). Prolonged storage of lemons using individual seal-packaging. *Journal of the American Society for Horticultural Science* **115**, 251-255.

D’Aquino, S., Piga, A. Agabbio, M., and McCollum, T.G. (1998). Film wrapping delays ageing of ‘Minneola’ tangelos under shelf-life conditions. *Postharvest Biology and Technology* **14**, 107–116.

D’Aquino, S., Molinu, M.G. Piga, A., and Agabbio, M. (2001). Influence of film wrapping on quality maintenance of “Salustiana” oranges under shelf-life condition. *Italian Journal of Food Science* **1**, 87-100.

Hassan, Z.H., Lesmayati, S. Qomariah, R., and Hasbianto, A. (2014). Effects of wax coating applications and storage temperatures on the quality of tangerine citrus (*Citrus reticulata*) var. Siam Banjar. *International Food Research Journal* **21**, 641-648.

Lange, D.L. (2000). New film technologies for horticultural products. *Horticulture Technology* **10**, 487-490.

Machado, F.L.C., Costa, J.M.C., and Batista, E.N. (2012). Application of carnauba-based wax maintains postharvest quality of “Ortanique” tangor. *Ciência* e Tecnologia de *Alimentos* **32**, 261-268.

Oyedepo, T.A. (2012). Effect of *Citrus maxima* (Merr.) fruit juice in alloxan-induced diabetic wistar rats. *Science Journal of Medicine and Clinical Trials* **2012**, 1-6.

Pascall, M.A., and Lin, S.J. (2013). The application of edible polymeric films and coatings in the food industry. *Journal of Food Processing and Technology* **4**, 1-2.

Pavlath, A.E., and Orts, W. (2009). “Edible Films and Coatings: Why, What, And How?”. 1-23 pp. Springer.

Piga, A., D’Aquino, S., Agabbio, M., and Piergiovanni, L. (1997). Polyethylene film packaging affects quality of ‘Lisbon” lemons during long-term storage. *Italian Journal of Food Science* **1**, 25-35.

Rab, A., Haq, S., Khalil, S.A., and Ali, S.G. (2010). Fruit quality and senescene related changes in sweet orange cultivar blood red uni-packed in different packing materials. *Sarhad Journal of Agriculture* **26**, 221-227.

Rahayu, A. (2012). Karakterisasi dan Evaluasi Aksesi

Pamelo (*Citrus maxima* (Burm.) Merr.) Berbiji dan Tidak Berbiji Asli Indonesia. Thesis. Institut Pertanian Bogor. Indonesia.

Rodov, V., Agar, T., Peretz, J., Nafussi, B., Kim, J.J., and Ben-Yehoshua, S. (2000). Effect of combined application of heat treatments and plastic packaging on keeping quality of "Oroblanco" fruit (*Citrus grandis* L. x *C. paradisi* Macf.). *Postharvest Biology and Technology* **20**, 287-294.

Rusmono, M. (1999). Pengembangan Model Simulasi Penyimpanan Buah Terolah Minimal Berpelapis Edibel dalam Kemasan Atmosfir Termodifikasi. Thesis. Institut Pertanian Bogor. Indonesia.

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

Siahaan, O.S.B. (1998). Pengaruh Pelapisan Lilin Terhadap Daya Simpan Buah Jeruk Besar (*Citrus grandis* L. Osbeck) cv. Nambangan pada Dua Kondisi Suhu yang Berbeda. Thesis. Institut Pertanian Bogor. Indonesia.

Sonkar, R.K., and Ladaniya, M.S. (1999). Individual film wrapping of Nagpur mandarin (*Citrus reticulata* Blanco) with heat-shrinkable and stretch-cling films for refrigerated storage. *Journal of Food Science and Technology* **36**, 273-276.

Susanto, S. (2004). Changes in fruit quality of pummelo experiencing storage and remaining on the tree. *Journal Hayati* **11**, 25-28.

Susanto, S., Ginting, M.R., Tyas, K.N., and Rahayu, A. (2010). Change of fruit quality of 11 pummelo cultivars during storage. *In* "Re-Orientation Research for Optimize the Production and Horticultural Chain Value". (I.M.S. Utama, A.D. Susila, R. Poerwanto, N.S. Antara, N.K. Putra and K.B. Susrusa eds.), pp. 396-401. Indonesian Horti-cultural Association.

Tabatabaekoloor, R. (2012). Orange responses to storage conditions and polyethylene wrapped liner. *Agricultural Engineering International: CIGR Journal* **14**, 127-130.

Tariq, M.A., Thompson, A.K., Asi, A.A., Virk, N.A., and Javid, M.A. (2004). Curing and seal packaging effect on peel and pulp weight loss in scuffing damaged and undamaged citrus fruit. *Journal of Agricultural Research* **42**, 67-72.

Tsai, H.L., Chang,S.K.C., and Chang, S.J. (2007). Antioxidant content and free radical scavenging ability of fresh red pummelo [*Citrus grandis* (L.) Osbeck] juice and freeze-dried products. *Journal of Agricultural and Food Chemistry* **55**, 2867-2872.

Vicente, A.R., Saladie, M., Rose, J.K.C., and Labavitch, J.M. (2007). The linkage between cell wall metabolism and fruit softening: looking to the future. *Journal of the Science of Food and Agriculture* **87**, 1435-1448.