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Fruit Coating with Chitosan and Beeswax to Extend Papaya Shelf Life

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Abstract

Papaya (*Carica papaya*) is a climacteric fruit with an increased respiration rate during ripening process. Papaya respiration rate can be inhibited by providing a coating on the surface of the fruits, including chitosan, a polysaccharide derived from shrimp shell waste, or beeswax.The purpose of this research was to examine the effects of chitosan and beeswax coating on the shelf life and quality of papaya Callina fruit during storage. Results of the experiments showed that fruit coating with chitosan and beeswax can extend the shelf life of papaya Callina by four to five days compared to control due to inhibition respiration rate of papaya fruits during storage. The use of chitosan and beeswax was beneficial to maintain the physical and chemical quality of papaya Callina fruits.

Keywords: chemical quality, physical quality, postharvest ripening, respiration rate

Introduction

Papaya is a tropical fruit with high commercial importance in Indonesia and worldwide due its high nutritive and medicinal value. In 2013, Indonesia was able to export more than 25 tons of papaya to countries including Thailand, Singapore, Saudi Arabia, Kuwait, United Arab Emirates, Qatar, Bahrain and Netherlands amounting up to US $ 33732 (Kementerian Pertanian, 2014). Overseas markets as such require high quality fruits so efforts to inhibit the maturity is required to extend the shelf life and to maintain papaya fruit quality.

One of the methods to prolong the shelf life of fruit is by providing a thin layer of coating on the surface of the fruits. As reported by Simson and Straus (2010) fruit coating can extend post-harvest period by replacing lost natural waxes through leaching and repairing minor wounds during postharvest handling. Recent studies have shown the benefit uses of fruit coating materials including chitosan and beeswax to extend fruit shelf life. Perez-Garaldo et al. (2015) reported that blackberry coating with beeswax allow gas exchange (O_2 and CO_2) and reduced accumulation of volatile compounds associated to fruit fermentative metabolism. Chien at al. (2007) reported that chitosan coating to mango fruits was effective to extend the shelf life and to maintain fruit quality.

Beeswax is derived from honeycomb and is produced by honey extraction. A study by Purwoko and Fitradesi (2000) showed that beeswax coating at 6% concentration can reduce weight loss and total soluble solids of papaya Solo cv Tainung compared to control after 14 days of storage. In Purwoko and Fitradesi (2000) study the beeswax emulsion was performed using triethanolamine. Triethanolamine is not suggested for consumption according to The Ministry of Health regulation (Kementerian Kesehatan, 2008) thus the beeswax emulsion using triethanolamine can not be used. Emulsion preparation can be done by using other emulsifying agents such as oleic acid, but the use of oleic acid will make the emulsion more concentrated. Therefore, in our study application by coating or smearing by brush was employed.

The use of chitosan in increasing post-harvest fruits and vegetables is an important concern in the food industry today. Chitosan is a polysaccharide derived from shrimp shell waste (Crustaceae), crabs, and crabs which can induce chitinase enzyme in plant tissue, that can degrade chitin which constitutes the fungi cell wall. Novita et al. (2012) reported in their study that chitosan can be used as a fungicide on tomatoes. In addition chitosan coating at 0.75% can be used to suppress disease infestation and damage intensity as well as inhibit fruit maturity in papaya during the six days of observation (Hamdayanty et al., 2012). The study, however, only recorded the shelf life and disease intensity and the optimum concentration of beeswax and chitosan to prolong the shelf life of papaya, but little is known about the effects of this compound on post-harvest parameters.

This study was conducted to evaluate the effects of chitosan and beeswax coating on shelf life and post harvest quality of papaya fruits.

Materials and Methods

The research was conducted in November 2014 until March 2015 in the experimental field of Center of Tropical Horticulture Study, Tajur, and Post Harvest Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University. The experiment used papaya fruits (*Carica papaya*) harvested at 120 days after anthesis (DAA). The fruit harvest and the coating treatment were performed on the same day after harvesting the fruits. Beeswax was made into 6% emulsion by heating 60 g of beeswax to melt, 160 ml oleic acid, and 840 ml of distilled water. Papaya were washed and drained prior to coating (polishing) with a beeswax emulsion, then aerated until the fruit dried.

The experiment was conducted using a completely randomised factorial design using three treatments with three replications, i.e. coating with chitosan at 0.75%, beeswax at 6%, and without coating material as control. Each treatments were repeated three times, so there were nine experimental units in total. The data obtained were analyzed by F-test and the comparison between treatments were further analyzed by Duncan Multiple Range Test (DMRT) test at 5% level of significance. The method described by Purwoko and Fitradesi (2000) was used for the production of beeswax emulsion.

Chitosan solution was prepared using the method described by Hamdayanty et al. (2012) which involved dissolving 0.75 g of chitosan in 100 ml of 10% acetic acid and pH was adjusted to pH 5.0 with sodium hydroxide (NaOH). Papaya fruits were prewashed and dried prior to coating with the chitosan solution. Papaya fruits were then dipped in chitosan solution for 15 seconds, drained, aerated to allow the fruits to dry quickly and coated evenly. Then papaya fruits were stored at room temperature (25-27°C).

Keeping quality was scored by recording the changes in color scale index, shelf life, fruit-scale color index, and respiration rate, fruit physical and chemical characters. Scoring of fruit shelf life started on the day fruits were harvested (day after harvest, DAH) until fruit reached index of color scale 6 or until the fruits are no longer suitable for consumption (Figure 1). Fruit color scale index was scored daily to determine changes in the skin color of the fruits. Our previous study (Suketi et al., 2015) determined that the use of the color scale index ≥ 4 can be used as a reference in determining the shelf life of papaya fruits as this is the stage where the papaya fruits are ready to be consumed.

Scoring on physical characters includes shrinkage of fruit weight, hardness of fruit skin, and hardness of fruit flesh.

1 2 3 4 5 6

Figure 1. Colour changes of the papaya skin (1) green; (2) green with a tint of yellow; (3) yellowish green; (4) greenish yellow; (5) yellow with green tips; (6) full yellow/orange

Scoring on chemical characteristics includes total soluble solids (TSS), total titratable acids (TTA), and content of vitamin C. Respiration rate was measured daily from the beginning of treatment until the papaya reached maturity stage six, or had exhibited signs of rotting. Weight loss, fruit skin hardness, TSS, TTA, and vitamin C content were scored when fruits had reached the maturity index six.

Results and Discussion

Keeping Quality and Fruit Color Scale Index

Coating with beeswax or chitosan extended the shelf life of the papaya Callina fruit (Table 1). The longest keeping duration was from the fruit treated

Table 1. Shelf life of papaya Callina treated with beeswax or chitosan at different fruit maturity stages

Treatments	Age (days after harvest)					
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Control	1	2.67b	4.00b	6.00	6.67b	7.67b
Beeswax	1	4.67a	7.33a	8.67	11.00a	damaged
Chitosan	1	6.00a	8.00a	9.00	10.33ab	11.33a

Note: Values followed by different letters in the same column are significantly different according to Duncan's multiple range test (DMRT) at α = 5%

with beeswax (12.33 DAH, Table 1). The shelf life of chitosan-treated papaya was 11.33 DAH, however, the differences were not significant from fruits treated with beeswax. The control papaya (uncoated) had the shortest shelf life of 7.67 DAH. Taris et al. (2015) reported that uncoated papaya Callina had a shelf life of 6.5 DAH when harvested at 120 days after anthesis.

Coated papaya fruits took a longer time to reach maturity stage six so their shelf life was longer, presumably due to lower respiration and transpiration. Straus (2010) reported that uncoated fruits had higher transpiration and respiration rate which rapidly increase fruit metabolism. The increase in metabolism may affect the rate of aging and ultimately reduce the fruit shelf life.

Chitosan coating on duku fruits was can inhibit the maturation process by preventing the release of gas, water vapor and contact with O_2, hence slows the maturation process (Trisnawati et al., 2013). The low respiration was due to non contact fruit surface with the environment, thus blocks water evaporating from the fruits.The beeswax-coated papaya fruits began to show symptoms of disease infection, indicated by the emergence of fungi and damaged during stage five, therefore the chemical scoring was conducted before the fruits reached stage six to avoid contamination. The growth of the fungus on beeswax-coated fruits may be related to the coating technique employed which had caused high humidity around the fruit. Rini (2008) reported that high humidity can cause the spores of papaya fruit to develop and spreading.

Chitosan-coated fruits had a better and smooth appearance and were free from fungi. Chitosan has antimicrobial properties that have the ability to inhibit pathogens and spoilage microorganisms, including fungi (Hafdani and Sadeghinia, 2011). The use of chitosan as a coating on varieties of food materials inhibits oxygen entry hence used in food packaging and is safe for consumption (Azeredo et al., 2010).

Respiration Rate

Scoring on the rate of respiration of papaya fruit showed climacteric pattern, result in increased respiration rate along with fruit ripening. Respiration rate of uncoated papaya fruit was higher than coated fruits (Figure 2).

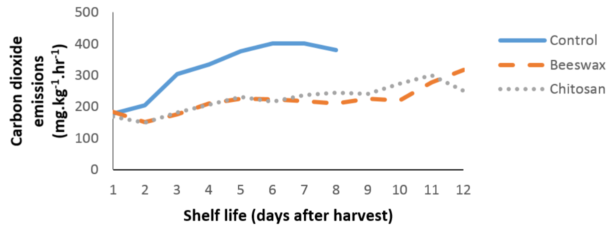

Figure 2. The effects of fruit coating with chitosan or beeswax on carbon dioxide emissions of papaya Callina fruits during storage.

There were no significant differences in the rate of respiration in papaya fruit treated with beeswax and those coated with chitosan. Respiration of the control and chitosan-coated fruits increased up to one day before fruits ripened when the skin color of the fruit reaches scale of six, but beeswax-coated fruits still respired until day 12 and there was no decrease in rate of respiration compared to the other treatments. In papaya fruit coated with beeswax, it was observed before reaching stage six so it was assumed that papaya fruits had not reached climacteric peak and the decrease in the respiration rate had not occurred.

Coating treatment influenced the rate of respiration of papaya fruit; uncoated-fruit respiration rate was 319.05 $mg.kg^{-1}.hr^{-1}$ CO_2 with peak respiration occurred at six DAH, whereas those with chitosan and beewax coating were 221.60 $mg.kg^{-1}.hr^{-1}$ CO_2 (peak respiratory rate at 11 DAH) and 219.74 $mg.kg^{-1}.hr^{-1}$ CO_2 respectively. Fruis coated with beeswax did not experience the climacteric peak in our experiment environment. Coating with chitosan or beeswax inhibited respiration thus increased fruit shelf life. Similar results were reported in avocado fruits (Irmayanti, 2012) that fruits coated with wax had a decrease in the consumption rate of O_2 followed by the decrease of CO_2 production rate. The energy released from the sugar conversion into starch can be used to carry out respiration process.

Fruit Physical Quality

Coating reduced the shrinkage of papaya fruits compared to control fruits, but did not affect the hardness of the skin and the flesh of papaya. The highest shrinkage weight was found in the control fruits which was 8.54%, whereas the lowest shrinkage was in papaya fruit coated with beeswax which was 5.71% (Table 2). These findings are in line with reports of Purwoko and Fitradesi (2000) where papaya Solo cultivar Tainung fruits had a shrinkage of 9.2% at 14 days following treatment with beeswax coating at 6%. Taris et al. (2015) reported that decreases in weight of the scale six fruits ranged from 3.03 to 4.72%.

Coating provides a protection layer to the skin of the fruits so that respiration occurs more slowly and reduced fruit weight loss (Samson and Straus, 2010). A higher rate of respiration will increase loss of fruit weight during storage.

Tabel 2. Physical quality of the papaya Callina fruits coated with beeswax or chitosan

Treatment	Weight decrease (%)	Skin hardness ($mm.g^{-1} sec^{-1}$)	Fruit hardness ($mm.g^{-1} sec^{-1}$)
Control	8.54a	0.16	0.27
Beeswax	5.71b	0.14	0.24
Chitosan	6.76b	0.14	0.20

Note: The values followed by different letters in the same column are significantly different according to Duncan's multiple range test (DMRT) at α = 5%.

Tabel 3. Chemical quality of the papaya fruits coated with beeswax or chitosan

Treatment	Total soluble solids (TTA; Brix)	Total titratable acid (TTA)	Vitamin C content (mg per 100 g)	TSS/TTA
Control	10.61	0.81	61.01	13.19
Beeswax	9.83	1.09	73.53	9.12
Chitosan	10.07	0.81	61.01	12.59
F test	ns	ns	ns	ns

Note: ns = not significant according to Duncan's multiple range test (DMRT) at α = 5%.

Hardness of the skin and fruit flesh in both treatments was similar; there were no significant differences in the skin hardness of the treated fruits compared to the control (Table 2). Papaya fruit in each treatment did not have the difference TSS when the fruit reached the maturity stage six, or began to show signs of damage due to the fungus so it was directly proportional to the fruit hardness. According to Samson and Straus (2010) fruit without layers were unable to hold the metabolism during storage so the process of conversion of proto-pectin into soluble pectin occurs faster.

Fruit Chemical Quality

The chemical composition affects the fruit chemical quality because it is related to the taste of the fruits. Chemical quality will determine the quality of the fruit so it needs to be maintained to extend the shelf life of the fruits. In this study, papaya Callina without coating had TSS content of 10.61°brix, TTA of 0.81% and vitamin C of 61.01 mg (Table 3). Suketi et al. (2010) reported that papaya fruit IPB-9 or Callina has TSS of 11°brix, TTA of 0.146% and vitamin C level of 103.21 mg per 100 g fresh weight. Papaya fruits were harvested at maturity stage two which is marked by the presence of 25% yellow color on the fruit skin. The differences in time to harvest did not affect the fruit physical quality but can affect the chemical quality (Taris et al., 2015).

Fruit coating did not affect TSS and the vitamin C content of papaya (Table 3) and there were no significant differences in the hardness of the skin and the papaya fruit amongst treatments (Table 2). These results are similar to Hidayah (2013) where the use of wax at 6% at 13°C did not affect the TSS of papaya Callina fruits. According to Sjaifullah (1993) a higher sugar content of the fruit may lead to rapid softening during maturation.

Beeswax and chitosan coating did not affect the chemical properties of papaya fruit. TTA of the beeswax-coated fruits is 1.09 mg per 100 g, whereas the control and chitosan treated fruits had the similar average of 0.81 mg per 100 g. Table 3 shows that beeswax treatment did not affect TTA and its TSS / TTA ratio. Inhibition of respiration through beeswax coating caused the acid content of the fruit to be higher. High acid content reduced TSS / TTA ratio of beeswax-coated fruits. This study showed that there were no significant differences between the treatments of beeswax coating and chitosan on vitamin C content. Based on a the findings of Suketi et al. (2007) harvest age can affect vitamin C content, but does not affect shelf life. Mladenoska (2012) reported that coating provides a good barrier to prevent fruit skin contact with oxygen in the atmosphere, thus suppressing the process of ascorbic acid oxidation in the fruits. The coated apricots had higher vitamin C than the untreated fruits.

Conclusion

Fruit coating with chitosan at 0.75%, or beeswax at 6% can inhibit the rate of papaya Calina respiration during storage and delaying the maturity by four to five days compared to uncoated fruits. The use of chitosan or beeswax can maintain the physical and chemical properties of papaya Callina fruits; the longest keeping duration of 12.33 days after harvest was with beeswax coating at 6%. Chitosan can be used as a post harvest treatment on papaya fruits to maintain fruit physical appearance and inhibit fungus infections which ultimately maintain the fruit quality and shelf life.

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