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EFFECTS OF MICROPERFORATED POLYPROPYLENE FILM PACKAGING ON MANGOSTEEN FRUITS QUALITY AT LOW TEMPERATURE STORAGE

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ABSTRACT

The study was conducted to explore the effects of micro-perforated polypropylene (PP) film bag with different numbers of perforations (holes) on the quality of mangosteen fruit stored for 25 days at 13°C. Further, study was aimed to identify a best suitable method for packaging mangosteen which can improve the storage time along with maintaining the fruit quality. In this study fruits were packed in expanded PP perforated with different numbers of holes i.e. 10, 20, 30 and 40 per bag, and the results were compared with the commercially available MAP-Lifespan bag and non-bagged treatment. The experiment was carried out in completely randomized design with 4 replications and 12 fruits per replication. After 10, 20 and 25 days of storage, gas composition of package and physicochemical qualities of the fruit were determined. The results of study revealed that fruits stored in polypropylene bags with 30 pores (PP30) could maintained the postharvest quality of mangosteen up to 25 days at 13°C and reported more effective than the MAP Lifespan bag. These results can recommended that PP30 can use for commercial purpose.

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1 Introduction

Mangosteen (*Garcinia mangostana* L.) is a tropical fruit with a high economic value and also known as a queen of tropical fruits (Wieble et al., 1992; Deewatthanawong et al., 2003). Although fruit has great economic value but short shelf life has a biggest obstacle in its wide scale consumption and transportation. Normally it has 3-7 days shelf life at room temperature and it can extend up to 7-14 days at lower temperature such as 13°C or below this (Ketsa & Koolpluksee, 1993). Common disorders which occurred during the storage of this fruit are browning of the pericarp (peel), weight loss, shrinkage of the calyx and pericarp at the stem end and chilling injury (Deewatthanawong et al., 2003). In addition, reduction in the internal fruit quality was also reported. These changes resulted in reduced marketability and loss of economic value of the fruit (Deewatthanawong et al., 2003). Use of modified atmosphere packaging (MAP) in storage can provide significant advantages.

This MAP method reduced the rate of respiration; make delayed in ripening and aging process and also reduced the water loss from the fruit which finally increase the storage life of fruit. According to Manurakchinakorn et al., (2008) mangosteen fruit can retained acceptable eating quality for 28 days if these were harvested at ripeness Stage 1 (light greenish-yellow skin and 5-50% scattered pink spots) and packed in LDPE with 6% O₂: 15% CO₂ atmosphere at 13°C. Similarly, Pakkasarn et al. (2003) reported that the storage of mangosteen fruits at 13°C under an atmosphere of 10% CO₂ caused delay in peel color changes and firmness which finally caused reduction in weight loss and rate of respiration and maintained fruit quality for 28 days. No information is available on the use of specialized packaging materials in Vietnam for maintaining the quality of mangosteen fruit during the storage or transport to distant markets.

Although bags used for packaging are capable in delivering a modified atmosphere (MA) and are effective in controlling in-package gas composition, respiratory rate and physicochemical changes e.g. commercially available MAP Lifespan bag but the cost of such bags are very high and it is difficult to obtain these bags for commercial use. This study aimed to compare the use of polypropylene (PP) film bags with different numbers of micropores (holes) with the MAP Lifespan bag on the composition of the atmosphere and physiological changes of Vietnamese mangosteen during low temperature storage.

2 Materials and Methods

2.1 Fruits and packaging materials

2.1.1 Fruit characteristics

Mangosteen fruits were harvested at Stage 2 maturity with light greenish-yellow skin and 51-100% scattered pink spots as suggested by Tongdee & Suwanagul (1989) (Figure 1), from a

mangosteen orchard situated at Cho Lach district, Ben Tre Province, Mekong Delta, Viet Nam. After harvest, fruits were transported immediately to the laboratory where they were graded for uniform in colour and size (70-80 g) and hand-washed in chlorinated water (250 ppm), this was followed by the air-drying of fruits under fans.

Figure 1 Mangosteen using in the experiment

2.1.2 Packaging materials and preparations

Packaging materials used in the study were including polypropylene (PP) bags with a dimension (20x32 cm) and a thickness of 0.5 mm; MAP Lifespan (Lifespan) bags and perforated cardboard boxes (2.5 kg) were used as fruit containers for the experiment. To make micro-perforated PP bags for the experience, the polypropylene (PP) bags were punctured with a 0.33mm hypodermic needle to produce bags with 10, 20, 30 and 40 holes per bag (PP10, PP20, PP30, PP40 respectively).

2.2 Experimental design and treatments

This experiment was designed in a completely randomized design (CRD) with one factor of five bagging treatments including four treatments of micro-perforated polypropylene (PP) bags (i.e. PP10, PP20, PP30, PP40) and one of MAP Lifespan bag and a non-bagged control. The treatment of Lifespan bag was used here to compare the results of polypropylene (PP) bags with a commercial MAP (Lifespan) bag. All the treatments were replicated four times and each replication has 12 fruits.

Harvested mangosteen fruits after graded, hand-washed then air-dried under fans as described as above, they were randomly divided into six groups (144 fruits/group) and packed in order in micro-perforated polypropylene (PP) and Lifespan bags (12 fruits/bag) and then the fruit bags were put individually into perforated cardboard boxes. For the control, fruits were just put into perforated cardboard boxes (12 fruits/cardboard box). The fruit boxes were then stored in a cool store with a temperature set at 13°C and relative humidity in the range of 80-85%. In each storage period of 10, 20 and 25 days, five fruit boxes containing all treatment and control were taken out from the coolstore and subjected to measure in-package gas composition which was followed by assessing physicochemical qualities of mangosteen fruit.

2.3 Studied physicochemical attributes of Mangosteen fruits

After completion storage periods, measurements were made for packaged gas composition and physicochemical assessments. Gas composition (Percentage of O₂ and CO₂) of packaging atmosphere was directly measured by using Dansensor (Checkmate 3- Germany) once fruit boxes had been taken out from the coolstore. For physicochemical assessment, fruits were removed from their bags and hold at a cool room (20°C) for 2 two hours before the assessment had taken place. The physicochemical assessment was carried out on the basis of external and internal quality attributes of mangosteen fruit. The selected external quality attributes were pericarp color, calyx and stem appearance, pericarp hardening and weight loss and they were non-destructively assessed from 144 fruits for each treatment at each measurement time including at the beginning, 10, 20 and 25 days of storage. After non-destructive assessment, the fruits were subjected to measure titratable acidity (TA) and total soluble solid (TSS) of fruit flesh. Among various physical characteristics, pericarp color was measured at or around the equator for each fruit by using a Minolta-CR400 chromameter (Japan) and the color was expressed as L* (lightness), a* (green to red color) and b* (blue to yellow).

Further, Calyx and stem appearance was assessed by visualization and based on the scoring rates given by Jiang & Li (2001). Calyx appearance was assessed on the 0-5 scale, where: 0 = no browning of calyx surface, 1 = 1-5% browning, 2 = 6-11% browning, 3 = 11- 25 % browning, 4 = 26-50 % browning, 5 = > 50 % browning and a browning index was calculated using the formula of Jiang & Li (2001):

$$\sum(\text{browning value} \times \text{percentage of fruit in each class}).$$

Further, stem appearance was also assessed by the 0-3 scale given by Jiang & Li (2001) where: 1 = green normal, 2 = yellow color, 3 = brown and black color and a browning index was similarly calculated as using the formula Jiang & Li (2001):

$$\sum(\text{browning value} \times \text{percentage of fruit in each class})$$

Fruits having a browning index of calyx and stem appearance above 3.0 were rated as unacceptable.

Weight loss was expressed as percent weight loss which was calculated from initial weight and weight after storage using an electric balance (UX420S, Japan), according to the method given by Tefera et al. (2007).

$$\text{Weight loss (\%)} = (\text{Initial weight} - \text{weight at the assessment time}) / \text{initial weight} \times 100,$$

Further Pericarp hardening was expressed as the proportion of fruit with hardened pericarps, and it was calculated by the formula given below

$$\text{Pericarp hardening (\%)} = (\text{Number of fruit with hard pericarp} / \text{Total number of fruit in the treatment}) \times 100.$$

Titratable acidity (TA) was determined by the method of the Association of Official Analytical Chemists International (1990) while the TSS was measured as degrees brix in fruit juice using an ATAGO-Japan, refractometer with a 0 - 32° scale. Analyses of TA and TSS were performed before storage and after 10, 20 and 25 days of storage.

2.3 Statistical analysis

All data were statistically analyzed by ANOVA and treatments compared using (to 5% significance level) by using SAS, version 8.1 and Excel 2010 software.

3 Results and Discussion

3.1 Effects of packaging materials on in-package gas composition

Effects of the different types of packaging materials on gas composition are shown in Fig.2. Results of study revealed a consistent decrease in concentration of O₂ and simultaneous increases in the concentration of CO₂ over the storage period for all packaging conditions. After 25 days of storage, the lowest O₂ concentrations were reported from the Lifespan (5.29%) and PP10 (10.4%) packages and these two were significantly lower ($p < 0.05$) than the concentrations of the other treatments. The concentration of CO₂ increased with storage time and it was reported highest in the treatments PP 10 (10.5%) and Lifespan (7.4%) packages ($p \leq 0.05$) after 25 days of storages. Results of this study revealed that both PP microperforated and Lifespan bags has ability to modify the in-package gas composition. Results of present study are in agreement with the findings of previous researchers those who reported effect of different packaging material on the gaseous concentration of mangosteen fruits (Pranamornkith et al., 2003; Pakkasarn et al., 2003; Manurakchinakorn et al., 2008). From the results of this study, it can be conclude that in-package gas composition (O₂, CO₂) can be successfully modified by using permeable packaging materials.

Figure 2 Influence of the polypropylene materials with different numbers of holes and Lifespan bags on in-package gas composition of mangosteen fruits during storage at 13°C.

Further, modification in gaseous composition in-packing condition also modify the storage atmosphere which affect the rate of respiration, ethylene production and the growth of postharvest pathogens and these conditions alter the physico-chemical characteristics of the fruit (Suparlan & Kazuhiko, 2003; Xing et al., 2010).

3.2 Effects of different packaging materials on non-destructive quality attribute

3.2.1 Pericarp colour

Pericarp color is one of the most important visual attributes for mangosteen fruit quality and it is also a main criterion for maturity evaluation (Tongdee & Suwanagul, 1989). Changes in pericarp color can be measured by chromameter with the help of three different colors and its related symbols viz L^*

(lightness), a^* (green to red colour), b^* (blue to yellow). Results of pericarp color changes are shown in Table 1. Results of study suggested that L^* values rapidly decreased for the first 10 days of storage and later on rate of color changes reduced at slower rate by the 20th and 25th days of packaging. After 25 days of storage, fruit stored in PP 30 had shown highest brightness but the differences among other treatments were not significant ($P < 0.05$). All packaged fruit were significantly brighter (higher L^* values) than the unpackaged control. Further, it was also reported that values of a^* increases rapidly for the first 10 days of storage (except control) and later on the values of a^* increased slowly for next 15 days (up to 25 days). Reductions in b^* value also followed the same trends of L^* values during storage. This reduction in L^* and b^* values and increases in a^* values are correlated with color development of mangosteen due to ripening.

Table 1 Influence of packaging material with different numbers of holes and Lifespan bagson pericarp colour (L^* (lightness), a^* (green to red colour), b^* (blue to yellow) of mangosteen fruits during storage at 13°C.

Treatments	L^*				a^*				b^*			
	Storage times (Days)				Storage times (Days)				Storage times (Days)			
	0	10	20	25	0	10	20	25	0	10	20	25
PP10	55.70	41.99 ^a	36.93 ^a	32.22 ^{ab}	11.19	19.10 ^a	20.12 ^{ab}	20.09	30.45	19.05 ^a	14.51	12.12 ^{abc}
PP20	54.57	35.92 ^{bc}	33.39 ^b	32.87 ^a	9.96	18.73 ^a	18.66 ^b	19.03	28.59	13.55 ^b	12.94	11.04 ^{bc}
PP30	52.96	39.54 ^{ab}	31.93 ^b	34.31 ^a	9.57	19.09 ^a	19.95 ^{ab}	20.89	30.79	16.47 ^{ab}	9.62	10.40 ^{bc}
PP40	58.78	35.16 ^c	30.47 ^b	29.49 ^b	12.53	18.17 ^a	18.71 ^b	19.23	30.50	13.47 ^b	10.50	8.92 ^c
Lifespan	53.64	41.28 ^a	33.23 ^b	32.17 ^{ab}	11.90	17.04 ^{ab}	20.50 ^a	21.70	31.31	19.23 ^a	11.64	13.54 ^{ab}
Control	49.16	38.88 ^{abc}	37.59 ^a	31.93 ^{ab}	12.73	15.10 ^b	15.43 ^c	18.15	24.21	15.48 ^b	13.47	15.19 ^a
CV(%)	8.42	5.59	5.18	4.89	17.44	8.40	4.17	9.74	15.42	10.25	19.79	16.15
F	NS	*	*	*	NS	*	*	NS	NS	*	NS	*

Data shown in the table is mean values of four replicates; in the same column, values which have the same characteristics are not significant difference at ($P < 0.05$); NS: Non significant difference at ($P < 0.05$).

According to Noichinda (1992) mangosteen is a climateric fruit and it is continuously ripen even after the harvesting. Further, Ratanamarno et al.(2005) reported that the development of pericarp color is the result of chlorophyll degradation and anthocyanin synthesis and in case of mangosteen fruits, rate of anthocyanin synthesis is maximum during fruit ripening and fruit become purple-red when it is completely ripen (Du & Francis, 1977). The fruit from all the packaged treatments continued to ripen during the three day shelf life storage period at 20°C. Fruit from the unpackaged control did not ripen well and at the end of the experiment retained a yellow skin color with scattered pink spots. Overall the best quality fruit at the end of the storage and shelf life period were those which stored in PP30 bags and these results are in agreement with the findings of Palapol et al. (2009).

3.2.2 Calyx characteristics

Changes in the appearance of the calyx and stem color during storage time are shown in Fig.2. The extent of browning and shrinkage of the calyx and stem increased with the increasing of storage time and significant differences was reported among the various treatments ($p < 0.05$). Rate of browning index increased with the storage time and among various tested treatments, lowest browning index (score above 1) was reported for the fruit stored in PP30 (score = 1.14) which was significantly lower than the control fruit which scored 2.41. After 25 days of storage only fruit stored in PP30 had as significantly lower ($p < 0.05$) browning index of the calyx (score = 2.84) than the other treatments (score 4-5) in which the calyx color turned to yellowish- brown (Figure 3a).

3.2.3 Stem characteristics

Storage time has visual effect on stem color and it gradually changes from green to yellow to brown. Among various tested

conditions highest stem browning index was reported in non-packed fruit (score =2.75). Chlorophyll discoloration in the calyx and stem highly influences consumer behavior of acceptance the fruit (Manurakchinakorn et al., 2008). Most acceptable stem color was maintained in fruit stored in PP30 which had a score of 2.53 (Figure 3b) and which was significantly lower than that of the other treatments. Color changes of calyx and stem could be related to the degradation of chlorophyll by chlorophyllase and water loss during the cold storage (Azuma et al., 1999; Manurakchinakorn et al., 2014).

3.2.4 Pericarp hardening percentage

Pericarp hardening in mangosteen greatly influences consumer behavior (Tongdee & Suwanagul, 1989; Ketsa & Koolpluksee, 1993; Deewatthanawong et al., 2003). Effects of packaging conditions on pericarp hardening are presented in Fig.4a. No pericarp hardening percentage (PHP) was observed in any treatment for the first 10 days of storage. After 10th days of storage PHP starting appearing stored mangosteen fruits and on 20th day highest PHP was detected in the control (16.67%) and it was followed by PP10 and Lifespan stored fruit. However, differences in PHP between packaged treatments were not found significant ($p < 0.05$). After 25 days of storage, the PHPs of all bagged treatments were significantly lower ($p < 0.05$) than the unpackaged control (44.4%). Among various treatments, fruit bagged in PP30 had lowest PHP (2.77%) but that value was not significantly lower than that of fruit in any of the other packaging treatments. Increases in peel hardness during cold storage could be the result of an increase in lignin and cross-linking between lignin, cell wall polysaccharides (Ralph et al., 1995) and protein (Whetten et al., 1998) creating solid lignin compounds (Iiyama et al., 1994). Results of this study are in agreement with data reported by Manurakchinakorn et al. (2008). Thus the use of appropriate packaging could inhibit pericarp hardening during cold storage.

Figure 3 Influence of use PP micro holes to calyx (a) and stem colour changes (b) of mangosteen fruits during storage at 13°C.

3.2.5 Weight loss

Fruit weight loss is associated with the dehydration and it may affect the commercial values of the fruits. Effects of the different packaging materials on weight loss in present study are shown in Figure 3b. The percentage weight loss increased progressively with storage time in all the treatments. Unpackaged control fruit sustained an average of 15.45% weight loss. Weight loss was minimal (approximately 1%) in all packaged fruit and significantly lower ($p < 0.05$) than the control fruit.

Among various tested packing conditions, least weight loss was reported in fruit stored in the PP10 bags but this weight difference were not significant different in weight loss among the packaging treatments. These results are consistent with Daryono & Sabari (1986) and Choehom, (1997) those who suggested that surface coatings and fruits wrapping in polyethylene film bags reduced weight loss during storage (Figure 4b).

3.3 Effects packaging materials on Total Soluble Solids (TSS) and Titratable Acidity (TA)

Effect of different packaging material on stored fruits TSS and TA have been shown in table 2. In general, very few changes was reported in TSS during storage, and it ranged from 15.7 to 18.6°Brix (table 2). Further, it was reported that TSS value increased slightly up to the 20th day of storage and later on it start decreasing towards the end of storage time. However, there were no significant differences reported among the means value of various treatments ($p < 0.05$). TSS values reported for this study were similar to reported by Augustin & Azudim (1986) who found that the TSS of mangosteen stored at 8 °C ranged from 17.7 and 20.4 °Brix.

In case of TA, some changes were reported in titratable acidity during storage in all treatments but these changes were not significantly different ($p < 0.05$) among the means of the six treatments. Further, slight reduction in TA value was reported after 20th day of storage and later on this value started increasing during the last five days. The average values ranged from 0.81% (day zero) to 0.78% (day 25) (table 2). The overall decrease in TA is attributable to the metabolism of organic acids and other chemical components by respiration and transpiration (Chitarra & Chitarra, 2005). These results are in agreement with the findings of Manurakchinakorn et al. (2008) those who reported that during the ripening process TA decreased and TSS increased in most of the fruits.

Conclusions and Recommendations

The microperforated PP film used in this trial was just as effective as the commercial packaging product MAP Lifespan for controlling the in-package gas composition of stored mangosteen fruits. Among the various treatments, the PP bag with 30 holes was reported most effective at minimizing browning and shrinkage of calyx and stem, weight loss and pericarp hardening. It was also able to provide stability to biochemical components such as TSS and TA. The fruit were maintained in good physical and physiological condition for 25 days at 13°C.

This trial provides evidence that quality losses in mangosteen fruits during the low temperature storage can be avoided by packaging in microperforated polyethylene bags. It is recommended that a further series of trials comparative PP30 and MAP Lifespan should be carried out to ensure that there result obtained here for PP30 is consistent and is a reliable alternative to MAP Lifespan. Further research on combining the use of PP30 packaging with other treatments such as 1-mcp may lead to an even longer storage life of mangosteen fruits.

Figure 4 Influence of different packaging materials on pericarp hardening (a) and weight loss (b) of mangosteen fruits during storage at 13°C.

Table 2 Influence of packaging material with different numbers of holes and Lifespan bags on total soluble solid (TSS) and total acidity (TA) of mangosteen fruits during storage at 13°C.

Treatments	TSS (°Brix)				Total acidity (%)			
	0D	10D	20D	25D	0D	10D	20D	25D
PP 10	15.70	17.23	18.16 ^a	17.20 ^{ab}	0.83	0.76	0.58 ^b	0.99 ^{ba}
PP 20	16.26	17.46	18.22 ^a	17.10 ^{ab}	0.83	0.71	0.59 ^b	0.96 ^{bc}
PP 30	16.16	17.03	18.60 ^a	17.83 ^a	0.81	0.0	0.61 ^{ab}	0.82 ^c
PP 40	16.50	16.83	18.20 ^a	16.93 ^b	0.82	0.67	0.62 ^{ab}	0.92 ^{bc}
Lifespan	16.76	17.70	17.26 ^b	16.60 ^b	0.80	0.68	0.61 ^{ab}	1.10 ^b
Control	16.50	17.13	17.36 ^b	16.70 ^b	0.76	0.70	0.67 ^a	1.36 ^a
CV(%)	3.65	3.70	1.98	2.66	11.48	7.47	5.86	12.06
F	ns	ns	*	ns	ns	ns	ns	*

Data shown in the table is mean values of four replicates; in the same column, values which have the same characteristics are not significant difference at ($P < 0.05$); NS: Non significant difference at ($P < 0.05$)

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Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

References

- Association of Official Analytical Chemists International (1990) Association Of Official Analytical Chemists. Inc. Washington, D.C.
- Augustin MA, Azudim MN(1986) Storage of mangosteen (*Garcinia mangostana* L.). ASEAN Food Journal 2: 78-80.
- Azuma R, Takahashi Y, Kurata S, Kawano T, Shimokawa K, Adachi M (1999) Does peroxidase act as a peroxidase 'Mg-dechelatase'. Plant Peroxidase Newsletter 13:145-151.
- Chitarra AB, Chitarra MIF (2005) Pós-colheita de frutas e hortaliças: fisiologia e manuseio. 2. ed. Lavras: UFLA: 785.
- Choehom R (1997) Effect of waxing and plant growth regulators on quality and storage-life of mangosteen (*Garcinia mangostana* L.) fruit during cold storage. Bangkok: Kasetsart University, Department of Horticulture, Graduate Special Problem.
- Daryono M, Sabari S(1986)The practical method of harvest time on mangosteen fruit and its characteristics in storage. Bulletin Penelitian Hortikultura 14: 38-44.
- Deewatthanawong R, Ketsa S, van Doorn WG (2003) Chilling injury in mangosteen fruit. Journal of Horticultural Science and Biotechnology 78: 559-562.
- Du CT, Francis FJ (1977) Anthocyanin of mangosteen (*Garcinia mangostana* L.). Journal of Food Science 42: 1667–1668. DOI: 10.1111/j.1365-2621.1977.tb08452.x.
- Iiyama K, Lan TBT, Stone BA(1994) Covalent cross-links in the cell wall. Plant Physiology 104: 315–320.
- Jiang Y, Li Y(2001) Effects of chitosan coating on postharvest life and quality of longan fruit. Food Chemical 73: 139-143. [http://dx.doi.org/10.1016/S0308-8146\(00\)00246-6](http://dx.doi.org/10.1016/S0308-8146(00)00246-6).
- Ketsa S, Koolpluksee M (1993) Some physical and biochemical characteristics of damaged pericarp of mangosteen fruit after impact. Postharvest Biology and Technology 2: 209-215. doi:10.1016/0925-5214(93)90048-8.
- Manurakchinakorn S, Issalakraisila M, Nuymak P (2008) Physiological and quality attributes of Mangosteens (*Garcinia mangostana* L.) as affected by modified atmosphere packaging. ActaHorticulturae 768: 239-246. DOI: 10.17660/ActaHortic.2008.768.29.
- Manurakchinakorn S, Nuymak P, Issarakraisila M (2014) Enhanced chilling tolerance in heat-treated mangosteen. International Food Research Journal 21: 173-180.
- Noichinda S (1992) Effect of modified atmosphere on quality and storage-life of mangosteen (*Garciniamangostana* L.) fruit. Master thesis submitted to Kasetsart University Bangkok Pp. 74 (In Thai).
- Pakkasarn S, Kanlayanarat S, Uthairatanakij A(2003) High carbon dioxide storage for improving the postharvest life of mangosteen fruit (*Garcinia mangostana* L.). ActaHorticulturae 600:813-816. DOI: 10.17660/ActaHortic.2003.600.127.

- Palapol Y, Ketsa S, Lin-Wang K, Ferguson IB, Allan AC (2009) A MYB transcription factor regulates anthocyanin biosynthesis in mangosteen (*Garcinia mangostana* L.) fruit during ripening. *Planta* 229: 1323–1334. doi: 10.1007/s00425-009-0917-3.
- Pranamornkith T, Kanlayanarat S, Uthairatanakij A (2003) Effect of polyethylene film packaging on the storage life of mangosteen fruit (*Garcinia mangostana* L.). In: Australian Post Harvest Horticulture Conference.
- Ralph J, Grabber JH, Hatfield RD (1995) Lignin-ferulate crosslinks in grasses: active incorporation of ferulate polysaccharide esters into ryegrass lignins. *Carbohydrate Research* 275: 167–178. doi:10.1016/0008-6215(95)00237-N.
- Ratanamarno S, Uthaibutra J, Saengnil K (2005) Effects of bagging and storage temperature on anthocyanin content and phenylalanine ammonia-lyase (PAL) activity in mangosteen (*Garcinia mangostana* L.) fruit pericarp during maturation. *Songklanakarin Journal Science Technology* 27: 711–717.
- Suparlan, Kazuhiko ITOH (2003) Combined effects of hot water treatment (hwt) and modified atmosphere packaging (map) on quality of tomatoes. *Packaging Technology and Science* 16: 171–178. DOI: 10.1002/pts.626.
- Tefera A, Seyoum T, Woldetsadik K (2007) Effect of disinfection, packaging and storage environment on the shelf life on mango. *Biosystems Engineering* 96: 201–212. DOI: <http://dx.doi.org/10.1016/j.biosystemseng.2006.10.006>.
- Tongdee SC, Suwanagul A (1989) Postharvest mechanical damage in mangosteen. *ASEAN Food Journal* 4: 151–155.
- Whetten RW, MacKay JJ, Sederoff RR (1998) Recent advances in understanding lignin biosynthesis. *Annual Review Plant Physiology and Plant Molecular Biology* 49: 585–609. DOI: 10.1146/annurev.arplant.49.1.585.
- Wieble J, Chacko EK, Downton WJS (1992) Mangosteen (*Garcinia mangostana* L.) a potential crop for tropical northern Australia. *Acta Horticulturae* 321: 132–137.
- Xing Y, Li X, Xu Q, Jiang Y, Yun J, Li W (2010) Effects of chitosan-based coating and modified atmosphere packaging (MAP) on browning and shelf life of fresh cut lotus root (*Nelumbo nucifera* Gaertn.). *Innovative Food Science and Emerging Technologies* 11: 684–689. DOI: <http://dx.doi.org/10.1016/j.ifset.2010.07.006>.