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*Original Article*

# Effects of minimal processing on the respiration rate and quality of rambutan cv. 'Rong-Rien'

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**Abstract**

Respiration rate at 4°C and minimal processing of rambutan cv. 'Rong-Rien' were investigated. Rambutan was harvested from Amphur Ban Na San, Surat Thani Province, at the stage when its skin was turning into a combination of red, green and yellow. After harvesting, the fruits were size-graded to 27-30 fruits/kg, hydrocooled to 14°C, packed with ice in Styrofoam boxes and transported to the laboratory at Prince of Songkla University within 6 h. The respiration rate of fresh rambutan fruits was monitored. For minimal processing, the fruits were soaked in warm solution (55°C) of 100 ppm sodium hypochlorite for one min and immediately cooled in cold water until their internal temperature reached 14°C. The minimal process included peeling, with and without coring. The peeled and peeled and cored rambutan samples were immersed in a solution of 0.5% citric acid + 0.5% $CaCl_2$ at 4°C for 2 min. The average respiration rates (within 6 h) at 4°C of whole fruit, peeled, and peeled and cored rambutan samples were measured and found to be 122, 134 and 143 mg $CO_2$/kg/h, respectively. These findings indicated that a preparation style as peeled rambutan without coring, nylon/LLDPE bag, storage temperature of 4.0±1°C, were suitably applied for processed rambutans. To obtain a longer extended shelf life (>12 days) of minimally processed peeled rambutans, further study on food additives, including acidulants and preservative used and gas composition in modified atmosphere packaging (MAP) is needed.

**Keywords:** respiration rate, rambutan, rambutan cv.Rong-Rien, minimally processed rambutan, modified atmosphere packaging

## 1. Introduction

Rambutan (*Nephelium lappaeum* Linn.) cv. 'Rong-Rien' is one of Thailand's economic crops with a sizeable export market. It has been classified as nonclimacteric fruit (O'Hare, 1995). The fruit will not ripen if removed from the tree before full maturity, the state of which can be determined principally by appearance (O'Hare, 1995). Rambutan shelf life is limited by dehydration of the fruit and browning of spinterns (long soft hair) and skin (Ketsa, 1985; Wanichkul and Kosiyachinda, 1982). The darkening of spinterns and skin renders rambutan unmarketable, even though its pulp is still of acceptable eating quality.

The deterioration of rambutan skin can occur rapidly within three days under ambient conditions (O'Hare, 1995). There have been many reports on shelf life extension of rambutan with modified atmosphere packaging (MAP) combined with low storage temperature (Mendoza *et al*., 1972; Klaewkasetkorn, 1993; Srilaong *et al*., 2002; Patika-

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butr, 2001). Luckanatinwong (2005) reported that packaging rambutan in polyethylene bags (70 µm thick) under 5% $CO_2$, 5% $O_2$ and 90% $N_2$ and stored at 10°C could extend its shelf life for 23 days. Minimally processed fruits and vegetables have recently become popular products due to consumer demand for convenience and fresh or near-fresh quality. It has many advantages over fresh produce, especially for export market. For example, it has lower product volume, thus lower transport cost. It can circumvent problems common to exporting fresh whole produce, e.g. dehydration and rotting, and the needs for quarantine process. Minimally processed fruits and vegetables provide consumer with a new class of products where convenience, quality and relatively long shelf life are desirable (Siriphanich, 1994). However, quality and shelf life of minimally processed fruits and vegetables depend greatly on factors such as respiration rate, environment they are packaged under, processing techniques, storage temperature, etc. (Zagory and Kader, 1988). Respiration is the process by which stored organic materials (carbohydrates, proteins, fats) are broken down into simple end products with a release of energy for cellular functions (Kader, 2002). After the fruits are separated from the tree, the respiratory process must continue to produce energy or the tissues will die leading to cellular senescence. The processing procedures of peeling and cutting cause tissue wounding and induce a high respiration rate, which triggers faster water loss and susceptibility to microbial deterioration compared to intact tissues (Dong *et al*., 2000; Kader, 2002). Edible coating with many types of additives may be applied on minimally processed fruits to serve several different purposes such as reduction in water loss and microbial decay, and maintaining an accepatable appearance (Olivas and Barbosa-Cánovas, 2005). Fresh-cut mango, similar in minimal process as other various tropical fruits, cutting into 3.0 x 4.0 in., soaking in mixture solution of 2-5% citric acid, 2-5% ascorbic acid and 0.5-2.0% calcium chloride (by volume) at 3-4°C for 1 min, placing 100-150 g each on a plastic tray, packaging in Nylon/PE/LLDPE bags, flushing with a mixture (by volume) of 15-25% $CO_2$, 0-6% $O_2$ (balance $N_2$), sealed and stored at 10°C, had acceptable qualities for consumption after 14 days storage (Ngarmsak *et al*., 2003). Agar *et al.* (1999) reported that fresh-cut kiwifruit slices had a shelf life of 9-12 days if treated with 1% $CaCl_2$ or 2% Ca lactate in combination with cholrine water (100µl·$L^{-1}$) dip and stored in 1.9-L jars at 0-2°C, RH >90%, with $C_2H_4$ scrubbing, in 2 to 4 kPa $O_2$ and/or 5 to 10 kPa $CO_2$. Rambutan is a major export fruit in Thailand; however, there have been only a few reports dealing with minimal processing of fresh-cut products (Ngarmsak *et al*., 2003). The objectives of this research were to study the effects of minimal processing including peeling with and without coring, suitable additives, types of packaging films, modified atmosphere and storage temperatures on the respiration rate and qualities of rambutan.

## 2. Materials and Methods

### 2.1 Raw materials

Fresh rambutans cv. 'Rong-Rien', from the orchards in Amphur Ban Na San, Surat Thani Province, were harvested at the stage when their skin was turning into a combination of red, green and yellow (100 days after blooming). After harvesting, the fruits were size-graded to 27-30 fruits/kg, hydrocooled to 14°C, packed with ice in styrofoam boxes and transported to the laboratory at Prince of Songkla University within 6 h.

### 1) Respiration rate measurement

Respiration rate measurements of fresh fruits and minimally processed rambutan were carried out. Fresh rambutan fruits were washed with tap water, and excess water removed by basket centrifugation. For minimal processing, the fruits were soaked in warm solution (55°C) of 100 ppm sodium hypochlorite for one minute and immediately cooled in ice water until their internal temperature reached at 14°C. The minimal processing was conducted in a temperature-controlled (25°C) room fitted with a UV-lamp (40Wx2, Narva), which was turned on at least 12 h prior to the experiment. The minimal process included peeling, with and without coring. The peeled and peeled and cored rambutan samples were immersed in a solution of 0.5% citric acid + 0.5% $CaCl_2$ at 4°C for 2 min. Approximately 200 g each of peeled and peeled and cored rambutan samples were placed in 1,200 ml sterile jars. Each set had six replicates. The jar lids had stoppers for gas sampling and rubber tubes were connected to allow airflow through the jars. The inlet tube was inserted down to the bottom of the jars to ensure consistent flushing of the air. The jars were stored at 4°C and a flow-through system was used to allow quantification of the $CO_2$ production rate over time. Humidified air at 4°C was fed to the jars at a flow rate of 152-154 ml/min. Gas samples of 10 ml were taken at the jar outlet at 1 h interval for 6 h with a 10 ml NIPRO (NIPRO, Thailand) plastic syringe with 26G (0.45x25mm) needles. $CO_2$ production rate (%) at a given time was determined by a gas chromatograph (Shimadzu Scientific Instruments Inc., Model GC-8A, Kyoto, Japan) operated at 70°C oven temperature, 150°C for the injector port and thermal conductivity detector, and calculated as mg $CO_2$/kg/h, according to the method of Watada and Pratt (1980, cited in Postharvest Research Laboratory, Kasetsart University Kamphaeng Saen Campus, 2004). The amounts of $N_2$, $O_2$, and $CO_2$, were determined in the gas chromatograph using a stainless steel column packed with Porapak Q (80/100 mesh, ID 3.0mm) and 1.93 m in length. The respiratory rates (average $CO_2$ production from six replicates) at 4°C were plotted against time.

**2) Minimal processing of rambutan**

The minimal process for rambutan in this part of the study, i.e. peeling with and without coring, was similar to the method described above, except different additive solutions were used. The samples were immersed in the solutions for different periods of time before being placed on polystyrene trays pre-sterilized with 70% ethanol. A water absorbent sheet was placed underneath the samples and the trays were sealed in plastic bags under various modified atmospheres and stored at either 4.0±1.0 or 8.0±1.0°C for up to two weeks. The following factors affecting quality changes in the product were investigated:

*Preparation style:* peeled vs. peeled and cored

*Food additive:* various solutions of food additives and immersion times are shown in Table 1.

*Plastic bags:* types of plastic bags used in this study are shown in Table 2.

*Packaging condition:* samples were packaged either in air (control) or modified atmosphere (50% flushing mode) with a gas mixture of 5% $CO_2$, 5% $O_2$ and 90% $N_2$ (by volume).

*Storage temperature:* either 4.0±1.0 or 8.0±1.0°C, with 76% RH.

Table 1. Additive solutions and immersion times used for minimally processed rambutan.

| Solution code | Additives used, %(w/w) | Immersion time, min |
|---|---|---|
| A | 0.7% ascorbic acid + 0.75% alginate + 1.0% $CaCl_2$ | 2 |
| B | 0.5% citric acid + 0.5% ascorbic acid + 2.0% sorbital + 0.2% $CaCl_2$ | 5 |
| C | 0.5% citric acid + 0.5% ascorbic acid + 2.0% sorbital + 0.2% $CaCl_2$ + 1.5% Ca-lactate + 0.1% pectin | 5 |
| D | 0.5% citric acid + 0.5% ascorbic acid + 1.0% $CaCl_2$ | 3 |
| E | 0.5% citric acid + 0.5% $CaCl_2$ | 2 |

Table 2. Properties of three different types of plastic bags (250x250mm, 800 cc.).

| Types | Thickness (µm) | Oxygen Transmission Rate (OTR, cc/m$^2$/d, at 23°C, 0% RH) |
|---|---|---|
| PET/LLDPE[1] (PET) | 52 | 128.18 |
| CPP/LLDPE[2] (CPP) | 120 | 932.80 |
| Nylon/LLDPE[3] (nylon) | 80 | 36.60 |

Notes: [1]Polyethylene Terephthalate/linear low density polyethylene
[2]Cast-polypropylene/linear low-density polyethylene
[3]Nylon/ linear low-density polyethylene

**2.1) Experimental Design**

The experiment design for this study is presented in Table 3.

**2.2) Quality measurement**

Weight loss with respect to initial fresh weight in minimally processed rambutan during storage was determined. Color change was monitored using a colorimeter (Hunterlab, Model Colorflex, USA). pH was measured according to A.O.A.C. (2000) with a Sartorius pH meter (model PB-20, Germany). Total soluble solids of the samples were determined using a hand refractometer (Atago, model N1, Japan).

Microbiological quality of the samples was evaluated by taking duplicate 25 g samples from a sealed plastic bag and homogenizing them in sterile Stomacher bags with 225 ml of sterile buffer peptone water for 1 min at 200 beats per min. Appropriate dilutions of 0.1 ml homogenate were plated out in triplicate on total plate count agar and incubated at 30.0±1.0°C for 48 h (BAM, 2001).

**2.3) Statistical analyses**

All experiments were conducted in duplicate. Data were analyzed using a completely randomized design. Significant level was established at $p \le 0.05$. Duncan's New Multiple Range

Table 3. Experimental design for minimal processing of rambutan.

| Experiment/ preparation style | Solution code / immersion time (min) | Type of plastic bag | Packaging condition | Storage temperature (°C) | Storage time (days) |
|---|---|---|---|---|---|
| 1. Peeled & cored | A/2 | nylon | Air | 4.0±1 and 8.0±1 | 14 |
| 2. Peeled & cored | B/5 | PET nylonCPP | Air | 4.0±1 | 14 |
| 3. Peeled & cored | C/5 | nylon | Air | 8.0±1 | 7 |
| 4. Peeled | D/3 | nylon | Air | 8.0±1 | 10 |
| 5. Peeled | E/2 | nylon | 5% $CO_2$,5% $O_2$, 90% $N_2$ | 4.0±1 | 12 |

Note: Each experiment was done in duplicate.

Table 4. Respiration rate (mg $CO_2$/kg/h) of whole, peeled, peeled and cored rambutan stored at 4°C.

| Time(h) | Respiration rate (mg $CO_2$/kg/h)[1] | | |
|---|---|---|---|
| | Whole rambutan | Peeled rambutan | Peeled and cored rambutan |
| 1 | 146.90±54.36 | 156.05±41.43 | 174.40±59.78 |
| 2 | 110.16±24.61 | 156.06±41.43 | 165.25±53.61 |
| 3 | 110.16±31.07 | 123.95±13.12 | 142.29±50.53 |
| 4 | 128.52±45.32 | 142.29±35.20 | 169.85±67.75 |
| 5 | 119.35±26.58 | 123.93±41.93 | 110.15±18.05 |
| 6 | 114.75±34.71 | 105.57±17.82 | 96.40±12.20 |

Note: [1] average respiration rate ± standard deviation from six replicates.

Test (DMRT) was used to determine significant difference between treatment means. SPSS for Window Version 10.5 was used for all statistical analyses.

## 3. Results and Discussion

### 3.1 Respiration rate

Table 4 shows the respiration rate (mg $CO_2$/kg/h) of whole, peeled, and peeled and cored rambutans over 6 h at 4°C. The average rates for whole intact fruits, peeled, peeled and cored rambutans were 122, 134, 143 mg $CO_2$/kg/h, respectively. After processing 1 h, the maximum respiration rates of whole, peeled, peeled and cored rambutans were observed, and subsequently decreased throughout the 6 h period. The response of tissues to processing wounds generally increases as the severity of the injury increases (Cantwell and Suslow, 2002; Del Aguila *et al.*, 2006). Damaging rambutan tissues through peeling and coring resulted in higher respiration rates as compared to that of whole fruits. In addition, peeling and coring severely injured the tissues more than peeling alone, resulting in the highest increase in respiration rate. Cantwell and Suslow (2002) reported that whole carrots produced 1.0 µg $CO_2$/kg/s at 0°C, while carrot slices produced 1.7 µg $CO_2$/kg/s at 0°C. Sliced carrots showed an increase of 62.2% in respiration rate at 0°C compared to whole carrots. Del Aguila *et al*. (2006) also reported that whole, sliced and shredded radish, after processing and storage at 5°C for 1 and 4 h , produced 4.5 and 2.4, 4.6 and 2.9, and 5.6 and 3.4 µg $CO_2$/kg/s, respectively. Furthermore, Saltveit (2003) hypothesized that the initial increase in respiration rate was due to the stress caused by cutting or the cellular repair mechanism. The subsequent decrease in respiration rate was probably due to severity of tissue damage from cutting contributing to juice leakage, less in respiratory substrates and faster deterioration (Saltveit, 2003).

### 3.2 Qualities of minimally processed rambutan

Figure 1(a) shows weight loss (%) of peeled and cored rambutan immersed in solution A, packed in nylon bags, stored at 4.0±1.0 and 8.0±1.0°C for up to 14 days. Storage temperature appeared to significantly influence (P<0.05) on weight loss when stored for up to 4 days. Weight loss increased as the storage time increased in both at 4.0 and 8.0°C storage. At 14 days, samples stored at 8.0°C lost more weight than those stored at 4.0°C. Landrigan *et al.* (1996)

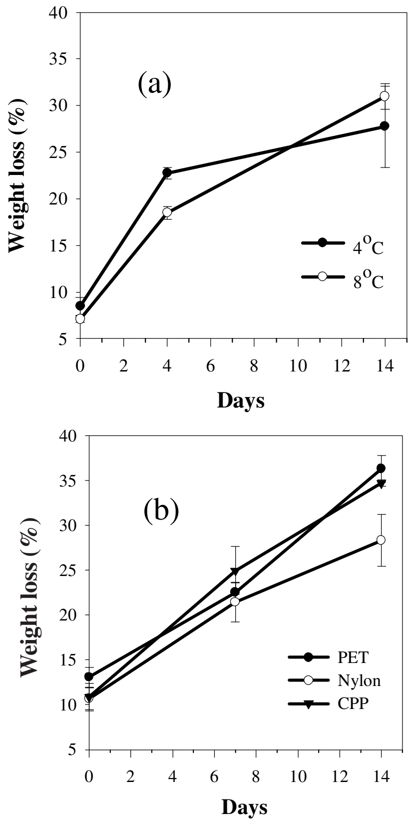


Figure 1. Weight loss (%) of peeled and cored rambutan soaked in solution A, packed in nylon bags and stored at 4° and 8°C (a), and in solution B, packed in PET, nylon, CPP bags stored at 4°C (b). (Solution A = 0.7% ascorbic acid + 0.75% alginate + 1.0% $CaCl_2$ for 2 min, Solution B = 0.5% citric acid + 0.5% ascorbic acid + 2.0% sorbital + 0.2% $CaCl_2$ for 5 min)

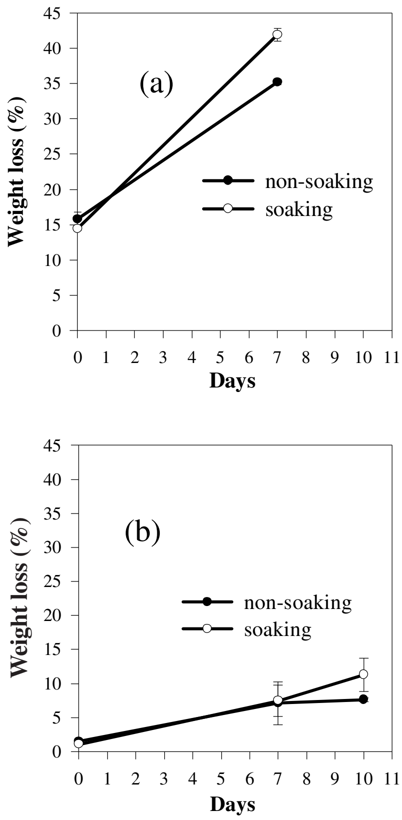


Figure 2. Weight loss (%) of peeled and cored rambutan with and without soaking in solution C packed in nylon bags and stored at 8°C (a), of peeled rambutan with and without soaking in solution D packed in nylon bags and stored at 8°C (b). (Solution C = 0.5% citric acid + 0.5% ascorbic acid + 2.0% sorbital + 0.2% $CaCl_2$ + 1.5% Ca-lactate + 0.1% pectin for 5 min, Solution D = 0.5% citric acid + 0.5% ascorbic acid + 1.0% $CaCl_2$ for 3 min)

studied weight loss in components of rambutan fruit stored under 20°C and 60%RH and reported that the flesh lost approximately 20% weight after 7 days of storage. Boonya-ritthongchai (1999) also reported that rambutan fruits stored at 20°C lost more weight than those at 13°C. In the current research the storage temperature of 4°C was, therefore, selected for subsequent experiments.

Figure 1(b) shows weight loss (%) of peeled and cored rambutan immersed in solution B. After 14 days of storage, weight loss of samples packed in nylon bags was significantly less (P<0.05) than those packed in PET and CPP. Results showed that types of packaging bags with differences in OTR (cc/m$^2$/d, at 23°C, 0%RH) values significantly influenced on weight loss of samples, especially at 14 days storage. The present study implied that under severe test conditions consisting of high temperature at 8°C and preparation style of peeling and coring, samples packed in the nylon bag with the OTR value of 36.60 cc/m$^2$/d exhibited maintaining desirable quality in term of water loss compared to the other two bags. In addition, Kim *et al.* (2004) reported that film oxygen transmission rates significantly effected quality of fresh-cut salad savoy under the test conditions. Packages with optimum OTR films attained the desired $O_2$ and $CO_2$ levels throughout 25 days storage period at 5°C contributing to salad savoy remaining in freshness and acceptable quality. Salad savoy from packages with high in OTR value developed discoloration on the cut-ends due to high $O_2$ in the package. While the packages with low in OTR value exhibited a rapid depletion of $O_2$ and accumulated $CO_2$ in the packages, resulting in off-odor, decay and unacceptable quality.

Figure 2(a) shows weight loss (%) in peeled and cored rambutan with and without soaking in solution C. Results showed that after 7 days of storage, samples soaking in solution C had significant (P<0.05) greater in weight loss (41.9%)

Table 5. Quality changes of minimally processed peeled rambutan soaking in solution E[1], packed in nylon bags with and without modified atmosphere and stored at 4°C.

| Treatment (4°C) | Storage time (days) | Quality changes[2] | | | | Total viable count (CFU/g) |
|---|---|---|---|---|---|---|
| | | Weight loss (%) | °Brix | pH | *L** | |
| Control | 0 | 0.65±0.06d | 16.67±1.20a | 5.40±0.40a | 47.08±2.16ab | < 250 |
| | 3 | 3.83±0.11bc | 15.53±0.23a | 4.94±0.05c | 45.35±1.19c | |
| | 6 | 4.92±0.50abc | 14.53±0.50a | 4.99±0.17bc | 44.48±1.94c | |
| | 9 | 5.90±0.89ab | 15.60±0.28a | 4.73±0.02d | 46.77±0.55bc | |
| | 12 | 6.95±0.11a | 15.40±0.28a | 4.80±0.16d | 46.32±0.33c | $4.5x10^6$ |
| 5% $CO_2$, | 0 | 0.60±0.08d | 16.10±1.01a | 5.40±0.48a | 48.20±2.59a | < 250 |
| 5% $O_2$, | 3 | 2.85±0.88cd | 15.80±0.53a | 5.08±0.02bc | 46.96±4.15a | |
| 90% $N_2$ | 6 | 5.96±2.72a | 15.47±0.14a | 5.07±0.19b | 45.49±2.41bc | |
| | 9 | 5.95±0.46ab | 14.70±0.14a | 4.99±0.02c | 45.20±1.41c | |
| | 12 | 7.54±0.43a | 15.20±0.85a | 4.96±0.06c | 45.25±2.12c | $6.4x10^4$ |

Note: [1] solution E = 0.5% citric acid + 0.5% $CaCl_2$ for 2 min.
[2] Mean±standard deviation of two replicates. Means within each column not sharing a common letter are statistically different (P<0.05)

than that of non-soaked ones (35.2%). Figure 2(b) shows weight loss in peeled rambutan with and without soaking in solution D. Similarly results showed that after 10 days of storage, sample soaking in solution D had significant (P< 0.05) greater in weight loss (11.3%) than that of non-soaked ones (7.6%). Poovaiah (1986) hypothesized that the major effect of calcium was maintaining the structure integrity of membranes and cell walls by forming cross-links between free carboxyl groups of the pectin chains. However, both peeled, peeled and cored samples exhibited severe leakage of water at the end of storage period, as a consequence of water loss, adverse effects on appearance changes remarkly occured in soaked samples compared to non-soaked ones. As a result, extension of shelf life of peeled rambutan beyond 10 days appeared possible, as compared to that of peeled and cored samples. However, the use of suitable food additives and lowering the storage temperature may possibly aid longer extension of fresh-cut shelf life (Garcia and Barrett, 2002).

Table 5 shows quality changes in peeled rambutan, immersed in solution E, packed in nylon bags with and without modified atmosphere. The results demonstrated that MAP greatly influenced microbial counts of samples. After 12 days storage at 4.0±1.0°C, samples packed in the atmosphere of 5% $CO_2$, 5% $O_2$ and 90% $N_2$ had lower microbial count ($6.4x10^4$ CFU/g) than that of control ($4.5x10^6$ CFU/g). Modified atmosphere did not significantly affect weight loss, total soluble solids content (°Brix) and $L*$ values of the samples. pH of MAP and control samples after 12 days of storage, was significantly different (P<0.05), being in the range of 4.73-5.40. Kader (2002) reported that the combination effects of gas composition in MAP (low $O_2$ level and high $CO_2$ level) and low storage temperature could delay aerobic microbial spoilage of fresh-cut products. Low level of $O_2$ suppressed the growth of aerobic microorganisms. In addition, Hu *et al*.(2007) reported that the effects of initial low 5% $O_2$ of fresh-cut cabbages packed in perforated film with stored at 5°C not only suppressing surface microbial growth but also respiration rates and the oxidation of ascorbic acid leading to obtaining better color and quality of samples. These also suggest that the use of chemicals such as acidulants and preservative may prolong better shelf life of peeled rambutan.

## 4. Conclusions

The respiration rate at 4°C of whole fruit, peeled, and peeled and cored rambutans can be used to indicate potential quality changes in rambutan tissues as a consequence of minimal processing. Processing method, packaging film, and storage temperature were important factors influencing the quality of minimally processed rambutans. To obtain longer shelf life of peeled rambutans, further study on food additives used and gas composition in MAP is needed.

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## References

Agar, I.T., Massantini, R., Hess-Pierce, B. and Kader, A.A. 1999. Postharvest $CO_2$ and ethylene production and quality maintainance of fresh-cut kiwifruit slices. J. Food Sci., 64(3): 433-440.

A.O.A.C. 2000. Official Methods of Analytical of the Association of Official Chemists International, 17th ed. The Association of Official Chemists International. Gaithersburg.

Bacteriological Analytical Manual. 2001. U.S. Food and Drug. [Online]: Available from: http://www.cfsan.fda.gov/~ebam/bam-2.html. (Accessed in Jan, 2001).

Boonyaritthongchai, P. 1999. Effect of carbon dioxide on prolong storage life of 'Rong-Rien' rambutan (*Nephelium lappaceum* Linn.). Master Thesis. King Mongkut's University of Technology Thonburi, Bangkok, Thailand.

Cantwell, M.I. and Suslow, T.V. 2002. Postharvest handling systems: fresh-cut fruits and vegetables. *In*: A.K. Adel (ed), Postharvest Technology of Horticultural Crops, 3rd ed., University of California, Davis, Agriculture & Natural Resources, Pub 3311, pp.445-463.

Del Aguila, J.S., Sasaki, F.F., Heiffig, L.S., Ortege, E.M.M., Jacomono, A.P. and Kluge, R.A. 2006. Fresh-cut radish using different cut types and storage temperatures. Postharv. Biol. Technol., 40: 149-154.

Dong, X., Wrolstad, R.E. and Sugar, D. 2000. Extending shelf life of fresh-cut pears. J. Food Sci., 65(1): 181-186.

Garcia, E. and Barrett, D.M. 2002. Preservative treatments for fresh-cut fruits and vegetables. *In*: L., Olusola (ed), Fresh-cut Fruits and Vegetables: Science, Technology, and Market. CRC Press LLC, Florida, pp.267-303.

Hu, W.Z., Jiang, A.L., Pang, K. and Qi, H.P. 2007. Atmospheric compositions, respiration rate and quality of fresh-cut cabbages in active modified atmosphere packaging. Acta Horticulturae 746: 69-75.

Kader, A.A. 2002. Postharvest biology and technology: An Overview. *In*: A.K. Adel (ed), Postharvest Technology of Horticultural Crops, 3rd ed., University of California, Davis, Agriculture & Natural Resources, Pub 3311, pp. 39-47.

Ketsa, S. 1985. Postharvest physiology and technology of vegetables and fruits. National Agricultural Extension and Training Center Publishing, Kasetsart University, Kampaengsaen Campus, Nakornpathom, Thailand. p 364.

Kim, J.G., Luo, Y. And Gross, K.C. 2004. Effect of package film on the quality of fresh-cut salad savoy. Postharv. Biol. Technol., 32: 99-107.

Klaewkasetkorn, O. 1993. Postharvest losses and influence of modified atmospheres, plastic film wrap, $CO_2$ pre-treatment and temperature on quality and storage life of 'Rong-Rien' rambutan (*Nephelium lappaceum* Linn.) fruit. Master Thesis. Kasetsart University, Bangkok, Thailand.

Landrigan, M., Morris, S.C., Eamus, D. and McGlasson, W.B. 1996. Postharvest water relationships and tissue browning of rambutan fruit. Sci.Hort., 66: 201-208.

Luckanatinvong, V. 2005. Modified atmosphere storage of rambutan for export. J. Sci. and Tech. (Tharmmasat University), 13(2): 6-34.

Mendoza, D.B., Pantastico, E.B. and Javier, F.B. 1972. Storage and handling of rambutan (*Nephelium lappaceum* L.). Philipp. Agric., 55: 322-332.

Ngarmsak, T., Ooraikul, B. and Ngarmsak, M. 2003. Minimal processing and modified atmosphere packaging of fresh-cut tropical fruits. Patty Patent No. 967, Ministry of Commerce, Bangkok, Thailand.

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

Olivas, G.I. and Barbosa-Cánovas, G.V. 2005. Edible coatings for fresh-cut fruits. Crit. Rev. Food Sci. Nutr., 45(7/8): 657-670.

Patikabutr, P. 2001. Effects of relative humidity and surface coating on quality and storage life of 'Rong-Rien' rambutan (*Nephelium lappaceum* Linn.). Master Thesis. King Mongkut's University of Technology Thonburi, Bangkok, Thailand.

Postharvest Research Laboratory, 2004. Laboratory manual for horticulture postharvest technology. Training programe, 9th Horticulture Postharvest Technology, Postharvest Research Laboratory, Kasetsart University, Kamphaeng Saen District, Nakhon Pathom, Thailand. pp. 24-27.

Saltveit, M.E. 2003. Fresh-cut vegetables. *In*: J.A. Bartz and J.K. Brecht (eds), Postharvest Physiology and Pathology of Vegetables. Vol.22. Marcel Dekker, New York, pp. 691-712.

Siriphanich, J. 1994. Minimal processing of tropical fruits. Proceedings of International Conference on Postharvest Handling of Tropical Fruits, Chiangmai, Thailand, July 19-23, 1993: 127-137.

Srilaong, V., Kanlayanarat, S., Tatsumi, Y. 2002. Changes in commercial quality of 'Rong-Rien' rambutan in modified atmosphere packaging. Food Sci. & Tech. Res., 8(4): 337-341.

Wanichkul, K. and Kosiyachinda, S. 1982. Fruit development and harvesting index of rambutan (*Nephelium lappaceum* Linn.) var. Seechompoo. Proceedings of Workshop on Mango and Rambutan, University of the Philippines Los Baños, Los Banos, Philippines, April 18-25, 1982: 117-124.

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