Kasetsart J. (Nat. Sci.) 43 : 275 - 281 (2009)

Effect of High Gas Permeable Materials on Quality and Shelf Life of Rambutan cv. 'Rong Rian'

Piyarat Pongsai[1], Sasitorn Tongchitpakdee[2], Asira Fuongfuchat[3] and Vanee Chonhenchob[1]*

ABSTRACT

The effect of high gas permeable materials on the quality and shelf life of rambutans (cv. 'Rong Rian') was studied. Rambutan fruit were stored at 12°C after being packaged in polypropylene (PP) trays and heat-sealed with three types of polyethylene film with different gas transmission rates, denoted as PE-0 (OTR = 3,800 cc/m^2/d), PE-1 (OTR = 7,000 cc/m^2/d), PE-2 (OTR = 12,000 cc/m^2/d) and compared with a control without film packaging. An equilibrium-modified atmosphere (EMA) was achieved in the PE-1 and PE-2 systems after storage for 4 d. The gas compositions at equilibrium in the packages of rambutan with PE-2 and PE-1 were 3.6%O_2+9.8%CO_2 and 2.6%O_2+16.1%CO_2, respectively. The EMA conditions in PE-2 and PE-1 could maintain the quality and resulted in the longest shelf life of rambutans of 18 d and 12 d, respectively. Rambutans in PE-0 and the control (without any packaging film) had a shelf life of 9 and 6 d, respectively. Rambutans in PE-2 had the lowest spintern browning, while the control had the most severe browning. Browning of the spintern and skin was also observed in the rambutans packaged in PE-0 and PE-1 due to the high CO_2 atmosphere.

Key words: rambutan, high gas permeable materials, film, modified atmosphere packaging

INTRODUCTION

Rambutan (*Nephelium lappaceum* Linn.) cv. 'Rong Rian' is an important economic fruit crop of Thailand. It has been classified as a non-climacteric fruit (O'Hare, 1995). At room temperature conditions, the fresh quality of rambutan fruits can be retained for only 3-4 d and then the spinterns turn brown and ultimately black (Lam and Kosiyachinda, 1987). Its deterioration is generally associated with a decline in appearance, due to skin desiccation and browning from water loss. Skin desiccation and browning can be minimized substantially by storing rambutans under high relative humidity (RH) and low temperature (O'Hare *et al*., 1994; Landrigan *et al*., 1996). Lam and Kosiyachinda (1987) reported that the optimum storage temperature for rambutans was about 12°C, which was found to maintain their quality for one week.

Modified atmosphere packaging (MAP) is a successful technique to maintain the quality and extend the storage life of many fruits and vegetables by reducing losses and also suppressing the physiological disorders of browning and chilling injury (Zagory and Kader, 1988). MAP

[1] Department of Packaging Technology, Faculty of Agro-Industry, Kasetsart University, Bangkok 10900, Thailand.
[2] Department of Food Science and Technology, Faculty of Agro-Industry, Kasetsart University, Bangkok 10900, Thailand.
[3] National Metal and Materials Technology Center, PathumThani 12120, Thailand.
* Corresponding author, e-mail: vanee.c@ku.ac.th

implies the use of polymeric films, with different gas permeabilities, to create and maintain an optimum equilibrium in the modified atmosphere conditions inside the packaged produce. The in-package O_2 and CO_2 concentrations vary as a function of produce respiration rate, temperature and the O_2 and CO_2 permeability coefficients of the packaging materials. Gas permeability of the films is also related to package area and film thickness (Al-Ati and Hotchkiss, 2003). Film selection is an important factor for the MAP system, since a proper matching of the produce respiration rate with the film permeability results in the desired equilibrium modified atmosphere (EMA) within the package (Mir and Beaudry, 2004). However, packaging of fresh produce with most commercially available films results in low O_2 and/or high CO_2 in the package causing physiological injury and off-flavor. There are some specific films available for produce packaging. However, these imported films are particularly expensive and may not be suitable for tropical produce.

Recently, the National Metal and Materials Technology Center (MTEC) developed some high gas permeable packaging materials. The films have been shown to maintain the quality and shelf life of many fruits and vegetables by creating optimum EMA conditions inside the packages (Fuongfuchat *et al.*, 2006). However, there is limited information on the use of high gas-permeable films in maintaining quality and extending the shelf life of rambutans.

The objectives of this study were to determine the equilibrium modified atmosphere conditions established in packages of rambutan (cv. 'Rong Rian') and their effects on maintaining quality and the shelf life of rambutan (cv. 'Rong Rian') during storage at 12°C.

MATERIALS AND METHODS

Rambutans and packaging films

Samples of rambutan (*Nephelium lappaceum* Linn.) cv. 'Rong Rian' were harvested from an orchard in Rayong province, in eastern Thailand and transported to the laboratory at Kasetsart University in Bangkok by an air-conditioned truck at a temperature of 20 ± 2°C. Fruits that were uniform in color (light red peel and green spinterns) and size (about 27-30 fruit/kg) were selected for use in this study. Six fruit were packaged in a polypropylene (PP) tray (12 × 18 × 6 cm.) and then heat-sealed with three types of polyethylene films, denoted as PE-0 (the common LDPE film), PE-1, and PE-2. The oxygen transmission rates of PE-0, PE-1, and PE-2 films were 3,800, 7,000, and 12,000 cc/m^2/d, respectively. Rambutans packaged in the same type of tray without any film were used as a control. All the treatments were stored at 12 ± 0.5° C, 90 ± 5% RH. The experiments were conducted in triplicate.

In-package gas composition

The concentrations of O_2 and CO_2 in each package were measured using a gas chromatograph (Agilent 6890, U.S.A.) equipped with a thermal conductivity detector (TCD) of 200°C and a molecular sieve 5A column for O_2 and a Hayesep Q column for CO_2. Helium at 80 ml/min was used as the carrier gas. The gas concentrations inside the package were measured by withdrawing 3 ml of headspace gas from the packages and injecting it into the gas chromatograph.

Quality evaluation

Changes in color were measured in the middle part of each fruit using a Minolta colorimeter CR-310 (Minolta Co., Japan) and expressed in L* a* b* values. The spintern browning score of the rambutans was measured on a 0-4 scale based on the browning area of the total spinterns, where: 0 = no browning, 1 = 1-25%, 2 = 26-50%, 3 = 51-75% and 4 = 76-100%. A spintern browning score > 2.0 was considered unacceptable. The browning score due to a high CO_2 atmosphere was shown to be a combination of spintern and skin browning, which was measured visually on a 0-4 scale based on the injury area, where: 0 = no browning, 1 = 1-10%, 2 = 11-25%, 3 = 26-50% and 4 = 51-100%. Browning from a high CO_2 atmosphere was unacceptable at score > 2.0. Weight loss was also evaluated based on the weight of each sample before and after storage and was expressed as a percentage of the initial sample weight.

Statistical analysis

A completely randomized design was used in this study. All data were analyzed by analysis of variance (ANOVA) using SPSS for Windows Version 12.0. To determine differences between treatments, Duncan's multiple range test was applied and significant differences were recognized at $p \leq 0.05$.

RESULTS AND DISCUSSION

Changes in the CO_2 and O_2 concentrations inside the packages of rambutans are shown in Figure 1. Table 1 shows the EMA conditions together with the shelf life of the

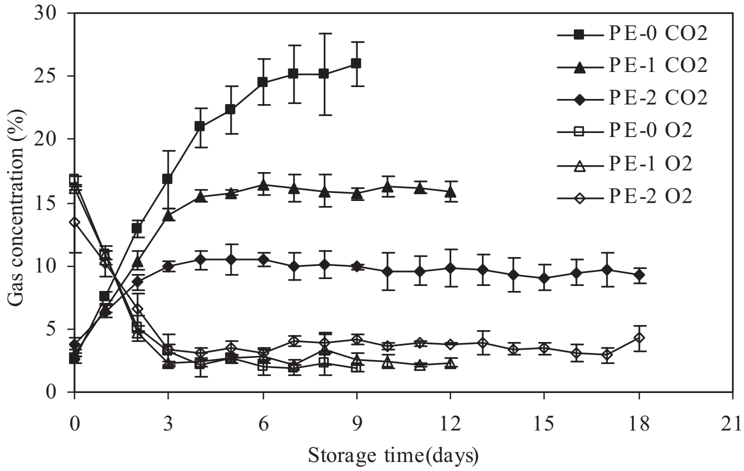

Figure 1 Changes of CO_2 (closed symbol) and O_2 (open symbol) concentrations in rambutans stored in PP trays heat-sealed with different plastic films at 12 ± 0.5°C. Vertical bars represent the mean ± standard deviation (SD).

Table 1 Equilibrium modified atmosphere conditions and shelf life of rambutans in different packaging systems stored at 12 ± 0.5°C.

Packaging film	Equilibrium modified atmosphere		Shelf life(days)
	CO_2 (%)	O_2 (%)	
PE-0	25.2*	1.9*	9
PE-1	16.1	2.6	12
PE-2	9.8	3.6	18
control (without film)	-	-	6

* = PE-0 systems did not achieve EMA conditions. The data shown was at nine days of storage.

rambutan samples in different packaging systems. The gas compositions at equilibrium in the samples with PE-1 and PE-2 were 2.6%O_2+16.1%CO_2 and 3.6%O_2+9.8%CO_2, respectively. The longest shelf life of rambutans was observed in PE-2 (18 d), followed by PE-1 (12 d), PE-0 (9 d), and the control (6 d), respectively. The results show that reduced O_2 and elevated CO_2 were achieved in all high gas permeable systems (PE-1 and PE-2). The results were consistent with the finding of Kader (1993) that the recommended controlled atmosphere conditions for storage and transportation of rambutan fruit were 7 to 12% CO_2 and 3 to 5% O_2 at 10°C. O'Hare *et al*. (1994) also reported that 9 to 12% CO_2 retained the color and extended the shelf life of rambutans for 4 to 5 d.

Carbon dioxide accumulation in PE-0 reached 25.2% after storage for 9 d. The accumulation of CO_2 in the packages was due to the relatively high respiration rates of the fruit, compared to the low oxygen and carbon dioxide permeability of the films (Zagory and Kader, 1988). PE-0 had the lowest gas permeability compared with PE-1 and PE-2. Therefore, the highest CO_2 accumulation was observed in PE-0, followed by PE-1 and PE-2, respectively.

Changes in color as determined by L* values are shown in Figure 2. Browning of rambutans was associated with a decrease in the L* values. The results showed that L* values generally decreased during storage under all treatments. The highest L* values were observed in rambutans packaged in PE-2, while the lowest L* values were observed in the control, which had severe browning. PE-1 and PE-0 were not significantly different ($p > 0.05$) until 6 d of storage, but were significantly different ($p \leq 0.05$) after storage for 9 d. The results indicated that the browning rate decreased as film permeability increased.

Browning was caused by dehydration, which was ascribed to the rambutan's morphology, as the skin is covered by hair-like protuberances (spinterns) that make rambutans tend to lose water (Landrigan, 1996). The water loss induces browning in the spinterns during storage. This type of browning was shown to be a limiting factor for rambutan fruit acceptability. All treatments showed deterioration due to spintern browning. The browning scores of rambutans stored in different packaging systems are shown in Figure 3A. The

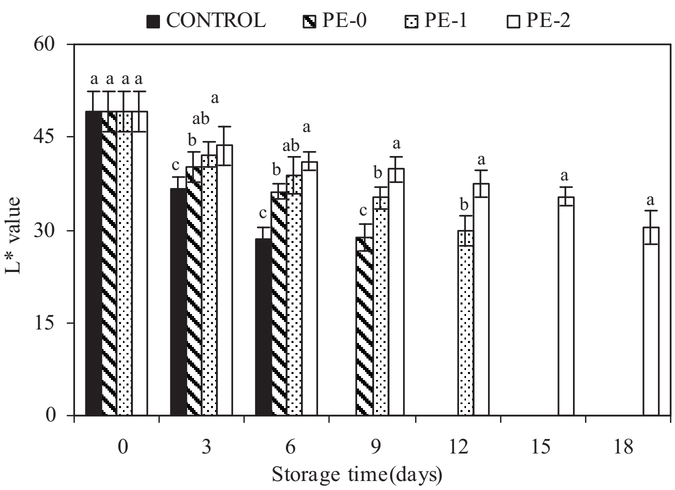

Figure 2 Change in L* values of the rambutans in different packaging materials and without packaging (CONTROL), stored at 12 ± 0.5°C. Vertical bars represent the mean ± SD. Means with different letters are significantly different ($p \leq 0.05$) by Duncan's multiple range test.

browning scores were highly correlated with L* values ($r^2 = 0.8781$).

In addition to water loss, a high CO_2 atmosphere could cause different browning symptoms in rambutans. The noticeable symptoms of rambutans stored in an elevated CO_2 atmosphere included the browning of skin and spintern. Browning of rambutan from the effect of an elevated CO_2 atmosphere (> 15% CO_2) was observed in PE-0 and PE-1 at the sixth day of storage (Figure 3B). As the spinterns of rambutans in PE-0 and PE-1 turned brown rather than violet or blue, it could have been due to water loss rather than the effect of CO_2 on anthocyanin stability. Skin browning was also observed in rambutans packaged in an elevated CO_2 atmosphere. This could have been due to the effect of CO_2 on chilling injury or CO_2 injury. The results suggested that elevated CO_2 could have an adverse effect on rambutans. However, further investigation is necessary for clearer explanation.

Changes in weight loss of rambutan fruit

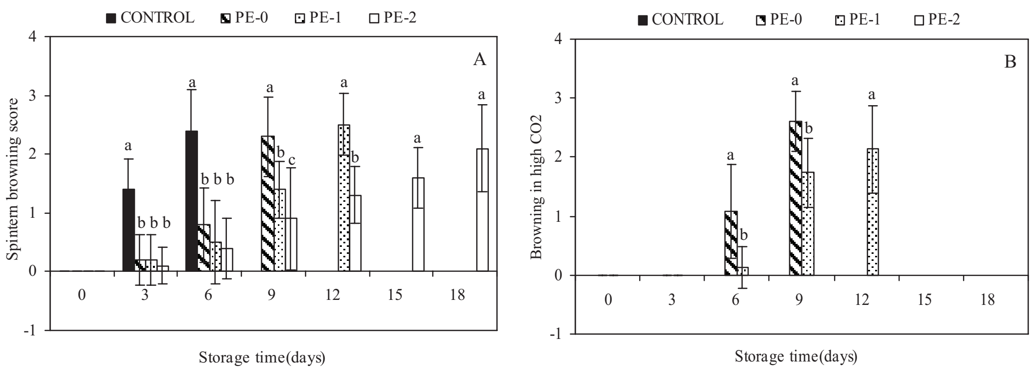

Figure 3 Scores of spintern browning (A) and CO_2 injury (B) of the rambutan fruit in different packaging materials and without packaging films (control), stored at 12 ± 0.5°C. Vertical bars represent the mean ± SD. Means with different letters are significantly different ($p \leq 0.05$) by Duncan's multiple range test. (Spintern browning score: 0 = no browning, 1 = 1-25%, 2 = 26-50%, 3 = 50-75%, 4 = 76-100% and elevated CO_2 browning score: 0 = no browning, 1 = 1-10%, 2 = 11-25%, 3 = 26-50%, 4 = 51-100%).

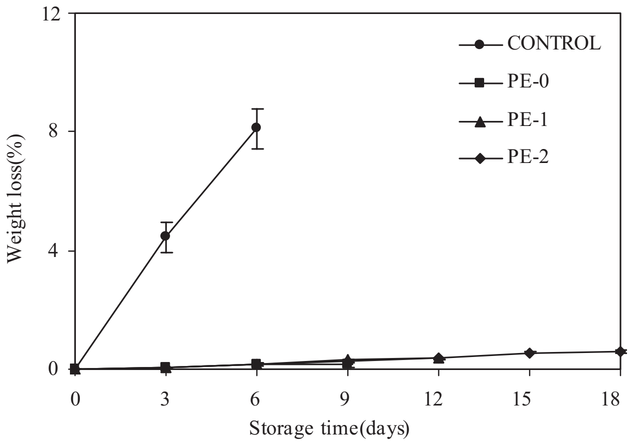

Figure 4 Changes in weight loss (%) of rambutans in different packaging materials and without packaging (CONTROL), stored at 12 ± 0.5°C. Vertical bars represent the mean ± SD.

in different packaging systems during storage are shown in Figure 4. Weight loss of rambutans was significantly different ($p \leq 0.05$) between those packaged in the trays heat-sealed with the films and those without any film. The weight loss of the rambutans without packaging films increased rapidly during storage, which was associated with the severe spintern browning due to water loss. MAP was shown to reduce water loss from rambutans (Lee and Leong, 1982; Lam and Kosiyachinda, 1987). In addition, MAP reduced the transpiration and respiration rates of the fruit, hence decreasing water loss (Fonseca *et al*., 2000). Furthermore, the characteristics of the polyethylene film maintained relative humidity levels inside the packages, hence controlling water loss and consequently mass loss of the fruit (Silva *et al*., 1999; Fonseca *et al*., 2000).

CONCLUSION

Use of high gas permeable packaging materials could extend the shelf life of rambutans to 18 d in PE-2 and 12 d in PE-1, from 9 d in the common LDPE (PE-0) and 6 d without any packaging film. The equilibrium modified atmosphere (EMA) conditions that were achieved in PE-2 (9.8% CO_2 and 3.6% O_2) appeared to be suitable MAP conditions to maintain the quality of rambutans and delay spintern browning. Carbon dioxide injury occurred in PE-0 and PE-1 due to high CO_2 concentrations in the packages.

ACKNOWLEDEMENTS

The authors would like to thank the National Metal and Materials Technology Center and the Postharvest Technology Innovation Center, Thailand for financial support for this research.

LITERATURE CITED

Al-Ati, T. and J.H. Hotchkiss. 2003. The role of packaging film permselectivity in modified atmosphere packaging. **J. Agric. Food. Chem.** 51: 4133-4138.

Fonseca, S.C., F.A.R. Oliveira, I.B.M. Lino, J. Brecht and K.V. Chau. 2000. Modelling O_2 and CO_2 exchange for development of perforation-mediated modified atmosphere packaging. **J. of Food Eng.** 43: 9-15.

Fuongfuchat, A., W. Chinsirikul, N. Kerddonfag, T. Trongsatitkul, S. Phiboonkulsumrit, S. Chaiwong and V. Chonhenchob. 2006. The Utilization of Simple Mathematical Model in Developing Equilibrium Modified Atmosphere inside The package of Fresh Produce. **Agricultural Science Journal** 37(5): 62-65.

Kader, A.A. 1993. Modified and controlled atmosphere storage of tropical fruits, pp. 239-249. *In* B.R. Champ, E. Highley and G.I. Johnson (eds.). **Postharvest Handling of Tropical Fruits**. Proc. Intern. Confer. Chiang Mai, Thailand, July 1993, ACIAR Pub. No. 50

Lam, P.F. and S. Kosiyachinda. 1987. **Rambutan - Fruit Development, Postharvest Physiology and Marketing in ASEAN**. ASEAN Food Handling Bureau, Kuala Lumpur, Malaysia. 82pp.

Landrigan, M. 1996. **Postharvest Browning of Rambutan (*Nephelium lappaceum* L.)**. Ph.D. Thesis, University of Western Sydney, Hawkesbury, Australia.

Landrigan, M., S.C. Morris and K.S. Gibb. 1996. Relative humidity influences postharvest browning in rambutan (*Nephelium Lappaceum* L.). **Hort Science** 31: 417-418.

Lee, S.K. and P.C. Leong. 1982. Storage studies on rambutan in Singapore, pp. 172-175. *In* **Workshop on Mango and Rambutan**. University of Philippines, Los Banos.

Mir, N. and R.M. Beaudry. 2004. Modified Atmosphere Packaging. *In* K.C. Gross, C.Y. Wang and M. Saltveit (eds.). **Agricultural Handbook 66**. USDA, Washington, DC, www.ba.ars.usda.gov/hb66/contents.html.

O'Hare, T.J. 1995. Postharvest physiology and storage of rambutan. **Postharvest Biol. Technol.** 6: 189-199.

O'Hare, T.J., A. Prasad and A.W. Cooke. 1994. Low temperature and controlled atmosphere storage of rambutan. **Postharvest Biol. Technol.** 4: 147-157.

Silva, F.M., K.V. Chau, J.K. Brecht and S.A. Sargnt. 1999. Modified atmosphere packaging for mixed loads of horticultural commodities exposed to two postharvest temperatures. **Postharvest Biol. Technol.** 17: 1-9.

Zagory, D. and A.A. Kader. 1988. Modified atmosphere packaging of fresh produce. **Food Tech.** 42(9): 70-77.