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Effect of Packaging and Modified Atmosphere on the Shelf Life of Rambutan *(Nephelium lappaceum)* I

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Key Words: Rambutans; low temperature storage; modified atmosphere storage and packaging.

ABSTRAK

Rambutan menjadi hitam dan kering di bahagian kulit, dalam masa 72 jam bila ianya disimpan pada suhu bilik tanpa bungkusan. Warna kulit, kemantapan dan berat rambutan dapat dikekalkan dengan menyimpan rambutan dalam bungkusan tidak telap, pada suhu rendah (8^oC) dan dalam udara 7% karbon dioksid. Penyimpanan rambutan pada suhu 8^oC, dapat melanjutkan kesegaran rambutan sehingga 6 hari tanpa bungkusan. Simpanan pada suhu rendah dalam bungkusan tidak telap (bekas polyethyelen) dapat melanjutkan usia penyimpanan kepada 18 hari. Peningkatan kandungan karbon dioksid ketahap optima 7% (kandungan awal) pada 8^oC dapat menekan pernafasan rambutan segar dan memanjangkan masa simpanan rambutan segar sehingga hampir sebulan. Dalam keadaan ini kesegaran rambutan dapat dikekalkan hampir sebulan. Kesegaran rambutan tidak dapat dikekalkan lama tanpa oksigen kerana pernafasannya terencat. Satu kaitan rapat ujud antara kehilangan kelembapan rambutan, kegelapan kulit dan kemantapan buah. Kerosakan rambutan lepas tuai adalah disebabkan perubahan-perubahan fisiologi.

ABSTRACT

Rambutans undergo rapid darkening and dehydration of the skin in 72 hours or less when stored unwrapped at ambient temperature. Skin colour, firmness and weight of rambutans could be effectively preserved by low temperature storage, packagings and modifying the storage atmosphere. Low temperature storage at 8^oC prolonged the shelf life of fresh unwrapped rambutans to 6 days. Low permeability packaging (polyethylene rigid containers) together with low temperature storage extended the shelf life further to 18 days. Increasing the initial concentration of carbon dioxide to an optimum level of 7% at 8^oC effectively suppressed respiration of fresh rambutan and prolonged the shelf life to nearly a month. Total absence of oxygen (as with vacuum packages) was detrimental to the shelf life of fresh rambutan, since the fruit was unable to respire normally. A good correlationship was found between weight loss of rambutan, darkening of skin and frimness of the fruit. The post harvest deterioration of rambutans was found to be mostly physiological.

INTRODUCTION

The rambutan is a seasonal tropical fruit, so called because of its hairy skin. The skin is green when young and ripens to red or yellow, depending on the variety. The fruit is closely related to the litchi (*Nephelium litchi*), longan (*N. longana*) and Pulasan (*N. mutabile*) and consists of a seed, surrounded by edible white pulp enclosed in the skin. The size of the seed, the thickness of the pulp and skin depend on variety. The planting area of rambutan in Malaysia was 15,548 hectares in 1980 and is projected to increase to 24,241 hectares by 1990 (Malaysian Agricultural Directory and Index, 1986).

Tests carried out to gauge acceptance and perception to rambutan by 100 Hong Kong visitors to the ASEAN Fruit and Vegetable Exposition in September 1986 resulted in a "degree of liking" score of 4.21 on a 1 to 5 scale where 1 = dislike a lot and 5 = like a lot. Most of them indicated a willingness to purchase these fruits if they were available in the market. (ASEAN Food Handling Newsletter, No. 24, 1987).

The main problem with rambutan is the rapid loss of moisture and physiological browning of the skin after harvest. This is normally followed cracking of the skin and exposure of the juicy flesh to pathological damage. This research attempts to prolong the storage life of fresh rambutans in order to reduce wastage and increase its market potential by packaging and modified atmosphere (MA) storage.

Films with different permeabilities to O_2 and CO_2 are available (Anon, 1971). In a sealed package, most of the free O_2 is used in a short time and CO_2 are produced. At room temperature, injurious CO_2 concentrations above 20% can build up. Film packages can be used to develop beneficial MA through product respiration which is greatly affected by temperature, humidity and time the fruits remain in the package. Type and thickness of package affect the O_2 and CO_2 levels; and each fruit has a different tolerance for low O_2 or increased CO_2 (Hall *et al.*, 1973). This therefore merits the investigation on the packaging of rambutan. MA storage implies addition or removal of gases resulting in an atmospheric composition substantially different from that of normal air. Modified Atmosphere storage, when combined with refrigeration, markedly retards respiratory activity and may delay softening, yellowing, quality changes and other breakdown process by maintaining an atmosphere with more CO_2 and less O_2 than in normal air (Do and Salunkhe, 1975).

MATERIALS AND METHODS

Rambutans of the red variety (R7) were harvested in bulk from the University Orchards (Ladang 5). They were sorted, weighed and subjected to various treatment and storage conditions on the same day. Each result is an average reading from an analysis of 6 fruits.

Low Temperature Storage Studies

Groups of fruits were sorted and stored at 8°C, 20°C and at ambient temperature (27 ± 3°C).

Different Packaging

Fruits were packed in groups of 6 in (i) 0.05 mm thickness low density polyethylene bags (LDPE); (ii) vacuum (suction pressure 5.93 kN/m); sealed in 0.05 mm LDPE; (iii) perforated 0.02 mm LDPE bags (4 mm diameter hole per square cm); and (iv) polystyrene tray (CP10) with PVC cling film overwrap. All the bags had a dimension of 15.5 cm x 22 cm. Unwrapped fruits were used as control for both temperatures of storage.

Modified Atmosphere Storage

Fruits were stored in 6-litre air tight plastic containers. Carbon dioxide was generated from a beaker containing weighed amounts of Na_2CO_3 and excess acid to produce an initial concentration of 3.5%, 7.0% and 10.0% carbon dioxide in the container. Fruits stored in normal atmosphere in similar air tight plastic containers were used as control.

Assessment of the Stored Fruits

Fruits were assessed for weight loss, skin colour, texture, % unacceptability and storage life. Colour was determined using the Hunter Lab tristimulus colorimeter, expressed as lightness (L), redness (a), and yellowness (b values), with the pink tile No. C2–22952 as reference (L = 68.8, a = 21.2, b = 12.2). Texture of the skin and pulp were determined using the Instron Universal Testing machine with the Kramer Shear cell attachment on samples of dimensions 1 x 1 cm (skin) and 2 x 2 cm (pulp). A drive speed of 50 mm/min and a chartspeed of 200 mm/min were used to determine the yield force. The % unacceptable fruits were assessed based on the appearance of the skin and not to the taste of the flesh. In most circumstances, under the low temperature storage, the flesh was still very fresh and acceptable even if the skin had turned dark. The shelf life of the fruits was taken as the number of days when 90% of the skin had discoloured.

Microbiological Assays

Peeled rambutan was immersed in 100 ml sterilized 0.1% peptone water in a beaker, followed by contimous shaking using an automatic shaker for 1 hour at ambient temperature. 0.1 ml of the above solution was spread plated onto various media as follows;

i) Plate Count Agar (pH 7)
   – for estimation of total aerobic bacteria.

ii) Czapek Dox Agar (pH 6.8)
   – for estimation of mold.

iii) Malt extract, yeast extract, glucose, peptone agar (pH 5.4)
   – for estimation of yeast.

The plates, done in duplicates, were then incubated for 1 – 5 days at 30°C. Microbial counts were made and stated in terms of number of colonies per gram (colonies/g).

RESULTS AND DISCUSSION

The shelf life of rambutans under various storage conditions and permeability of the various packaging material are summarised in Table 1. Unwrapped fruits stored at ambient temperatures, 20°C and 8°C had a shelf life of 3, 4 and 6 days respectively. On the 4th day, fruits stored at ambient temperature showed skin dehydration, which leads to skin browning and shrinking. The edible pulp became soft and had a fermented smell. By the 5th day, fungal growth was present. Although fruits stored at 8°C were shrivelled and darkened after 6 days storage, the flesh was still edible.

Storage of fresh rambutans in sealed LDPE at 8°C prolonged the shelf life to 16 days by reducing the amount of unacceptable fruits up to 90% (*Figure 1*). Storage of fruits in perforated LDPE at 8°C was less effective and resulted in a shelf life of 9 days, where the rate of browning and dehydration (% weight loss) was greater compared to unperforated LDPE package (*Figure 2*). At ambient temperatures, LDPE packaging managed to extend the shelf life of the fruits to 5 days (*Figure 3*). Vacuum packed fruits at 8°C had a shelf life of only 10 days. The absence of oxygen interfered with normal fruit respiration and resulted in increased injury or browning compared to normal LDPE packed fruits. However dehydration, which relates to respiration, was significantly reduced in vacuum packed fruits (*Figure 2*).

Fruits packed in polystyrene trays and over wrapped with cling film, had a shelf life of 12 days at 8°C. Moisture loss from expanded

TABLE 1
Storage life of fruits under different conditions and types of packaging materials.

Treatment	Storage Life (Days) ± 1		
	8°C	20°C	Ambient temperature
1. Packaging materials:			
a) Control	6	4	3
b) LDPE bag (0.05 mm thickness)	16		5
c) Perforated LDPE bag (0.02 mm thickness)	9		4
d) Vacuum pack (0.05 mm thick LDPE bag)	10		5
e) Polystyrene tray with cling film wrap	12		4
2. Modified atmosphere:			
a) Control	18		4
b) 3.5% CO	19		4
c) 7.0% CO	26		6
d) 10.0% CO	20		5

polystyrene with cling film wrap was higher compared to fruits wrapped in LDPE (*Figure 2*), thus explaining the shorter shelf life compared to LDPE packed fruits. Polystyrene is more permeable than LDPE but less permeable than perforated LDPE.

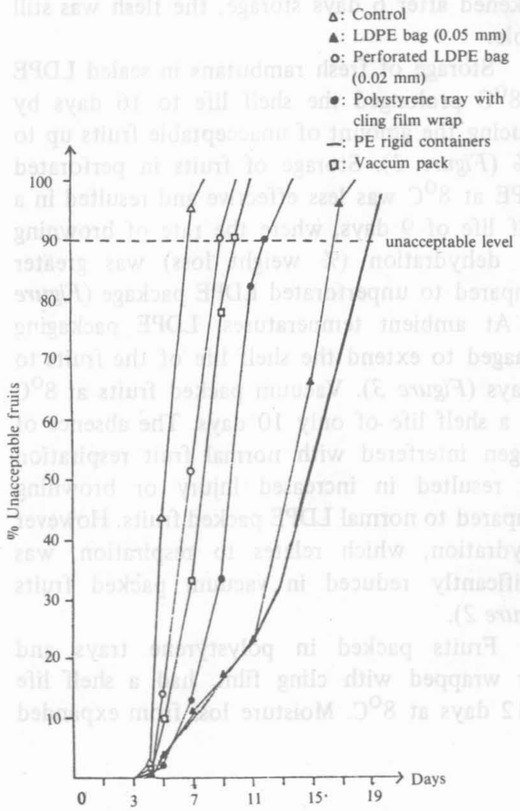

Fig. 1: % Unacceptable fruits with time stored at 8^{O}C (Various packaging)

This experiment indicates that the shelf life of rambutans stored at 8^{O}C is related to the permeability of the packaging material. The less permeable, the packaging materials, the longer will the rambutans remain attractive, provided oxygen is present for the normal respiration of the fruits. The permeability of the packaging material affected the storage life in 2 ways: (i) by reducing dehydration of the fruits, (ii) by causing the accumulations of carbon dioxide and reduction in oxygen since gaseous exchange between the atmosphere inside and outside the package is reduced. The accumulated carbon dioxide in the package suppressed the respiration and slowed down the physiological changes to the fruits.

Work by Mendoza *et al* (1972) on *Seematjan* and *Maharlika* rambutans showed that the most effective storage procedure was wrapping in sealed polyethylene bags and holding at 50^{O}F (10^{O}C) and 95% RH; by this mean a marketing life of 12 days was achieved. However, sealed polyethylene bags were ineffective at high room temperature and ventilated bags were found to be preferable. Chilling injury was observed at 7^{O}C (45^{O}F). The most satisfactory material for reducing weight loss during transport and strorage was sawdust.

Modified Atmosphere Storage

Fruits stored in air tight polyethylene rigid containers had a shelf life of 18 days at 8^{O}C. Storage of rambutan under 7.0% carbon dioxide extended the shelf life to 26 days at 8^{O}C (*Figure 4*). At this time, when 90% of the fruits had discoloured skin, a slight alcoholic smell could be detected although the flesh was still acceptable. Rambutans stored at 8^{O}C under 10.0% and 3.5% carbon dioxide had a

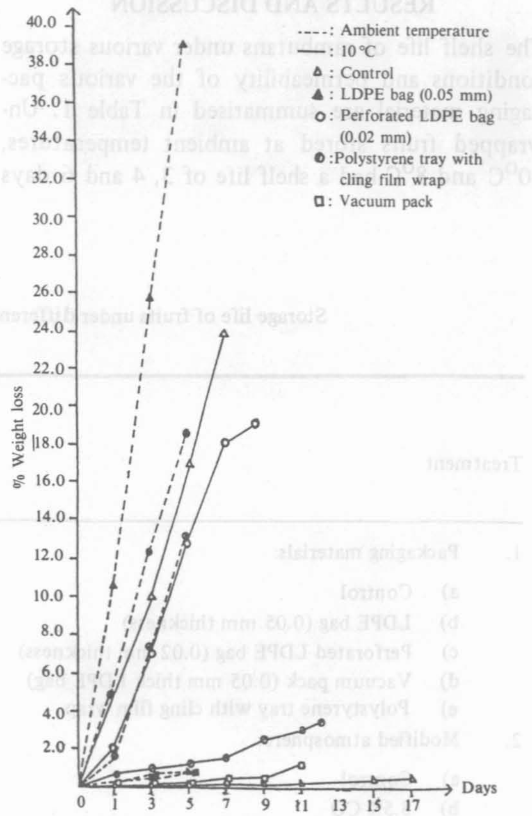

Fig. 2: % Weight loss with time (various packaging)

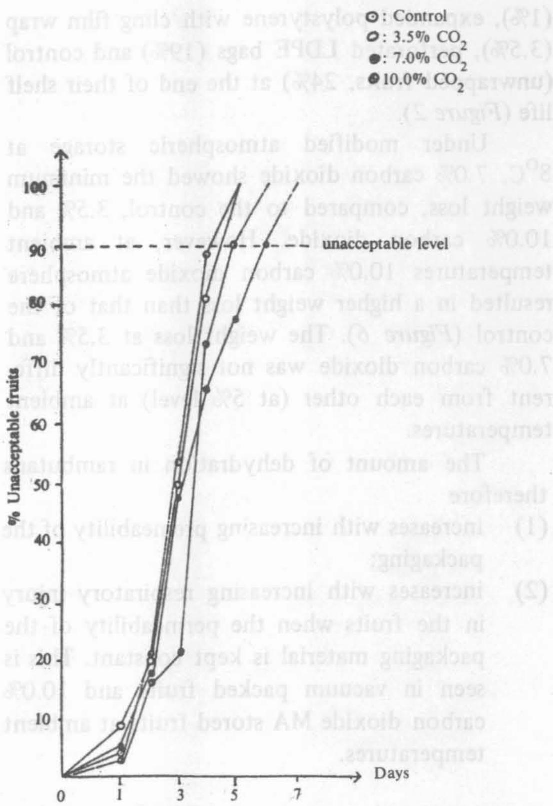

Fig. 5: % Unacceptable fruits with time stored at ambient temperature (Modified Atms.)

Colour

Objective colour measurements using the Hunter Lab colorimeter showed that modified atmospheric (MA) storage retained the colour of fruits stored at 8^{o}C best (Table 2). The retention of the red colour (a values) was highest under MA storage especially at 7.0% carbon dioxide level, followed closely by 3.5% carbon dioxide level.

Polythylene rigid containers and LDPE bags were effective in slowing down the darkening of the skin colour compared to other packaging materials tested, at 8^{o}C. However, fruit in perforated bags or vacuum packed bags showed rapid skin browning (drop in a and b values). At ambient temperature, fruits stored in LDPE bags and cling film showed better red colour retention compared to the other kinds of packaging, even if the storage life was not very much prolonged.

Texture

Texture changes of fruits stored under different packaging are shown in *Figure 7.* Rambutans stored unwrapped showed an increase in toughness on storage; the skin of those stored at ambient temperature being tougher than those stored at 8^{o}C. The increase in toughness of the skin was due to hardening of the skin with moisture loss. However, the texture of the pulp at both temperatures of storage showed decrease in firmness (*Figure 8*). This may be due to senescence of the fruit on storage causing breakdown of tissues and fibres by autolytic enzymes. On the other hand, fruits packed in various packaging materials showed decreased firmness in skin and pulp shearing test on storage.

During storage of rambutans, dehydration of the skin resulted in increasing toughness; while senescene, resulted in a decrease in firmness. When dehydration is inhibited or slowed down, the skin firmness was better maintained.

Increasing the initial level of carbon dioxide in the storage atmosphere, appeared to increase the firmness of rambutan skins (*Figure 9*). 10%

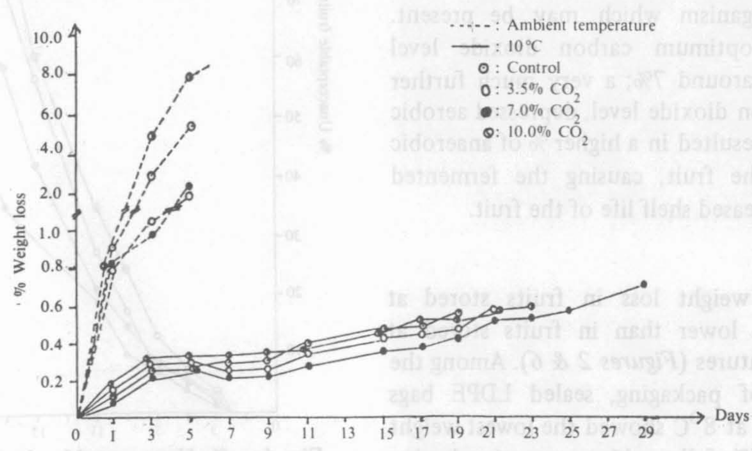

Fig. 6: % Weight loss with time (CO_2 treatments)

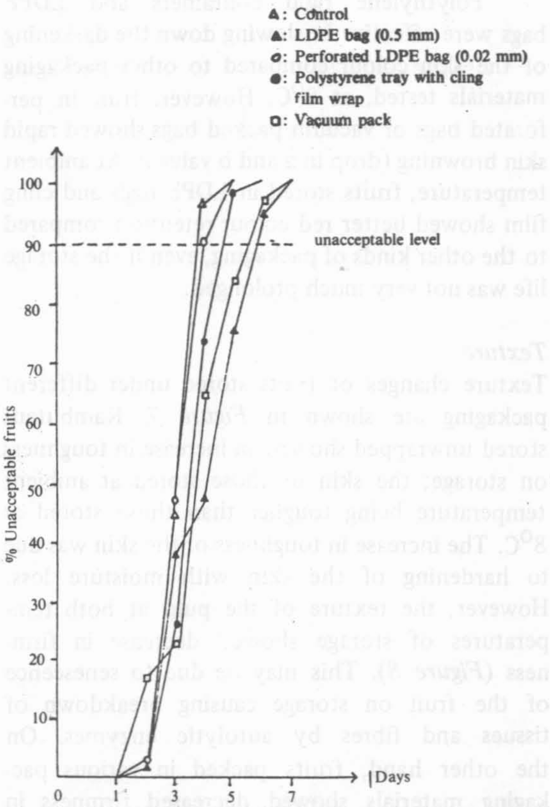

Fig. 3: % Unacceptable fruits with time stored at ambient temperature (Various packaging)

shelf life of 20 and 19 days respectively. Fruits stored at ambient temperature under 3.5%, 7% and 10% carbon dioxide, had a shelf life of 4, 6 and 5 days respectively (*Figure 5*), after which a fermented smell was observed and the flesh was acidic. The increased level of carbon dioxide retarded the respiration of the fruit as well as any aerobic microorganism which may be present. However, the optimum carbon dioxide level appeared to be around 7%; a very much further increase in carbon dioxide level, depressed aerobic respiration and resulted in a higher % of anaerobic respiration in the fruit, causing the fermented smell, and a decreased shelf life of the fruit.

Weight Loss

Generally, the weight loss in fruits stored at $8^{o}C$ was much lower than in fruits stored at ambient temperatures (*Figures 2 & 6*). Among the various types of packaging, sealed LDPE bags without vacuum at $8^{o}C$ showed the lowest weight loss of about 0.5%, followed by vacuum packaging (1%), expanded polystyrene with cling film wrap (3.5%), perforated LDPE bags (19%) and control (unwrapped fruits, 24%) at the end of their shelf life (*Figure 2*).

Under modified atmospheric storage at $8^{o}C$, 7.0% carbon dioxide showed the minimum weight loss, compared to the control, 3.5% and 10.0% carbon dioxide. However, at ambient temperatures 10.0% carbon dioxide atmosphere resulted in a higher weight loss than that of the control (*Figure 6*). The weight loss at 3.5% and 7.0% carbon dioxide was not significantly different from each other (at 5% level) at ambient temperatures.

The amount of dehydration in rambutans therefore

(1) increases with increasing premeability of the packaging;

(2) increases with increasing respiratory injury in the fruits when the permeability of the packaging material is kept constant. This is seen in vacuum packed fruits and 10.0% carbon dioxide MA stored fruits at ambient temperatures.

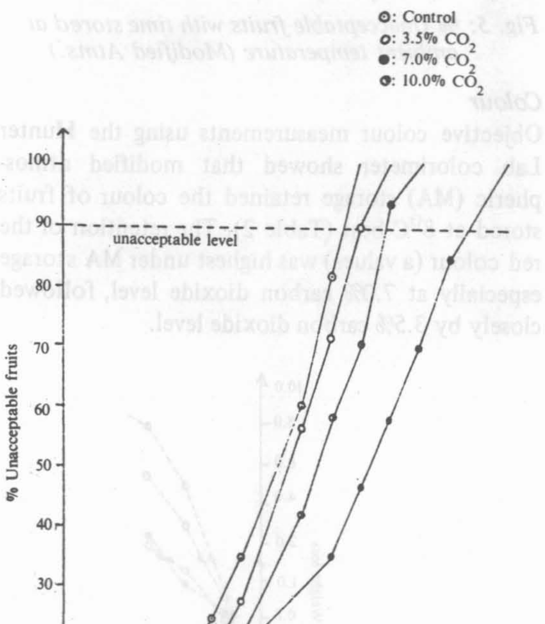

Fig. 4: % Unacceptable fruits with time stored at $8^{o}C$ (Modified Atmosphere)

TABLE 2
Effect of packaging and MA storage on rambutan skin color

Day	Control L	Control a	Control b	3.5% CO2 L	3.5% CO2 a	3.5% CO2 b	7.0% CO2 L	7.0% CO2 a	7.0% CO2 b	10.0% CO2 L	10.0% CO2 a	10.0% CO2 b
8°C												
1	26.4	6.0	2.4	22.3	10.4	2.9	23.9	9.8	4.0	23.0	10.3	2.2
3	25.9	7.7	3.0	21,9	11.4	3.2	23.8	9.5	4.2	22.9	10.5	2.4
5	23.7	8.2	4.1	20.0	13.7	4.4	22.7	9.1	4.3	21.0	10.7	2.5
7	19.9	9.5	4.5	17.9	15.7	4.6	19.6	15.0	4.8	20.0	11.4	2.8
9	15.9	10.	5.5	15.9	12.5	5.1	16.7	15.3	4.9	17.0	12.3	3.5
11	16.4	9.4	6.3	15.5	9.3	7.1	14.6	11.9	4.6	16.0	12.7	3.9
15	15.8	8.5	5.6	14.3	8.7	5.8	13.5	9.8	4.1	15.4	9.1	5.3
17	17.0	7.7	3.9	14.2	8.4	5.3	13.1	9.0	4.0	14.7	7.7	5.5
19	12.5	4.8	3.3	14.1	7.9	3.5	12.9	8.3	3.7	6.2	4.1	
21				13.5	7.4	3.5	12.7	8.1	3.4	12.0	5.8	3.2
23							12.6	7.4	3.3	11.8	5.4	2.9
25							12.3	6.5	3.2			
29							12.0	6.9	2.8			
Ambient												
1	24.7	2.1	3.6	25.0	7.2	2.8	24.7	3.9	1.4	24.1	7.9	3.6
2	19.0	3.7	3.1	19.3	6.5	3.5	18.4	4.5	2.3	20.9	7.1	3.3
5	12.9	4.0	2.7	14.5	4.2	2.9	13.0	5.9	3.3	14.7	5.9	3.3

Various packaging 8 C	Control L	Control a	Control b	LDPE L	LDPE a	LDPE b	Perforated LDPE L	Perforated LDPE a	Perforated LDPE b	Polystyrene L	Polystyrene a	Polystyrene b	Vacuum L	Vacuum a	Vacuum b
1	17.7	8.3	6.9	19.9	13.0	6.9	18.5	10.1	7.7	22.2	14.2	6.9	18.7	9.2	6.9
3	15.0	6.5	5.7	18.2	10.9	6.4	17.8	9.0	6.5	20.2	13.3	6.5	17.9	7.6	6.3
5	14.1	5.1	4.0	18.5	10.4	6.0	15.3	7.3	5.8	19.1	11.0	5.8	17.6	6.8	5.9
7	13.4	4.9	3.4	17.7	9.8	5.7	14.9	6.1	4.8	17.0	9.4	5.3	16.0	4.3	5.0
9				16.7	8.5	5.4	14.5	6.1	4.2	15.9	8.4	4.1	15.6	4.0	3.8
11				15.9	7.8	5.2				14.7	7.5	3.4	13.5	3.7	3.5
13										14.3	6.8	3.3			
15				15.0	7.0	4.1									
17				13.5	6.2	3.9									
Ambient															
1	16.1	6.5	4.2	20.1	11.9	7.0	18.3	8.5	6.1	21.7	11.1	4.8	19.5	7.4	6.9
3	15.2	5.7	3.5	18.6	11.3	5.8	16.8	6.9	4.7	18.2	9.4	4.1	17.4	5.4	5.7
5	13.4	3.7	3.1	15.5	9.7	3.9	14.7	4.0	3.4	15.0	7.6	3.5	16.5	4.9	4.3

S.D. between 0.1 – 0.3 units

carbon dioxide gave a firmer skin texture than 7.0% carbon dioxide, and 7.0% carbon dioxide gave a firmer texture than 3.5% carbon dioxide. The high carbon dioxide levels may have suppressed respiration which in turn may have reduced the production of enzyme responsible for the pectin degradation in the fruits, hence retarding softening. However, fruits stored in 10% carbon dioxide also showed greater weight loss and shorter shelf life, indicating carbon dioxide injury.

Packaging and modified atmospheric storage appeared to benefit pulp firmness (*Figures 8 and 10*). The pulp was firmest under vacuum packaging followed by LDPE packaging. The vacuum packaging appeared to retard cell structure breakdown, but on prolonged storage (after the 11th day) caused fruit injury. In modified atmospheric storage, the pulp firmness followed an almost similar trend to skin firmness, i.e. 10% carbon dioxide gave the best response, but prolonged storage in 10% carbon dioxide resulted in

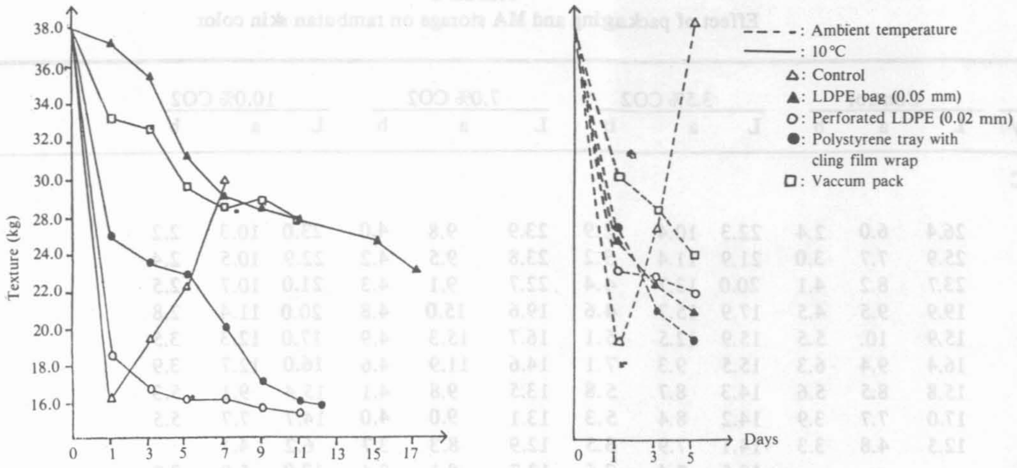

Fig. 7: Skin firmness with time (Various packaging).

a shorter shelf life compared to 7% carbon dioxide storage, because of carbon dioxide injury.

Correlationship between Weight Loss, Texture and Colour

There appears to be a good correlationship between skin firmness and L value for all the treatments both at 8°C and ambient temperature. Under the packaging experiments a good correlationship could be seen between texture and all the tristimulus values, L, a and b (Table 3) for skin colour.

Table 4 shows the close correlationship between skin texture and weight loss (dehydration), or pulp texture and weight loss both at 8°C and ambient temperature. This indicates that the loss in turgidity of cells is the major cause of the reduction in skin and pulp firmness.

The existence of a correlationship between firmness with lightness (L value) and firmness with dehydration indicates the presence of a correlationship between fruit darkening with dehydration. Theoretically therefore, fruit darkening can be prevented by preventing dehydration. However, there appear to be no strong correlation between a values (redness) or b values (yellowness) to texture of dehydration. Therefore the overall skin colour could not be preserved by merely preventing dehydration. Dehydration triggers physiological changes in the fruit and causes cell injury which would trigger the enzymic browning in the skin.

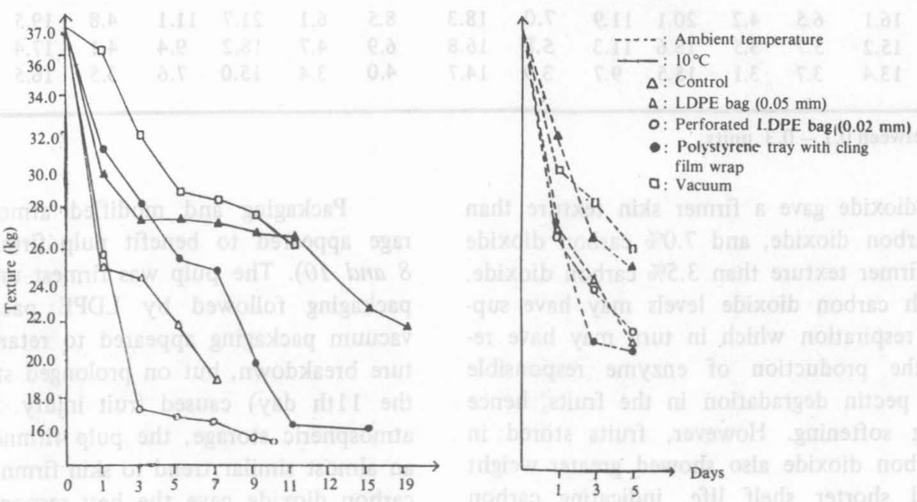

Fig. 8: Pulp firmness with time (Various packaging).

TABLE 3

Correlationship between skin firmness with colour

Treatments		Correlation Coefficient Texture vs Colour			Best Fitted Line Texture vs Colour		
	N	L	a	b	L	a	b
MODIFIED ATMOSPHERE (CO_2) (8^oC)							
a) Control	18	0.948	−0.034	−0.507	y = 0.729 x + 9.601	y = − 0.07 x + 24.226	y = − 1.477 x +29.993
b) 3.5%	20	0.997	0.580	−0.520	y = 1.564 x + 0.619	y = 1.116 x +15.391	y = −2.074 x +36.570
c) 7.0%	26	0.983	0.514	0.631	y = 1.10 x + 12.457	y = 0.962 x +20.894	y = 5.118 x +10.067
d) 10.0%	22	0.970	0.606	0.690	y = 1.077 x +13.357	y = 1.061 x +21.827	y = 12.828 x +41.521
PACKAGING MATERIAL(8^oC)							
a) Control	8	−0.901	−0.895	−0.947	y = −2.411 x +59.841	y = −2.873 x +41.372	y = −2.985 x +38.487
b) LDPE bags (0.05 mm)	16	0.893	0.948	0.922	y = 1.815 x −0.442	y = 1.778 x + 13.925	y = 3.716 x +10.03
c) Perforated LDPE bags (0.02 mm)	10	0.885	0.901	0.917	y = 0.554 x + 9.827	y = 0.576 x + 14.364	y = 0.755 x +14.427
d) Polystyrene tray with cling film	14	0.983	0.968	0.989	y = 1.239 x + 0.268	y = 1.287 x + 9.180	y = 2.567 x + 9.217
e) Vacuum pack	12	0.857	0.932	0.875	y = 1.029 x +13.152	y = 0.941 x + 24.609	y = 1.451 x +22.59
MODIFIED ATMOSPHERE (CO_2) (Ambient)							
a) Control	6	0.988	−0.852	0.972	y = 0.760 x +21.009	y = −3.786 x +47.713	y = 9.780 x + 4.702
b) 3.5%	6	0.998	0.961	−0.115	y = 0.317 x +20.293	y = 1.022 x +20.407	y = 0.507 x +28.061
c) 7.0%	6	0.982	−0.895	−0.965	y = 0.982 x +26.028	y = −16.589 x +39.900	y = −19.314 x +36.500
d) 10.0%	6	0.990	0.978	0.661	y = 1.399 x + 4.229	y = 6.562 x −13.647	y = 25.767 x −55.540
PACKAGING MATERIALS (Ambient)							
a) Control	6	−0.999	−0.996	−0.951	y = −6.251 x +122.343	y = −5.940 x +60.690	y = −14.684 x +82.069
b) LDPE bags (0.05 mm)	6	0.919	0.894	0.841	y = 0.996 x +11.502	y = 2.000 x + 7.568	y = .0.983 x +25.017
c) Perforated LDPE bags (0.02 mm)	6	0.999	0.999	0.987	y = 0.368 x +18.741	y = 0.292 x +22.965	y = 0.487 x +22.547
d) Polystryene tray with cling film	6	0.975	0.965	0.979	y = 0.874 x + 8.069	y = 1.655 x + 8.555	y = 5.519 x + 5.382
e) Vacuum pack	6	0.960	0.925	0.999	y = 2.212 x − 7.817	y = 2.480 x +16.921	y = 2.724 x +16.20

N: Number of readings for calculation of correlationship.

TABLE 4

Correlationships between skin firmness with weight loss and pulp firmness with weight loss

Treatments	N	Correlation Coefficient		Best Fitted Line	
		Skin Texture vs Wt. Loss	Pulp Texture vs. Wt. Loss	Skin Texture vs. Wt. Loss	Pulp Texture vs. Wt. Loss
MODIFIED ATMOSPHERE (CO_2) (8°C)					
a) Control	18	−0.941	−0.947	y = −23.078 x +32.045	y = −16.62 x +25.402
b) 3.5%	18	−0.901	0.914	y = −38.285 x +40.412	y = −44.491 x +37.319
c) 7.0%	26	−0.829	−0.932	y = −27.178 x +40.446	y = −17.238 x +29.448
d) 10.0%	26	−0.929	−0.923	y = −31.800 x +43.920	y = −13.563 x +28.548
PACKAGING MATERIALS (8°C)					
a) Control	8	0.992	−0.970	y = 0.614 x +14.776	y = −0.334 x +27.210
b) LDPE bags (0.05 mm)	16	−0.903	−0.918	y = 23.261 x + 36.502	y = −15.137 x +30.149
c) Perforated LDPE (0.02 mm)	12	−0.922	−0.827	y = −0.136 x +20.451	y = −0.405 x +23.437
d) Polystryene tray with cling film	14	−0.978	−0.991	y = −3.142 x +28.614	y = −4.845 x +33.027
e) Vacuum pack	12	−0.662	−0.610	y = −3.178 x +31.249	y = −5.677 x +31.999
MODIFIED ATMOSPHERE (CO_2) (ambient)					
a) Control	6	−0.987	−0.968	y = −2.078 x +41.640	y = −1.762 x +36.447
b) 3.5%	6	−0.999	−0.993	y = −3.242 x +30.646	y = −6.636 x +32.432
c) 7.0%	6	−0.840	−0.940	y = −2.957 x +35.503	y = −2.521 x +29.411
d) 10.0%	6	−0.904	−0.973	y = −1.810 x +39.871	y = −1.255 x +34.727
PACKAGING MATERIALS (ambient)					
a) Control	6	0.982	−0.992	y = 0.588 x +14.310	y = −0.210 x +29.567
b) LDPE bags (0.05 mm)	6	−0.943	−0.880	y = −6.0969 x +32.433	y = −8.395 x +32.069
c) Perforated LDPE (0.02 mm)	6	−0.983	−0.999	y = −0.094 x +25.984	y = −0.381 x +28.827
d) Polystryene tray with cling film	6	−0.966	−0.895	y = −0.538 x +28.142	y = −0.589 x +27.378
e) Vacuum pack	6	−0.944	−0.936	y = −10.718 x 38.200	y = −6.467 x +32.336

N: Number of readings for calculation of correlationship.

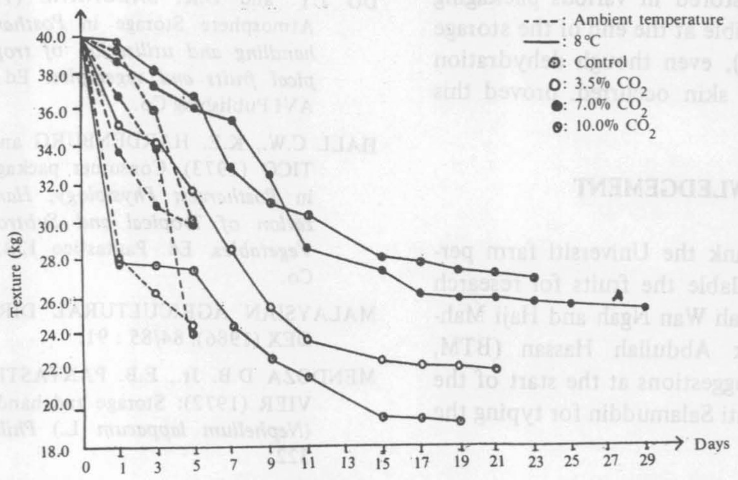

Fig. 9: Skin firmness with time (CO_2 treatments)

Microbiology Assays

Storage of fruits at 8°C with respect to types of packaging showed low levels of microbial count. Only yeasts were found in each packaging treatment in the range of 1.0 x 10^2 to 11 x 10^3 colonies/g. Vacuum packed treatment showed the highest yeast count of 1.1 x 10^3 colonies/g. Ambient temperature storage treatments showed a slightly higher amount of yeast count, in the range of 1.0 x 10^3 to 2.45 x 10^3 colonies/g.

The results obtained showed that spoilage of rambutans was not due to microbes, since storage at both temperatures of 8°C and ambient temperature only showed a slight difference in the microbial counts. The counts obtained may be due to contamination through handling during the experiment or may be due to insect infection on fruits before hand. Another factor which may be the cause of spoilage is through skin injury of the fruits.

Tongdee *et al.* (1982) observed that the initial browning during storage of tissue at the stem end adjacent to the seed of litchi fruits appeared to be a senescent process and not related to microbial deterioration. No fungal growth was obtained when isolations were made from the brown tissue early in storage but as browning progressed, positive isolations resulted.

The rambutan skin which is firm and thick helps to keep the flesh sterile for a period of time.

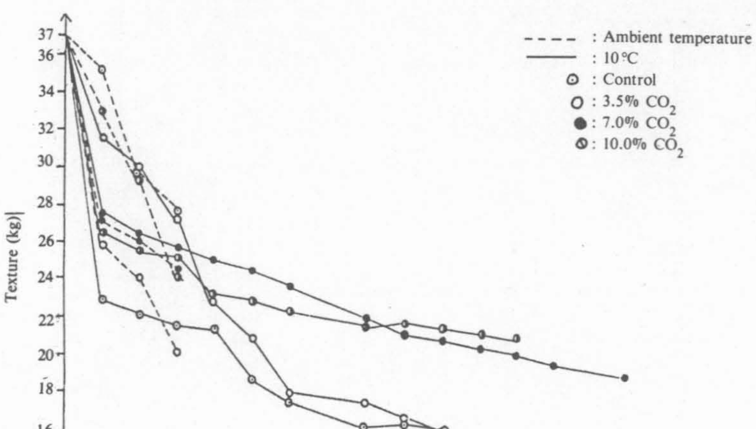

Fig. 10: Pulp firmness with time (CO_2 treatments)

The fact that fruits stored in various packaging materials were still edible at the end of the storage life at 8°C (26 days), even though dehydration and browning of the skin occurred, proved this point.

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