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EFFECTS OF FRUIT COATINGS, FUNGICIDE, AND STORAGE TEMPERATURE ON FRUIT SHELF-LIFE AND QUALITIES OF 'CALIFORNIA' PAPAYA

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ABSTRACT

'California' papaya is a newly released papaya cultivar in Indonesia that has a very short shelf-life. Increasing demands in both local and export markets warrant the need for a proper postharvest technology to prolong its shelf-life. This research was conducted to study the effects of fruit coatings (chitosan, KD-112, plastic wrapping), fungicide Prochloraz, and storage temperatures on its fruit shelf-life and quality. Three parallel experiments were conducted with treatments arranged in a completely randomized design of a 2 x 2 x 2 factorial design. The first factor was chitosan (with and without 1.25% chitosan), or KD-112 (with and without 14% KD-112), or plastic wrapping (with and without one layer plastic wrapping), the second was Prochloraz (with and without 0.67 mL/L Prochloraz), and the third was storage temperature (28 and 16-18 ºC). While Prochloraz did not affect fruit variables, cooler temperature and coatings lengthened fruit shelf-life with the best effect shown by plastic wrapping which lengthened fruit shelf-life by 12.70 days, without affecting fruit qualities. Significant effects of coating and cooler temperature determined their combined effects, with the best effect achieved by applying the three factors that lengthened fruit shelf-life by 11.20-23.40 days longer.

KEYWORDS coating, papaya, Prochloraz, storage, temperature

INTRODUCTION

'California' papaya is a newly released papaya cultivar in Indonesia that has a very short shelf-life with a quickly decrease of fruit qualities due to high respiration and transpiration rates. Increasing demands in both local and export markets warrant the need for a proper postharvest technology to prolong its shelf-life and maintain its high fruit qualities.

Chitosan is increasingly known as a potent fruit surface-coating of having both biodegradable and biofungicidal functions (Raqeeb, Mahmud, Omar, Zaki & Eryani, 2009; Yanti, Nugroho, Aprisa & Mulyana, 2009). It has been reported to be suitable for coating many fruits (Hernandez-Munoz, Almenar, Ocio, & Gavara, 2006; Widodo & Zulferiyenni, 2008; Widodo, Zulferiyenni, & Novaliana, 2010; Chutichudet & Chutichudet, 2011; Widodo, Zulferiyenni, & Arista, 2013; Widodo, Zulferiyenni, Ginting, Fazri, & Saputra, 2015; Sun, Liang, Xie, Lei, & Mo, 2010). Its effects in lengthening fruit shelf-life were due to less transpirational conductance (Chutichudet & Chutichudet, 2011) and decreased respiration (Hernandez-Munoz, Almenar, Valle, Velez, & Gavara, 2008). Widodo *et al.* (2016) confirmed that 1.25% chitosan was proven to be a potent fruit coating.

KD-112 is a sugar ester blend solution that is introduced as a fruit coating to delay pineapple ripening during its postharvest handlings. As with other sucrose polyester coatings, It is mainly used as biosurfactant (Neta *et al*., 2012) and its main effects are to decrease respiration and transpiration rates, ethylene production, and to delay fruit color development and softening (Sumnu & Bayindirli, 1997). During coating with sugar ester blend solution, due to low respiration and transpiration rates, fruits are expected to respond by having low fruit weight loss and softening rates, that was also reported by another coating (Zulferiyenni, Widodo, & Simatupang, 2015).

Amongs fruit coating practices, plastic wrapping is known as a common practice in postharvest handling of horticultural products due to its simplicity, effectivity, and economical reasons. It works by developing a modified athmospheric condition of low O_2 and high CO_2 inside the coating and providing a physical barrier to water vapor which promotes low respiration and transpiration rates (Workneh, Azene, & Tesfay, 2012; Nasution, Yusmanizar, & Melianda, 2012) due to its lower permeabilities to athmospheric gases and water vapour (Nasution, Yusmanizar, & Melianda, 2012).

When combining chitosan or sugar ester blend solution of KD-112 with plastic wrapping, a significantly longer shelf-life and maintaining high fruit qualities of ‘California’ papaya are expected. That is because chitosan, KD-112, and plastic wrapping, as fruit coatings, plays similar functions by lowering respiration and transpiration rates. However, energy that is released by respiration as heat and water vapor that is released by transpiration may be traped inside coating. When fruit shelf-life is extended, these develop a condition favouring pathogen buildup inside coating. Hamdayanty, Yunita, Amin, & Damayanty (2012) and Sharma (2015) reported pathogen buildup when fruit shelf-life was extended more than 6 and 12 days storage due to application of fruit coatings. Hewajulige & Wijeratnam (2010) also reported that as ripening progresses, lengthening fruit shelf-life might increase the risk of pathogen buildup.

Prochloraz (N-propyl-N-[2-(2,4,6-trichlorophenoxy)ethyl]-1H-imidazole-1-carboxamide) $C_{15}H_{16}Cl_3N_3O_2$ is known as a broad spectrum fungicide (Vinggaard et al., 2006). It is one of the most important imidazole fungicide that was reported to degrade much slower at pH 7.0 compared to pH 4.0 and 9.2 (Aktar, Sengupta, Purkait, Ganguly, & Paramasivam, 2008). Since its development in the late 1970s, it retains its uses as a popular fungicide in many agroindustries because of its effectiveness in disease control. As a market demand to ‘California’ papaya fruit increases, its effectiveness in postharvest handling needs to be tested.

Application of lower temperature during postharvest handling does not only decrease metabolic processes, but also decreases development of fungi sporulation (Singh, Mishra, & Tripathi, 2012). Therefore, a longer shelf-life and maintaining high fruit qualities of ‘California’ papaya are expected by combining fruit coating (chitosan or sugar ester blend solution of KD-112 or plastic wrapping) with fungicide Prochloraz and lower storage temperature. This research objectives were to study the effects of fruit coatings (chitosan, KD-112, plastic wrapping), fungicide Prochloraz, and storage temperatures on the fruit shelf-life and qualities of ‘California’ papaya.

MATERIALS AND METHODS

This research was conducted on July-September 2016 in the Horticultural Postharvest Laboratory, Faculty of Agriculture, University of Lampung, Bandar Lampung, Indonesia. ‘California’ papaya fruits at ripening stage I (green fruit with yellowing spot at peduncle side; Manenoi, Bayongan, Thumdee, & Paull, 2007) were received as a fresh harvest directly from Nusantara Tropical Farm, Co. Ltd., Labuhan Ratu, East Lampung, Indonesia. Fruit samples were then sorted based on physical appearances (fruit weight and shapes) and maturity (fruit color). Other materials were chitosan (cosmetic grade), sugar ester blend of KD-112, plastic wrapping of LDPE (Best Fresh®), Prochloraz, and other chemicals for chemical analyses.

Three parallel experiments were conducted with treatments arranged in a completely randomized design of a 2 x 2 x 2 factorial design. The first factor was chitosan [with (C1) and without (C0) 1.25% chitosan], or KD-112 [with (K1) and without (K0) 14% KD-112), or plastic wrapping [with (W1) and without (W0) one layer plastic wrapping], the second was Prochloraz [with (P1) and without (P0) 0.67 mL/L Prochloraz), and the third was storage temperature [28 (T0) and 16-18 ºC (T1)]. The experiments used five replications with one fruit each. The observation on fruit stage development was conducted daily, while the other observations were terminated once when the fruits reached stage IV (perfectly yellow/orange).

Chitosan was diluted in 0.5% acetic acid (Widodo, Zulferiyenni, Ginting, Fazri, & Saputra, 2015; Zulferiyenni, Widodo, & Simatupang, 2015). KD-112 solutions were prepared by adding destilled water to KD-112 stock solution according to their applied concentrations. The fruits were quickly dipped in Prochloraz solution, air-dried, and then quickly dipped in chitosan or KD-112 solutions (or water in the control) or wrapped in one-layer of plastic wrapping. Treated fruits were then placed in a storage room of room temperature of 28 ± 1 °C or a cooler one of 16-18 ºC. The cool storage room temperature of 16-18 ºC was the lowest possible temperature that could be achieved in the storage room of $5.8 \times 2.8 \times 3.15\ m^3$ with four ACs, humidifiers, and a thermohygrometer.

Observations were made on fruit shelf-life, weight loss, firmness (with a penetrometer typed

FHM-5, with a cylindrical point of 5 mm in diameter of Takemura Electric Work, Co. Ltd., Japan), soluble solid as ^{o}Brix (with an Atago N-1E hand refractometer), titratable acidity (titrated with 0.1 N NaOH and phenolphthalein as an indicator, presented as g citric acid/100 g), and sweetness level (^{o}Brix/acidity ratio). All data were analyzed with ANOVA, and then further tested with Least Significantly Difference (LSD) at 5%.

RESULTS AND DISCUSSION

Without receiving fruit coating, fungicide, and cooler storage, 'California' papaya fruits reached fruit ripening stage IV (perfectly yellow/orange) at 5-7 days storage. As their ripening was progressed, the fruits were softened from 25.10 kg/cm^2 to 5.43-5.87 kg/cm^2, their soluble solid contents (ºBrix) were increased from 9.20% to about 11%, and without significant changes of acid content, their sweetness levels were increased significantly.

The results showed that while fungicide Prochloraz did not affect fruit variables, coatings and cooler temperature lengthened the shelf-life of 'California' papaya fruits (Tables 1-3). 'California' papaya fruits responded similarly to chitosan and sugar ester blend of KD-112, by which their shelf-life was extended by 3.25-3.75 days longer than the control (Tables 1-2). The best effect shown by plastic wrapping which extended 'California' papaya fruit shelf-life by 12.70 days (Table 3), without affecting fruit qualities.

Table 1. Effects of chitosan, fungicide Prochloraz, and storage temperature on fruit shelf-life and qualities of 'California' papaya

Treatments		Shelf-life (days)*	Weight loss (%)*	Firmness (kg/cm^2)*	ºBrix (%)*	Acidity (g/100 g)*	Sweetness *
Chitosan	(C):						
Without	(C0)	11.20 b	10.30 a	5.58 a	9.92 a	0.14 a	70.42 a
1.25%	(C1)	14.45 a	11.49 a	6.78 a	10.11 a	0.14 a	78.05 a
Prochloraz	(F):						
Control	(F0)	11.60 a	10.19 a	5.36 b	10.13 a	0.14 a	73.17 a
0.67 mL/L	(F1)	14.05 a	11.60 a	7.00 a	9.90 a	0.14 a	75.30 a
Temperature	(T):						
28 ± 1 °C	(T0)	8.05 b	7.15 b	5.10 b	10.56 a	0.14 a	76.96 a
16-18 ºC	(T1)	17.60 a	14.64 a	7.27 a	9.47 b	0.14 a	71.51 a
C x F:							
C0F0		9.40 b	9.13 a	5.32 b	10.20 a	0.16 a	65.41 b
C0F1		13.00 ab	11.48 a	5.85 b	9.64 a	0.13 a	75.44 a
C1F0		13.80 ab	11.26 a	5.39 b	10.06 a	0.13 a	80.92 ab
C1F1		15.10 a	11.72 a	8.16 a	10.15 a	0.14 a	75.17 ab
C x T:							
C0T0		6.70 b	6.02 b	6.13 b	10.38 ab	0.15 a	72.12 a
C0T1		15.70 a	14.60 a	5.04 b	9.46 b	0.14 a	68.72 a
C1T0		9.40 b	8.28 b	8.40 a	10.74 a	0.14 a	81.79 a
C1T1		19.50 a	14.69 a	5.15 b	9.47 b	0.14 a	74.30 a
F x T:							
F0T0		7.30 b	6.83 b	5.53 b	10.65 a	0.14 a	78.75 a
F0T1		15.90 a	13.56 a	5.19 b	9.61 ab	0.15 a	67.58 a
F1T0		8.80 b	7.47 b	9.01 a	10.47 ab	0.14 a	75.17 a
F1T1		19.30 a	15.73 a	5.00 b	9.32 b	0.13 a	75.44 a
C x F × T:							
C0F0T0		5.20 d	5.02 b	5.64 b	10.78 a	0.16 a	69.21 ab
C1F0T0		9.40 cd	8.64 b	5.42 b	10.52 a	0.13 a	88.28 a
C0F1T0		8.20 cd	7.01 b	6.62 b	9.98 a	0.14 a	75.03 ab
C1F1T0		9.40 cd	7.93 b	11.39 a	10.96 a	0.15 a	75.31 ab
C0F0T1		13.60 bc	13.23 a	5.00 b	9.62 a	0.16 a	61.60 b
C1F0T1		18.20 ab	13.88 a	5.37 b	9.60 a	0.14 a	75.57 ab
C0F1T1		17.80 ab	15.95 a	5.07 b	9.30 a	0.13 a	75.85 ab
C1F1T1		20.80 a	15.50 a	4.93 b	9.34 a	0.14 a	75.03 ab

Remarks: *Values in the same column of each treatment followed with the same letters were not significantly different at LSD 5%. Values of fruit firmness, soluble solid content (°Brix), acidity, and sweetness (°Brix/acid ratio) at 0 day-storage was 25.10 kg/cm^2, 9.20%, 0.15 g/100 g, and 63.12, consecutively.

Table 2. Effects of sugar ester blend of KD-112, fungicide Prochloraz, and storage temperature on fruit shelf-life and qualities of 'California' papaya

Treatments		Shelf-life (days)*	Weight loss (%)*	Firmness (kg/cm^2)*	ºBrix (%)*	Acidity (g/100 g)*	Sweetness *
KD-112	(K):						
Without	(K0)	10.55 b	8.56 b	5.06 a	10.21 a	0.13 a	84.88 a
14%	(K1)	14.30 a	12.04 a	4.76 a	9.92 a	0.12 a	84.37 a
Prochloraz	(F):						
Control	(F0)	12.30 a	10.21 a	4.76 a	9.73 a	0.13 a	79.87 a
0.67 mL/L	(F1)	12.55 a	10.38 a	5.06 a	10.41 a	0.12 a	89.38 a
Temperature	(T):						
28 ± 1 °C	(T0)	8.30 b	6.86 b	5.75 a	9.75 a	0.13 a	76.76 b
16-18 ºC	(T1)	16.55 a	13.74 a	4.07 b	10.38 a	0.12 a	92.49 a
K x F:							
K0F0		10.50 b	8.70 b	4.91 a	9.98 a	0.13 a	79.44 a
K0F1		10.60 b	8.42 b	5.21 a	10.44 a	0.12 a	90.31 a
K1F0		14.10 ab	11.73 a	4.61 a	9.47 a	0.12 a	80.30 a
K1F1		14.50 a	12.35 a	4.91 a	10.37 a	0.12 a	88.44 a
K x T:							
K0T0		6.30 c	5.09 d	5.99 a	9.72 a	0.14 a	73.03 b
K0T1		14.80 a	12.02 b	4.14 b	10.70 a	0.12 a	96.72 a
K1T0		10.30 b	8.62 c	5.52 a	9.78 a	0.13 a	80.48 ab
K1T1		18.30 a	15.46 a	4.00 b	10.06 a	0.12 a	88.26 ab
F x T:							
F0T0		8.40 b	6.95 b	5.35 ab	9.11 a	0.13 a	70.30 b
F0T1		16.20 a	13.47 a	4.17 bc	10.34 a	0.12 a	89.43 ab
F1T0		8.20 b	6.76 b	6.16 a	10.39 a	0.13 a	83.21 ab
F1T1		16.90 a	14.01 a	3.97 c	10.42 a	0.12 a	95.55 a
K x F × T:							
K0F0T0		7.00 d	5.54 de	5.87 ab	8.62 b	0.13 a	65.60 b
K1F0T0		9.80 cd	8.36 cde	4.84 abc	9.60 ab	0.13 a	75.01 ab
K0F1T0		5.60 d	4.64 e	6.11 a	10.82 ab	0.14 a	80.47 ab
K1F1T0		10.80 bcd	8.87 cd	6.20 a	9.96 ab	0.12 a	85.95 ab
K0F0T1		14.00 abc	11.85 bc	3.96 bc	11.34 a	0.12 a	93.28 ab
K1F0T1		18.40 a	15.09 ab	4.38 abc	9.34 ab	0.11 a	85.59 ab
K0F1T1		15.60 ab	12.19 abc	4.32 abc	10.06 ab	0.11 a	100.16 a
K1F1T1		18.20 a	15.83 a	3.63 c	10.78 ab	0.12 a	90.93 ab

*See remarks on Table 1.

Fungicide application with 0.67 ml/L Prochloraz did not affect fruit shelf-life significantly (Tables 1-3). It did not mean that the fungicide was not effective. Its ineffectiveness due to improper concentration was unlikely, because Diczbalis, Henriod, Sole, & Campbell (2014) reported that 0.55 ml/L Prochloraz was effective for a disease control of papaya. In our research, because the fruit samples were not received any sanitation prior to fungicide treatment, this result indicated that the pathogen might exist and need a longer incubation period to buildup. In fact, some samples were infected by anthracnose *Colletrotichum gloeosporioides* (Penz.) Sacc., but in general, the infection did not affect fruit shelf-life. Hamdayanty, Yunita, Amin, & Damayanty (2012) and Sharma (2015) reported 6-12 days incubation periods for pathogen buildup. Hewajulige & Wijeratnam (2010) also reported that as ripening progresses, lengthening fruit shelf-life might increase the risk of pathogen buildup.

Lowering storage temperature to 16-18 ºC extended 'California' papaya fruit shelf-life by 8.25-9.55 days longer than the control (Tables 1-3). Lower temperature storage during postharvest handling might not only extended fruit shelf-life due to decreased metabolic processes such as respiration and ethylene production (Workneh, Azene, & Tesfay, 2012; Nasution, Yusmanizar, & Melianda, 2012), but it might also decrease development of fungi sporulation (Singh, Mishra, & Tripathi, 2012).

Significant effects of coatings and cooler temperature determined their combined effects, with the best effect achieved by applying the three factors that lengthened fruit shelf-life by 11.20-23.40 days longer (Tables 1-3). That was the combined application of fruit coating of one layer plastic wrapping, fungicide application of 0.67 mL/L Prochloraz, and a cooler temperature storage of 16-18 ºC that was capable of lengthening 'California' papaya fruit shelf-life up to 30 days storage, 23.40 days longer than the control.

When cooler temperature storage was not available, fruit coatings (chitosan or KD-112 or plastic wrapping) and fungicide Prochloraz could be applied during postharvest handling. The two combination were capable of lengthening 'California' papaya fruit by 4.00-8.30 days longer than the control (Tables 1-3). Based on economical and simplicity considerations, however, a combination with one layer plastic wrapping was the best, because it was capable of extending fruit shelf-life of more than 8 days longer than the control (Table 3).

Table 3. Effects of plastic wrapping, fungicide, and storage temperature on fruit shelf-life and qualities of 'California' papaya

Treatments		Shelf-life (days)*	Weight loss (%)*	Firmness (kg/cm^2)*	ºBrix (%)*	Acidity (g/100 g)*	Sweetness *
Wrapping	(W):						
Without	(W0)	10.25 b	8.34 a	4.60 b	10.49 a	0.16 a	68.96 a
One layer	(W1)	22.95 a	5.99 b	10.60 a	10.60 a	0.14 a	80.90 a
Prochloraz	(F):						
Control	(F0)	15.65 a	6.59 a	6.98 a	10.70 a	0.15 a	75.26 a
0.67 mL/L	(F1)	17.55 a	7.74 a	8.17 a	10.39 a	0.15 a	74.59 a
Temperature	(T):						
28 ± 1 °C	(T0)	12.45 b	5.72 b	8.41 a	10.60 a	0.15 a	73.76 a
16-18 ºC	(T1)	20.75 a	8.60 a	6.74 a	10.49 a	0.15 a	76.09 a
W x F:							
W0F0		9.50 b	7.42 ab	4.54 b	10.87 a	0.16 a	71.72 a
W0F1		11.00 b	9.25 a	4.60 b	10.11 a	0.16 a	66.20 a
W1F0		21.80 a	5.76 b	9.41 a	10.54 a	0.14 a	78.81 a
W1F1		24.10 a	6.23 b	11.74 a	10.67 a	0.14 a	82.98 a
W x T:							
W0T0		7.40 d	6.16 b	5.50 b	10.11 a	0.16 a	66.73 a
W0T1		13.10 c	10.51 a	3.70 b	10.87 a	0.16 a	71.19 a
W1T0		17.50 b	5.29 b	11.34 a	11.09 a	0.15 a	80.80 a
W1T1		28.40 a	6.70 b	9.81 a	10.12 a	0.13 a	81.00 a
F x T:							
F0T0		11.70 b	5.26 c	7.34 a	10.45 a	0.15 a	75.75 a
F0T1		19.60 a	7.93 ab	6.61 a	10.96 a	0.15 a	74.78 a
F1T0		13.20 b	6.19 bc	9.50 a	10.75 a	0.16 a	71.78 a
F1T1		21.90 a	9.29 a	6.70 a	10.03 a	0.14 a	77.41 a
W x F × T:							
W0F0T0		6.60 e	5.33 c	5.43 bc	10.48 ab	0.16 a	71.14 a
W1F0T0		16.80 bc	5.19 c	9.30 ab	10.42 ab	0.14 a	80.36 a
W0F1T0		8.20 de	6.98 bc	5.53 bc	9.74 b	0.17 a	62.32 a
W1F1T0		18.20 b	5.39 c	13.42 a	11.76 a	0.15 a	81.24 a
W0F0T1		12.40 cd	9.53 ab	3.70 c	11.26 ab	0.16 a	72.29 a
W1F0T1		26.80 a	6.34 c	9.60 ab	10.66 ab	0.14 a	77.27 a
W0F1T1		13.80 bc	11.50 a	3.70 c	10.48 ab	0.16 a	70.09 a
W1F1T1		30.00 a	7.06 bc	10.06 ab	9.58 b	0.12 a	84.73 a

* See remarks on Table 1.

In general, the applied treatments did not affect fruit qualities, such as fruit weight loss, firmness, soluble solid and acid contents, and therefore, fruit sweetness (Tables 1-3). Increased fruit weight loss due to lower temperature treatment might be an indirect effect of extended fruit shelf-life as also noted in our other results (Widodo & Zulferiyenni, 2008; Widodo, Zulferiyenni, & Arista, 2013; Zulferiyenni, Widodo, & Simatupang, 2015; Widodo, Zulferiyenni, Ginting, Fazri, & Saputra, 2015;

Widodo *et al*., 2016). As noted in fruit shelf-life, significant effects of coatings and cooler temperature determined their combined effects in some variables, mostly in fruit weight loss and firmness.

CONCLUSIONS AND SUGGESTION

While Prochloraz did not affect fruit variables, cooler temperature and coatings lengthened fruit shelf-life with the best effect shown by plastic wrapping which lengthened fruit shelf-life by 12.70 days, without affecting fruit qualities. Significant effects of coating and cooler temperature determined their combined effects, with the best effect achieved by applying the three factors that lengthened fruit shelf-life by 11.20-23.40 days longer. That was the combined application of fruit coating of one layer plastic wrapping, fungicide application of 0.67 mL/L Prochloraz, and a cooler temperature storage of 16-18 ºC that was capable of lengthening 'California' papaya fruit shelf-life up to 30 days storage, 23.40 days longer than the control.

Based on economical and simplicity considerations and when cooler temperature storage is not available, it is suggested that a combination of one layer plastic wrapping and fungicide Prochloraz is the best, because it was capable of extending 'California' papaya fruit shelf-life of more than 8 days longer than the control.

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