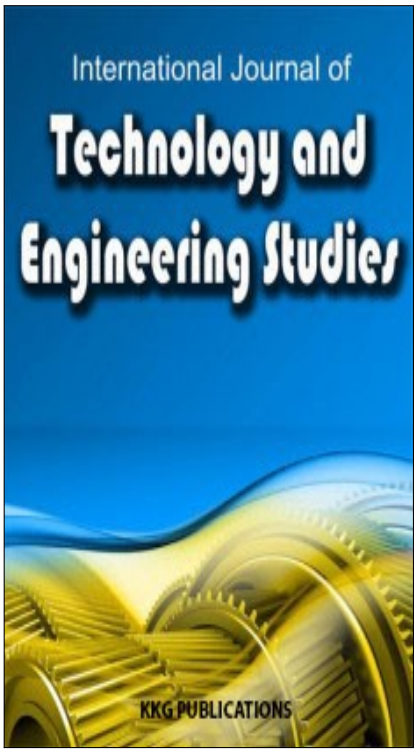

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Postharvest Applications of Chitosan and Plastic Wrapping to Mangosteen Fruits of Different Fruit Stages in Affecting Fruit Shelf-Life and Qualities

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POSTHARVEST APPLICATIONS OF CHITOSAN AND PLASTIC WRAPPING TO MANGOSTEEN FRUITS OF DIFFERENT FRUIT STAGES IN AFFECTING FRUIT SHELF-LIFE AND QUALITIES

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Abstract. The research objective is to study the effects of chitosan and plastic wrapping on mangosteen fruits harvested in different stages to prolong fruit shelf-life and maintain high quality. This research used a randomized complete block design of 4 x 3 x 2 factorial. The first factor was maturity stage (0, 2, 3, and 4), the second was chitosan (0, 1.25, and 2.50 %), and the third was plastic wrapping (without and with one-layer plastic wrapping). The results showed that fruit stages 0 and 2 had a shelf-life of 2.96 and 3.15 days longer than later stages. Single-chitosan treatment of 2.5% was able to extend shelf-life by 6.48 days longer than the control, and plastic wrapping could prolong shelf-life by 3.85 days longer than the control. Applying 2.50% chitosan and plastic wrapping to stages 0 and 2 lengthened fruit shelf-life significantly to 21.20 and 19.83 days, respectively, with the fruit qualities unaffected. Because there may be misjudged fruit physiological maturity of fruits at stage 0, applying 2.50% chitosan and plastic wrapping to fruit stage 2 seems more reasonable.

INTRODUCTION

Mangosteen is known as “the queen of Tropical fruits”. Its harvesting period is divided into two purposes of its fruits. For a fresh consumption or local markets, the fruits are generally harvested at stage 5 (dark purple) or stage 6 (purple black) [1], [2]. For export, however, most researchers recommend harvesting mangosteen at earlier stages of stage 2 and 3 [2], [3], [4], [5], [6], [7].

It is a common knowledge that mangosteen is a climacteric fruit. It means that the fruit can be harvested at a full maturity stage, and then the fruit reaches its full ripening stages during a storage period. A common harvesting index for mangosteen is then developed according to color changes of its fruit rind from yellowish white or yellowish white with light green (stage 0) to purple black (stage 6) [2]. While mangosteen fruits of stage 2-6 are considered useful for consumptions and receive much attention, mangosteen fruits of stage 0 are hardly studied for their postharvest handling.

[6] and [8] even classified fruits of this stage as immature fruits that would not ripen to full flavor if harvested. Facts found in the mangosteen tradings at farmer levels tell us that fruits of different maturity at stages 0-6 are common. The traders then select fruits at stages 2-3 for export and fruits at later stages for domestic markets. Again, fruits at stage 0 seem to be neglected. In addition, studies of postharvest handling for fruits at stage 0 are not available.

Mangosteen fruit has a very thick rind that occupies more than 70% of its fruit weight. Due to this very thick rind that is believed as a good physical barrier from a high transpiration rate leading to fruit deterioration, its post harvest technology is less studied and developed than its fruit characteristics themselves during storage. For those who are interested in mangosteen characteristics should consult [6]. Research studying any application of post harvest technology to different fruit stages of mangosteen is even unavailable. This research objective was to study the effects of chitosan and plastic wrapping applied to mangosteen fruits harvested at different fruit stages in order to prolong their fruit shelf-life and maintain their high fruit qualities.

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METHOD AND MATERIALS

This research was conducted in the Laboratory of Horticultural Postharvest, Faculty of Agriculture, University of Lampung, Bandar Lampung, Lampung, Indonesia, from July to August 2017. Mangosteen fruits at 0, 2, 3, and 4 stages [1] were obtained as a fresh harvest from a farmer in Mulang Maya village, Kota Agung district, Tanggamus regency, Lampung province, Indonesia, and treated on the same day of harvest.

This research used a completely randomized block design, arranged in a $4 \times 3 \times 2$ factorial, with five replications of one fruit each. The first factor was mangosteen fruit stage (yellowish white or yellowish white with light green (stage 0, S0), light greenish yellow with 51-100% scattered pink spots (stage 2, S2), reddish pink (stage 3, S3), and red to reddish purple (stage 4, S4) [2]. The second factor was chitosan [without chitosan (C0), with chitosan 1.25% (C1), and 2.5% (C2)]. The third factor was plastic wrapping [without (W0) and with one-layer of plastic wrapping (W1)]. Fruit stages were treated as a block.

The chitosans were diluted in 5% acetic acid. The samples of mangosteen fruits were dipped in the chitosan solutions of each treatment and let them air-dried, then packed with one-layer plastic wrapping (trademark Total' of 300 mm $\times$ 500 m $\times$ 11 μ m). All treated mangosteen fruits were stored in a storage room of room temperature 27-28°C. A unit treatment was ended when the fruit reach stage 6 (purple black) [2].

RESULTS AND DISCUSSION

Mangosteen fruit maturity is judged with color changes of its fruit rind. According to Palapol et al. [2] there are seven stages, namely yellowish white or yellowish white with light green (stage 0), light greenish yellow with 5-50% scattered pink spots (stage 1), light greenish yellow with 51-100% scattered pink spots (stage 2), reddish pink (stage 3), red to reddish purple (stage 4), dark purple (stage 5), and purple black (stage 6). As a climacteric fruit, mangosteen follows a common knowledge that the fruit can be harvested at a full maturity stage, and then the fruit reaches its full ripening stages during the storage period. Fruit reaching its full maturity means that it has already reached its physiological maturity, by which the fruits reach their perfect ripening stage. As another consequence, once the fruit reaches its physiological maturity it will ripen to its full ripening stage, no matter at what stage the fruit is harvested. At this point, this agrees with [2]. They observed that when the fruits at six different stages (excluding stage 0) were harvested and stored at a room temperature of 25°C, each stage developed fully to the purple black stage of stage 6, which was the full ripening stage.

Our data in Table 1 showed that the earlier the fruit was harvested, the longer its shelf-life was. This agreed with [9], who stated that the mangosteen fruit that was harvested at a later maturity led to a short shelf-life than the one harvested at an early stage of maturity. Highlighting the results of [2], the data in Table 1 showed clearly that no matter at what stage the fruit was harvested (including stage 0), the fruits were ripened to their full ripening stage of stage 6. In fact, our data proved that no matter at what stage the fruit was harvested, they reached their full ripening stage of stage 6 with no significant differences of fruit qualities, such as in weight loss, firmness (Table 1), free acid content, and sweetness level (Table 2).

The soluble solid content (°Brix value) was significantly increased when the fruit was harvested at stages 2 and 3 (Table 2), but because the free acid content tented to be slighly increased, fruit stages did not significantly affect the sweetness level.

The question is then "what are the proper stages for mangosteen to be harvested?" For table fruits to be directly consumed or for local markets, stage 5 (dark purple) and stage 6 (purple black) [1] and [2] might at last still be used as index maturities for harvest. For export, however, the length of shelf-life has to be taken into consideration.

The data in Table 1 showed that stage 2 (light greenish yellow with 51-100% scattered pink spots) [2] was the most appropriate stage for harvest because the stage lasted the longest during storage and was technically easy to be executed due to the appearance of clear pink spots. This agreed with most recomendations from mangosteen experts and researchers [2], [3], [4], [5], [6], [7].

TABLE 1
EFFECTS OF FRUIT STAGES, CHITOSAN, PLASTIC WRAPPING ON FRUIT SHELF-LIFE, WEIGHT LOSS, AND FIRMNESS OF MANGOSTEEN FRUITS

Treatment	Shelf-Life (Days)	Weight Loss (%)	Firmness (kg/cm^2)
Stage (S):			
Stage 0(S0)	17.23 ab	15.37 a	14.42 a
Stage 2 (S2)	17.42 a	16.54 a	14.99 a
Stage 3 (S3)	15.22 bc	14.57 a	13.47 a
Stage 4 (S4)	14.27 c	14.50 a	14.58 a
Chitosan (C)			
Chitosan 0% (C0)	12.86 c	12.97 b	12.04 b
Chitosan 1.25% (C1)	15.90 b	15.10 ab	14.68 ab
Chitosan 2.50% (C2)	19.34 a	17.66 a	16.37 a
Plastic Wrapping (W):			
Without (W0)	14.11 b	16.63 a	15.37 a
1 Layer (W1)	17.96 a	13.86 b	13.36 b
Stage × Chitosan	NS	NS	NS
Stage × Plastic Wrapping	NS	NS	NS
Chitosan × Plastic Wrapping	$P = 0.0134$	NS	NS
Stage × Chitosan Plastic Wrapping	NS	NS	NS

The values in the columns followed by the same letter are not significantly different according to the 5% LSD test; *NS* = non-significant; *P* = probability values generated with ANOVA test; Fruit firmness at 0 days store of stage 0 was 22.85 kg/cm^2, while at stage 2 was 15.85 kg/cm^2, at stage 3 was 14.20 kg/cm^2, at stage 4 was 12.19 kg/cm^2. Fruit shelf-lifes of S0C2W1 and S2C2W1 was 21.20 and 19.83 days storage, respectively, while that of control was 11.80 days' storage.

Stage 0, however, was proven to be an alternative index of maturity for harvest since it was as good as stage 2 for producing mangosteen fruits for export (Table 1), provided that its physiological maturity had been reached.

The prerequisite of physiological maturity might be the main objection for harvesting at stage 0 because there was no clear indicator except the color of yellowish white or yellowish white with light green that could be easily misjudged during harvest in the field. This phenomenon might have been experienced so that [6] and [8] classified fruits of this stage as immature fruits that would not ripen to full flavor if harvested. However, the data in Table 1 clearly showed that fruits of stage 0 should not be disregarded during post harvest in the packing house because when they reached their full ripening stage of stage 6, the fruits had as good qualities as compared to the later stages. Again, it was provided that the fruits had reached their physiological maturity. The individual treatment of chitosan (Table 1) was able to extend significantly the mangosteen fruit shelf-life by 3.04-6.48 days longer than the control. This was because chitosan formed a physical barrier to O_2 and CO_2 movements in the fruit environment that suppressed respiration rate and ethylene production, thus slowing the ripening process [10].

Single-chitosan treatment also affected the weight loss and fruit firmness (Table 1). Fruit weight loss and firmness tended to be higher due to higher chitosan concentrations. The increase of fruit weight loss might be a consequence of longer shelf-life. In addition, a greater weight loss indicated more water lost from the rind, thus causing hardening of the rind [11].

Longer shelf-life due to 2.5% chitosan application not only caused slightly higher fruit weight loss and firmness, but also decreased soluble solid content and acidity. However, because 2.5% chitosan affected more to decrease acidity than soluble solid content, as a result, 2.5% chitosan application significantly increased fruit sweetness (Table 2).

TABLE 2
EFFECTS OF FRUIT STAGES, CHITOSAN, PLASTIC WRAPPING ON FRUIT SOLUBLE SOLID CONTENT, FREE ACID CONTENT, AND SWEETNESS LEVEL OF MANGOSTEEN FRUITS

Treatment	Soluble Solid content (%)	Free Acid Content (g/100 g)	Sweetness level
Stage (S):			
Stage 0 (S0)	12.85 c	0.42 a	44.79 a
Stage 2 (S2)	14.91 a	0.46 a	40.96 a
Stage 3 (S3)	14.66 ab	0.44 a	44.16 a
Stage 4 (S4)	13.22 bc	0.40 a	40.33 a
Chitosan (C)			
Chitosan 0% (C0)	14.55 a	0.51 a	35.49 b
Chitosan 1.25% (C1)	14.65 a	0.44 ab	41.65 ab
Chitosan 2.50% (C2)	12.53 b	0.35 b	50.54 a
Plastic Wrapping (W)			
Without (W0)	13.99 a	0.46 a	42.45 a
1 Layer (W1)	13.83 a	0.39 a	42.67 a
Stage × Chitosan	NS	NS	NS
Stage × Plastic Wrapping	NS	NS	NS
Chitosan × Plastic Wrapping	$p = 0.0016$	$p = 0.0249$	NS
Stage × Chitosan × Plastic Wrapping	$p = 0.0053$	NS	NS

The values in the columns (Table 2) followed by the same letter are not significantly different according to the 5% LSD test; Sweetness level = °Brix; NS = non-significant, P = probability values generated with ANOVA test; Values of °Brix, free acid, and the sweetness level at 0 days storage of stage 0 were 15.48%, 0.39 g/100 g, and 39.69%. Those of stage 2 were 16.16%, 0.43 g/100 g, and 37.76%. Those of stage 3 were 16.52%, 0.48 g/100 g, and 34.11%. Those of stage 4 were 16.52%, 0.50g/100 g, and 33.04%, respectively.

The single plastic wrapping treatment was able to extend the shelf life by 3.85 days longer than the control, reducing the weight loss by 2.77%, and decreasing fruit firmness by 2.01 kg/cm^2 lower than the control. These results indicated that coating mangosteen with one-layer plastic wrapping suppressed respiration rate and inhibited respiration [12], [13] also reported that plastic wrapping was the best treatment in inhibiting weight loss, increased total soluble solids, sweetness, and decreased acid content.

The two or three factor combinations mostly did not affect variables measured (Tables 1 and 2). Their combination effects were simply due to their individually significant effect. Application of appropriate chitosan concentration to appropriate maturation stage would have a better effect on mangosteen fruit shelf-life. It was better to apply 2.50% chitosan and one-layer plastic wrapping to both mangosteen fruits of stage 0 and 2 because the three combinations lengthened fruit shelf-life to 21.20 and 19.83 days' storage, respectively (Table 1). They were 9.04 and 8.03 days' storage longer than the control, respectively, and the fruit qualities were unaffected (Table 2). However, because there might be misjudged physiological maturity of fruits at stage 0, and chitosan was proven for not having biopesticide effects in in-vivo application [14], applying 2.50% chitosan and one-layer plastic wrapping to mangosteen fruits of stage 2 seems to be more reasonable, and should be accompanied by a biopesticide application, such as Prochloraz (imidazole carboxamide) [15] that is a common practice in the fruit producing horticultural industries.

CONCLUSION AND RECOMMENDATIONS

The results showed that fruit with lower maturity stages (0 and 2) had a shelf-life of 2.96 and 3.15 days' longer, respectively, compared to later stages. Single-chitosan treatment of 2.5% was able to extend the fruit shelf-life by 6.48 days' longer than without chitosan, and plastic wrapping was able to prolong the fruit shelf-life by 3.85 days' longer than without plastic wrapping.

Applying 2.50% chitosan and one-layer plastic wrapping to both stages 0 and 2 lengthened significantly fruit shelf-life to 21.20 and 19.83 days' storage, respectively.

They were 9.04 and 8.03 days' storage longer than the control, respectively, with the fruit qualities unaffected. However, because there may be misjudged physiological maturity of fruits at stage 0, applying 2.50% chitosan and one-layer plastic

wrapping to mangosteen fruits of stage 2 seems to be more reasonable.

Declaration of Conflicting Interests

There are no conflicts of interest.

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— This article does not have any appendix. —