

Technical paper

Changes in Commercial Quality of ‘Rong-Rien’ Rambutan in Modified Atmosphere Packaging

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Modified atmosphere conditions which would prolong the storage life of ‘Rong-Rien’ rambutan (*Nephilium lappaceum*) was investigated. Rambutans were packed in 0.04 mm low-density polyethylene (LDPE) bags with 0, 1, 2 or 3 ventilation holes and stored at 12°C. Bags both with and without ventilation holes reduced the weight loss and extended the storage life of the fruit. Rambutan stored in a normal atmosphere had a storage life of only 8 days, while the fruits stored in the bags with and without ventilation holes retained a good appearance for 12 and 16 days, respectively. Respiration and ethylene production were significantly suppressed in rambutans that were stored in LDPE bags without ventilation hole, and electrolyte leakage from the peel tissue of the fruit was also reduced. Ascorbic acid content in control fruits decreased sharply while the fruits stored in LDPE bags maintained their original level for 10 days before decreasing. Gas composition inside the bag without ventilation holes had 7% oxygen and 14% carbon dioxide at the end of storage, while internal gas composition of the perforated bags was almost the same as normal air.

Keywords: rambutan, modified atmosphere, polyethylene bag, quality, storage life

Thailand is the biggest rambutan producer in the world (Van Welzen & Verheij, 1991). ‘Rong-Rien’ rambutan is the most popular variety of the fruit in Thailand and demand for this variety is high for export to other countries. Although the export value increases annually, fresh produce representing only 10% of the total potential value is exported because of the short storage life of the fruit. At room condition, the fresh quality of rambutan fruits can be retained for only 3–4 days, and then the spintern turns brown and, finally black (Lam & Kosiyachinda, 1987). This browning is the first unacceptable appearance and is due to spintern dehydration. Water loss from the fruits reportedly increases as the humidity declines, and the optimum relative humidity for storage is 95% (Mendoza *et al.*, 1972). Low temperature storage is successfully used to retain quality in various kinds of fresh produce. Most horticultural commodities of tropical origin are subject to physiological injury when stored at temperatures below 12.5°C (Morris, 1982). For ‘Rong-rien’ rambutan, chilling injury symptoms were observed when stored at 10°C for 2–3 days (Sri-laong *et al.* 1998); optimum temperature for storage and transportation was about 12°C which was found to maintain the quality for one week (Lam & Kosiyachinda, 1987). Application of modified a atmosphere technique had the effect of maintaining the quality and extending the storage life of fresh produce and also suppressed the physiological disorders of browning and chilling injury (Devon & Kader, 1988). A modified atmosphere condition can be achieved by storing the fresh

produce in plastic film packaging or applying a coating material. Lee and Leong (1982) studied the effect of polyethylene bags with micro-perforations on the quality of ‘Jitlee’ rambutan and found that after storage for 7 days at 10°C the fruits still retained a good quality and skin color loss was retarded. A study on cultivars ‘R3’ and ‘R156’ showed that the quality of the fruits was maintained for one week in perforated and non-perforated polyethylene bags at 10°C. Storage at a modified atmosphere also had the effect of extending storage life of many kinds of tropical fruit such as mango and banana (Thompson, 1998). There is limited information on use of modified atmosphere packaging in ‘Rong-Rien’ rambutan and knowledge gained from this research can be beneficial for the rambutan exporter and also useful for the consumer, especially those some distance from a tropical region and who delight in fresh fruit instead of frozen fruit.

This study was conducted to determine the effects of LDPE bags with and without perforation on the storability and some physiological and biochemical changes in ‘Rong-rien’ rambutan during storage at 12°C.

Materials and Methods

‘Rong-rien’ rambutans with commercial maturity were harvested from an orchard at Chantaburi province in an eastern area of Thailand and transported to a laboratory in Bangkok by air-conditioned car at 20°C. The fruits were cleaned and graded for uniformity of color and size. A fungicide of 1000 ppm of benomyl was applied for 5 min to control occurrence of disease during storage. Rambutans were packed in 0.04 mm thick LDPE zip bags (40×28 cm) (Okura Industrial Corporation, Kagawa) with

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0, 1, 2 or 3 ventilation holes (4 mm diameter), then stored at 12°C which is the optimum temperature for storage and transportation of this fruit (Lam & Kosiyachinda, 1987). Thirty fruits (about 1 kg) were packed per bag which was two-thirds of the bag volume. The observation during storage was done in every other day using the following analysis:

Water loss Fruits in each treatment were weighed individually during the storage period and the percentage of weight loss was calculated.

Respiration, ethylene production rate and gas concentration in packaging The fruits were removed from the polyethylene bags and placed individually in a 0.73 l plastic chamber with a cover at 20°C for 3 h. A sample of one milliliter of headspace gas was injected into a Shimadzu GC 8A gas chromatograph (Shimadzu, Kyoto) equipped with a thermal conductivity detector and a Porapack Q column (80/100 mesh) to measure carbon dioxide and a Molecular Sieve 5A to measure oxygen. Ethylene was measured on a Shimadzu GC 14B gas chromatograph (Shimadzu) equipped with a flame ionization detector and Porapack Q column (60/80 mesh). The gas concentration inside the package was measured by withdrawing 1 ml of headspace gas from the package and subjecting to gas chromatography.

Ascorbic acid content The ascorbic acid content (reduced form) was determined by the method of A.O.A.C (1990). Two milliliters of rambutan juice was extracted from the flesh and mixed with 5 ml of metaphosphoric-acetic acid solution. The mixed solution was titrated with dichlorophenolindophenol (dye solution) to an end point with pink coloration. The content of reduced ascorbic acid was calculated based on the A.O.A.C. (1990) procedure.

Ion leakage Ion leakage from the peel of rambutan fruits was measured following the method of Gemma *et al.* (1994) with a few modifications. Ten discs of peel tissue were obtained using a 15 mm diameter cork borer, then rinsed with distilled water and incubated in 50 ml of deionized water. Incubation was done on a shaker incubator 3528-1 (LabLine, IA) at 20°C for 3 h

with 50 strokes/min. The conductivity was measured by a conductivity-meter CM-5S (TOA Electronics, Ltd., Tokyo).

Browning evaluation and peel color measurement Browning at the end of the spintern area of rambutan was evaluated by a trained panelist and was based on a 0–4 scale: (0) none; (1) 1–25%; (2) 26–50%; (3) 50–75%; or (4) 76–100% of total spinterns. The peel color of the mid-side of each fruit was measured with a Minolta Chromometer CR-200 (Minolta, Tokyo) using Hunter's scale value. Since 'Rong-Rien' rambutan is classified as a red cultivar, the numerical values of 'L' and 'a' were used in recording the skin color (O'Hare *et al.*, 1994).

Statistical analysis The experiment was conducted in a completely randomized design, and significance of the difference between treatments was evaluated by 'F' test.

Results

Effect of LDPE bag packaging on physiological changes in rambutan fruits Rambutan fruits kept in LDPE bags sustained less weight loss during storage (Fig. 1); the loss was found to be least in the fruit stored in bags with 0 holes. Weight loss of fruits stored in bags with 1, 2 or 3 holes increased with the number of holes but was still lower than control fruit which had a loss of 20% at the end of storage. The quality of control fruit was maintained for 8 days in storage after which browning was observed, whereas the fruit in LDPE bags without ventilation holes re-

Table 1. Storage life of 'Rong-rien' rambutan in polyethylene bag with 0, 1, 2 or 3 ventilation holes at 12°C.

Treatment	Storage life (days)
Control (without packaging)	8 ^a
Polyethylene bag with 0 hole	16 ^c
Polyethylene bag with 1 hole	12 ^b
Polyethylene bag with 2 holes	12 ^b
Polyethylene bag with 3 holes	12 ^b
F-test	**

**Within column, treatment means (of three replicates) followed by different superscript letters differ significantly ($p < 0.01$).

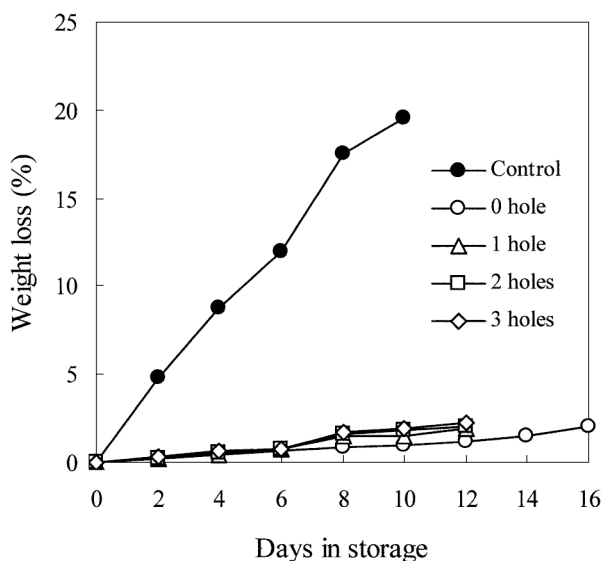


Fig. 1. Changes in the weight loss (%) of rambutan fruits stored in LDPE bag with 0, 1, 2 or 3 ventilation holes during storage at 12°C. Fruit without packaging served as control.

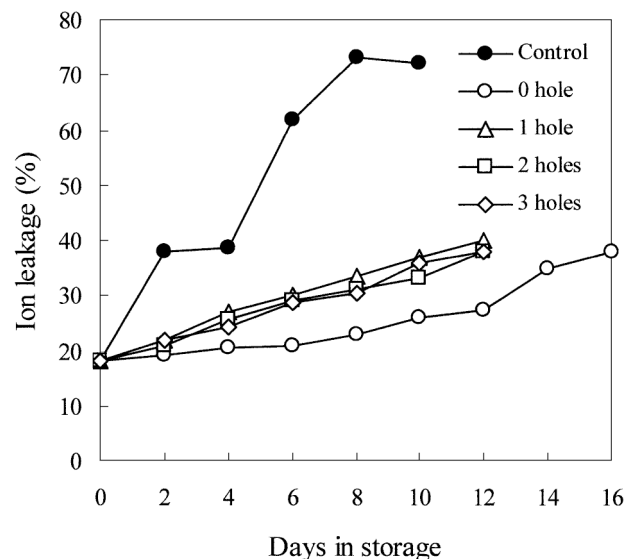


Fig. 2. Changes in the ion leakage (%) of peel tissue of rambutan fruits stored in LDPE bag with 0, 1, 2 or 3 ventilation holes during storage at 12°C. Fruit without packaging served as control.

tained a good appearance for 16 days and in bags with holes for 12 days (Table 1).

Ion leakage from the peel tissues of rambutan was reduced by the LDPE bag packaging (Fig. 2): fruit in the bag with 0 holes showed less leakage than either fruits in the ventilated bags or control fruit. The increase in ion leakage had high correlation with the weight loss (data not shown).

Effect of LDPE bag packaging on the respiration and ethylene production of rambutan fruits The respiration rate of the fruits stored in the LDPE bag with 0 holes was found to be reduced and the respiration peak delayed that on the 8th day of storage. Control and fruits stored in bags with holes showed the same pattern of respiration and the peak was seen on the 6th day of storage (Fig. 3). Ethylene production rate of the fruit stored in

bags with 0 hole was suppressed until the end of storage, whereas other treatments showed a peak on the 2nd day. Control fruit had higher ethylene production than fruits in the LDPE bags (Fig. 4).

Effect of LDPE bag packaging on ascorbic acid content of rambutan fruits Ascorbic acid content of control fruit decreased more rapidly than fruit in the LDPE bags (Fig. 5). In fruits stored in bags with 0, 1 or 2 holes the loss was delayed for 10 days. Decrease of ascorbic acid in fruit in the 3 holed bag declined 6 days after storage and showed the same trend of change as control fruit.

Changes of gas concentration in the package Monitoring of the gas concentration inside the packaging, of rambutan fruits, during storage (Fig. 6) showed that oxygen concentration in the bag with 0 holes declined continuously after storage and at the

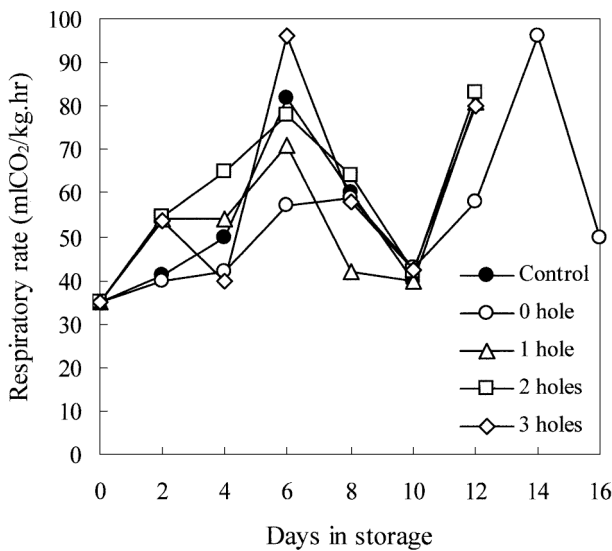


Fig. 3. Changes in the respiratory rate (mL CO₂/kg.h) of rambutan fruits stored in LDPE bag with 0, 1, 2 or 3 ventilation holes; control was the fruit without packaging. The respiration rate was measured at 20°C.

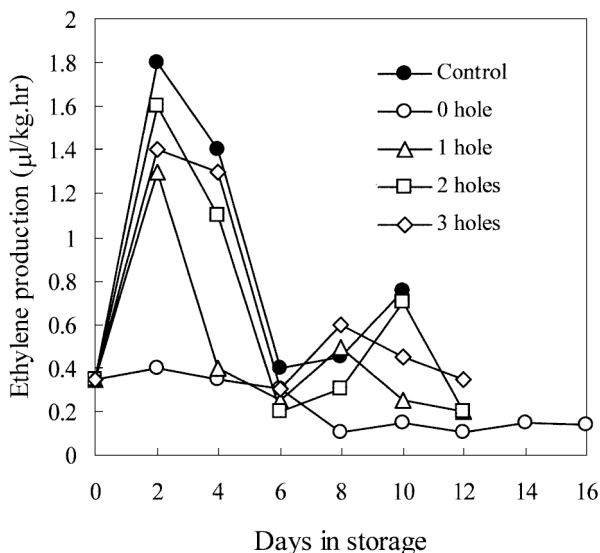


Fig. 4. Changes in the ethylene production rate (µL/kg.h) of rambutan fruits stored in LDPE bag with 0,1,2 or 3 ventilation holes; fruit without packaging served as control. The measurements were recorded at 20°C.

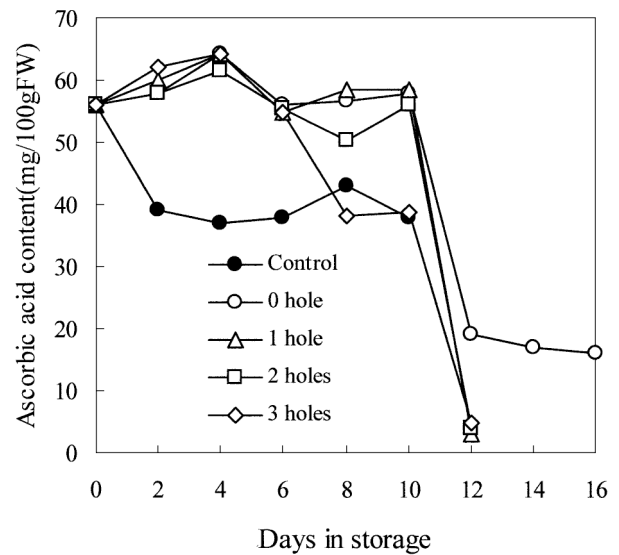


Fig. 5. Changes in the ascorbic acid content of rambutan fruits stored in LDPE bag with 0,1,2 or 3 ventilation holes during storage at 12°C. Fruit without packaging served as control.

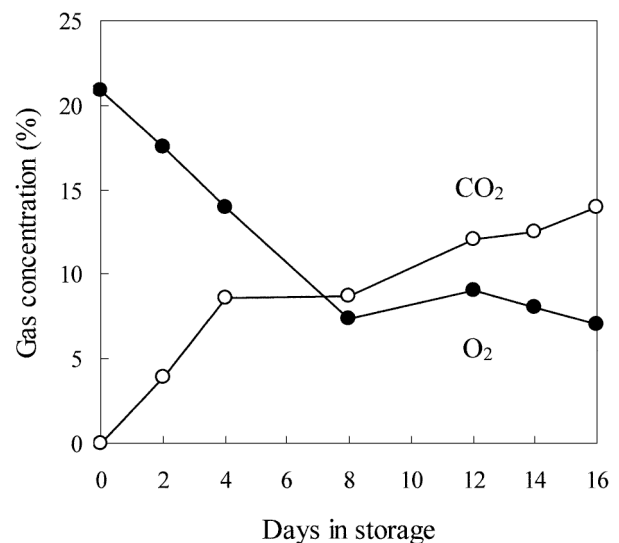


Fig. 6. Change of internal CO₂ (●) and O₂ (○) concentration in LDPE bag without ventilation hole during storage at 12°C.

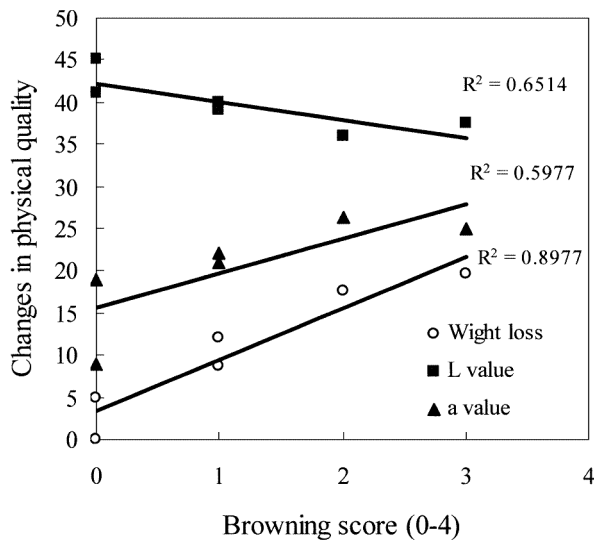


Fig. 7. The correlation between the browning score, weight loss and peel color of rambutan fruits during storage at 12°C.

end of storage had just 7%. In contrast, the concentration of carbon dioxide increased until the end of the storage period (14%). The concentration of gas inside the bags with 1, 2 or 3 ventilation holes was almost the same as that of the environmental gas condition (data not shown).

Relationship between browning score, weight loss and peel color of rambutan fruits Figure 7 shows high correlation between degree of browning and weight loss of rambutan ($R^2=0.8977$), but less correlation between peel color measured as 'L' and 'a' values ($R^2=0.6514$ and 0.5977 , respectively).

Discussion

Browning caused by dehydration is a limiting factor for the storage life of rambutan because of their morphology: the skin is covered by hair-like protuberances (spintern) that make the fruits tend to lose water (Landrigan, 1996). This water loss in 'Rong-Rien' rambutan has the effect of inducing browning during storage. From this study, it was found that there was high correlation between the percentage of water loss and browning score ($R^2=0.8977$) (Fig. 7), while the browning score was less correlated with 'L' and 'a' values (Fig. 7). The browning symptoms appeared from the spintern end. Modified atmosphere storage in a polyethylene bag was successful in reducing the browning problem in 'Rong-Rien' rambutan and water loss was also suppressed (Fig. 1). Lee and Leong (1982) found that modified atmosphere storage resulted in reduction of water loss from rambutan cv. Maharlika and Jitlee, and also in cv. R3 and R156 (Lam & Ng, 1982). The modification of gas inside the package reduced the respiration rate of the fruits so that water loss decreased, especially in fruit from the bag with 0 holes (Fig. 6). Although the composition of gas in the bag with ventilation holes and in normal air differed only slightly (data not shown), the water loss was lower than control and was similar to fruits stored in the 0 holes bag. It seems that the relative humidity inside the bag is an important factor in suppressing the water loss from rambutan fruits, the modified atmospheric gas condition might be a secondary effect cause of reducing the transpiration. A modified

atmosphere condition in the 0 holes bag significantly suppressed the respiratory and ethylene production in rambutan fruits (Figs. 3 and 4). The reduction of oxygen concentration during storage of the fruits was investigated earlier by O'Hare *et al.* (1994) who suggested that it did not significantly affect fruit quality, while 9–12% carbon dioxide retarded color loss and extended shelf life. A high quantity of carbon dioxide may affect the glycolytic pathway by effecting ATP: phosphofructokinase and pyruvate kinase activity (Kays, 1991) or inhibiting succinate dehydrogenase activity in the TCA cycle (Ke *et al.*, 1993). The increase of respiration rate in rambutan after 10 days of storage is probably due to the initiation of senescence. The ethylene production rate was significantly reduced in fruit from the bag with 0 holes. Under a high carbon dioxide condition, the ethylene production rate was reduced because carbon dioxide is a competitive inhibitor of ethylene production (Mattoo & Suttle, 1991). Furthermore, carbon dioxide can inhibit wound-induced ethylene production by suppression of ACC synthase gene expression at the transcription level and also where oxygen concentration is low. This had the effect of inhibiting ACC oxidase activity in the ethylene production pathway (Mathooko, 1996). Wills *et al.* (1998) stated that in a modified atmosphere condition, the metabolism in plants, both catabolic and anabolic, was reduced and the storability extended.

Ascorbic acid content was maintained in fruits in polyethylene bags. The results indicated that in a modified atmosphere condition (0 hole bags), the oxidation of ascorbic acid was reduced. Agar *et al.* (1995) also reported that the oxidation of ascorbic acid in berry fruit decreased in a modified atmosphere condition because this condition has low oxygen concentration. Another possibility is that a modified atmosphere condition can reduce the susceptibility of chilling injury in plants thus helping to maintain the ascorbic acid. Mapson (1970) stated that chilling injury induced peroxidase activity which was related to the loss of ascorbic acid in fresh produce. Ascorbic acid content in rambutan fruits stored in polyethylene bags with or without ventilation hole was maintained, which might have been due to the high humidity inside the package that suppressed the water loss. The relation of water loss and ascorbic content in rambutan fruits should be dealt with in future research.

Ion leakage is related to the stress and the development of a plant to senescence (Lacan & Baccou, 1996), and is an indicator of chilling injury of fresh produce (Chan *et al.*, 1985). A modified atmosphere condition reduced the ion leakage susceptibility, especially in fruit in 0 hole bags. These results indicated that this condition had delayed the senescence of rambutan fruits. Furthermore, low temperature stress was also reduced by this condition. Morris (1982) suggested that a modified gas condition during storage of fresh horticultural produce alleviated chilling injury.

In conclusion, modified atmosphere packaging significantly extended the storage life of 'Rong-Rien' rambutan, influencing the appearance and eating quality. From the overall results, the fruit stored in an LDPE bag with or without ventilation holes maintained a good external quality until 12 and 16 days after storage, respectively; the eating quality, especially nutritive value, could be maintained for 10 days of storage as judged by the decline of ascorbic acid content. Rambutan stored in LDPE bags seems to be good for consumption within 12 days storage. Effect of the modified gas condition in packaging of these fruits is still

unclear as to how it extends storage life. Further research should be done on the mechanism of a modified gas condition on the quality and storability of rambutan fruit.

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