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IMPROVING QUALITY AND SHELF LIFE OF VEGETABLES AND FRUITS BY EVAPORATIVE COOLING STORAGE

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ABSTRACT

Fresh fruits and vegetables deteriorate in quality very rapidly after harvest due to high rates of water loss and senescent changes. These processes rendered rambutan fruits and pechay crowns unmarketable in 2-3 days of storage and banana, mango, tomato and sweet pepper, in 7-13 days at ambient (27-32°C; 64-88% RH). Using a simple box-type evaporative cooler (EC), a cool (23-28°C) and humid (>90% RH) storage condition was established and inhibited fruit shrivelling and leaf wilting, reduced weight loss, retarded fruit ripening and rambutan pericarp browning, improved banana peel color quality, and as a result, prolonged shelf life considerably. However, the increased humidity favored disease infection in the later period of EC storage. Sodium hypochlorite washing minimized disease incidence in tomatoes, sweet peppers, pechay, and mango. Ethanol application was ineffective but retarded ripening of fruits, except in bananas. In rambutan, ascorbic acid did not retard pericarp browning. EC storage and the various treatments employed had no adverse effects on the chemical and sensory quality attributes of stored produce.

Keywords: *Vegetables, fruits, postharvest quality, storage life, evaporative cooling, high humidity, hypochlorite, ethanol*

INTRODUCTION

Vegetables and fruits play a decisive role in the country's economy and in human nutrition. Economic contributions as of 1993 of the vegetable and fruit industries are estimated at 6.5 and 10.5 billion pesos, respectively (Bautista and Acedo, 975). These commodities are also the richest source of vitamins, minerals, and plant proteins. A major constraint in the production of these crops is their high perishability which, together with lack of storage systems, greatly account for the serious losses of harvested produce (Bautista and Acedo, 1995; Acedo, 1996). Refrigerated storage is seldom available but evaporative cooling storage could minimize the problem. In this storage system, a cool and humid environment can be established since the heat from the storage chamber is dissipated with the evaporation of water. The decrease in temperature is usually small but the increase in humidity is substantial so that product quality deterioration due to moisture loss can be inhibited. A number of evaporative coolers (EC) has been found effective in improving the keeping quality of vegetables and fruits (Garcia and and Bautista, 1984; Labios and Bautista, 1984; Olea, 1984; Redulla et al., 1984; Rama et al., 1990; Thiagu et al., 1991). These ECs were typically simple and inexpensive since target users are the small, resource-poor farmers and entrepreneurs who dominate the industry. However, several gaps in the use of EC have not been addressed. These include disease development during storage, unretarded fruit ripening, inapplicability of some EC systems to certain produce, and unknown responses of many commodities to EC conditions. This paper describes the effectiveness of simple box-type Ecs in maintaining quality and prolonging shelf life of important vegetables and fruits and the commodity treatments that could be integrated with EC storage.

MATERIALS AND METHODS

Vegetable and Fruit Sampling

Leading commercial cultivars of three vegetables and three fruits were used; tomato ('Improved Pope'), sweet pepper ('Grossum'), and rambutan ('Maharlika'). Freshly harvested mature-green tomatoes, peppers, mangoes (about 114 days from flower induction), and bananas (full three-quarters), red-ripe rambutans, and 25-day old crowns of pechay were obtained from local growers and sorted, retaining defect-free samples of comparable size. Ten to 20 fruits or 5-10 pechay crowns were used for each treatment per replicate.

EC Structures and Storage Condition

The EC consisted of a wooden main frame 60 x 50 x 100 cm in length, width, and height, respectively. The storage compartment was raised 40 cm above the ground and had three drawer-type commodity holders made of screen wire. Two types of wall structure were used. In the first, the storage compartment including

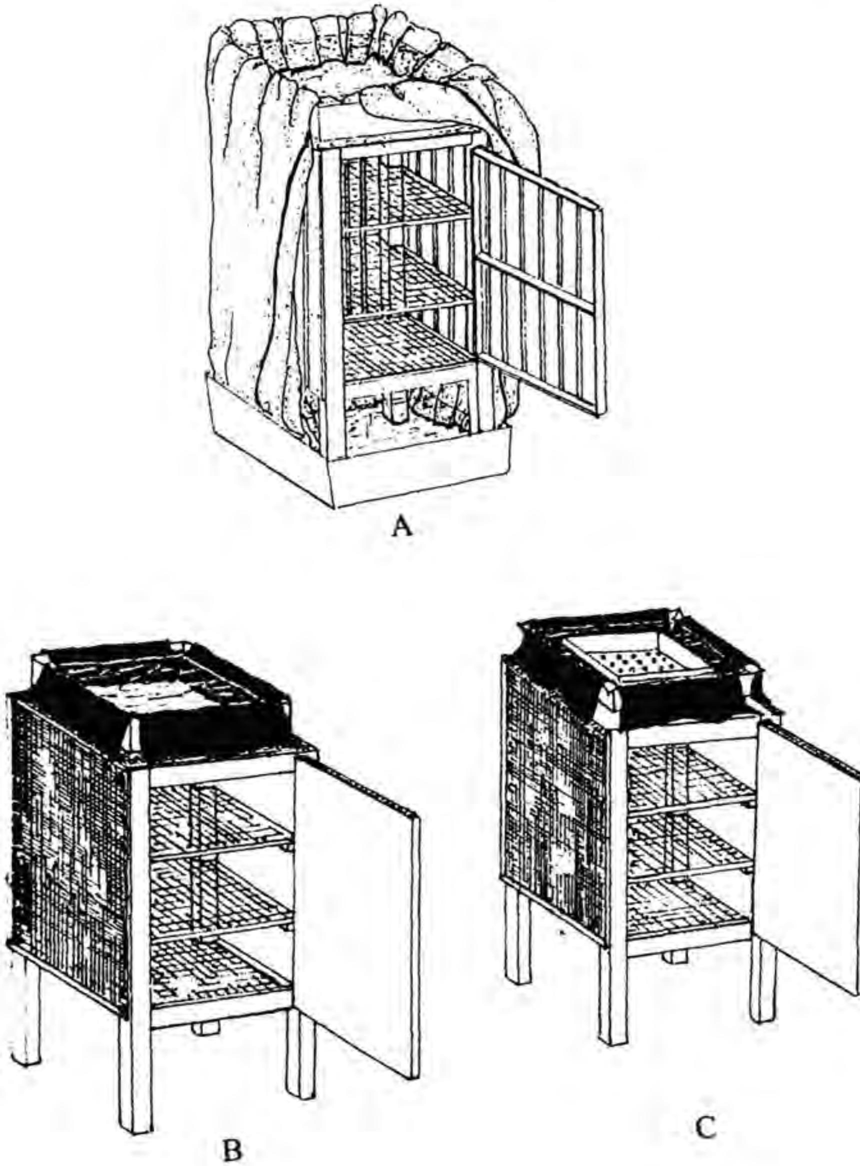

Figure 1. The evaporator coolers (EC) with jute sack walling (A) and with rice hull wall insert without vents (B) and with vents (C).

the door assembly were walled with wooden slabs spaced at 2 cm. The whole structure was covered with just sacking kept wet by dipping its top and bottom ends in water contained in a pan made of plain galvanized iron (GI) sheet. The jute sacking was sewn on except across the front to facilitate opening of the door (Figure 1A). In the other type, the inner side of the five walls and that of the door assembly were made of GI sheet with fine holes spaced at 5 x 5 cm while the outer side was made of 0.32 cm fine-meshed wire. The 1.5-cm space between the inner and outer walls was filled with rice hulls. A GI pan of water was placed on top, with cloth to draw water to the rice hull insert. This type of EC was either unvented (Figure 1B) or vented with 32 2-mm diameter holes in the top (Figure 1C). Storage in these ECs was compared with that at ambient in the same laboratory. The temperature and relative humidity (RH) were measured using a *Tri-Sense* digital meter. The vapor pressure deficit (VPD) in millibar (mb), a measure of the capacity of an atmosphere to dry out commodities, was traced from a psychrometric chart. The data presented are means of daily readings taken at three times, about 6 am, 12 noon and 6 pm.

Commodity Treatment

Sodium hypochlorite (NaOC1) was tried for disease control in tomatoes, peppers, pechay and mangoes, using commercial bleach diluted to 0.5 and 1.0% naOC1 and washing for about 1.5 minutes. Tap water was included for comparison. For ripening retardation, ethanol application was tried, as vapor or as dip. In the former, a 3.5-litter glass jar capped with rubber stopper was used and inside it was a filter paper-wick. Absolute ethanol at 1-3 ml/kg fruit was put onto the wick using a plastic syringe: it evaporated within 15 minutes, and the fruits were left for 6-12 hours. In the dip treatment, fruits were dipped in 20-40% ethanol for 2-4 minutes.

Measurement of Storage Characteristics

In tomato, pepper, mango and banana, the changes in peel color were visually determined using a color index (CI) of 1-6, with 1-green, 2-breaker, first trace of yellow or red, 3-more green than yellow or red, 4-more yellow or red than green, 5-yellow or red with trace of green, and 6-full yellow or red. The number of days to reach CI 4-5 (banana) or CI 6 (tomato, pepper, and mango) was taken as the ripening period. At the ripe stage, total soluble solids (TSS), titratable acidity (TA), and overall flavor were determined. TSS was measured using an *Atago* hand refractometer while TA, by titration against NaOH and phenophthalein; results are given on the wet weight basis. The overall flavor was evaluated by 10-15 trained panelists using a hedonic scale of 9 (liked extremely) to 1 (disliked extremely). In rambutans, TSS, TA and overall flavor were measured when the fruits reached the limit of marketability.

In pechay, yellowing of the leaf surface was rated on a scale of 1 – green, 2 – up to 10% of leaf surface yellow, 3 – li – 30% yellow, 4-31-60% yellow, 5-61-90%

yellow, and 6-more than 90% yellow. Chlorophyll content was also analyzed by the acetone method (Yoshida et al., 1976) using the second leaf from the base of the crown.

In rambutan, pericarp browning was scored using an index of 1-6 (Lam et al., 1987), with 1- none, 2 – up to ¼ of spintern brown, 3 – ¼ to ½ brown, 4 – ½ to ¾ brown, 5 – more than ¾ brown, and 6 – entire spintern brown.

The percent loss in weight of each vegetable and fruit was measured. The degree of fruit shrivelling or leaf wilting was scored 1-4 for none, slight, moderate and severe.

Disease-infected tomatoes and peppers were counted and expressed as percent of the total. In pechay and mango, severity of disease infection was rated on a scale of 0 for none to 5 for severe or more than 30% of the fruit or crown affected.

Shelf life was the number of days for each vegetable or fruit to reach the limit of marketability, due to shrivelling or wilting, overripening or leaf yellowing, and/or decay.

All experiments were in a completely randomized design using 3-4 replicates. Each experiment was repeated at least once. The results obtained were similar and the data presented here are pooled means of 2-3 trials.

RESULTS AND DISCUSION

The ECs had lower temperatures and higher RH than that at ambient (Table 1). VPD consequently decreased from about 8.8 mb at ambient to 1-2 mb in the Ecs. This indicates that the ambient atmosphere was 4-5 times drier than the EC atmosphere. Storage conditions in the three types of EC did not differ much. Similarly, storage characteristics of the vegetables and fruit did not vary with EC design. In the succeeding discussion, commodity responses to storage in the vented EC (Figure 1C) were compared to responses to ambient storage.

Fruit Ripening Characteristics

EC storage retarded ripening of tomato and mango by 1-2 days and that of sweet pepper, by 9-10 days later than the ripening periods of fruits at ambient (Table 2). It effected also normal peel reddening of peppers whereas at ambient, less than 50% of the fruits turned red-ripe. Ethanol vapor and dip treatments further

Table 1. Average temperature, RH and VPD during storage of vegetables and fruits.

Storage of Treatment	Temperature, °C	RH, %	VPD, mb
EC-jute sacking	26.7 ± 1.1	96.1 ± 1.8	1.8 ± 1.0
EC-rice hull	26.1 ± 0.9	96.2 ± 1.6	1.2 ± 0.6
EC-rice hull, vented	25.6 ± 0.8	93.8 ± 2.5	2.0 ± 1.2
Ambient	29.1 ± 1.4	78.1 ± 5.3	8.8 ± 2.5

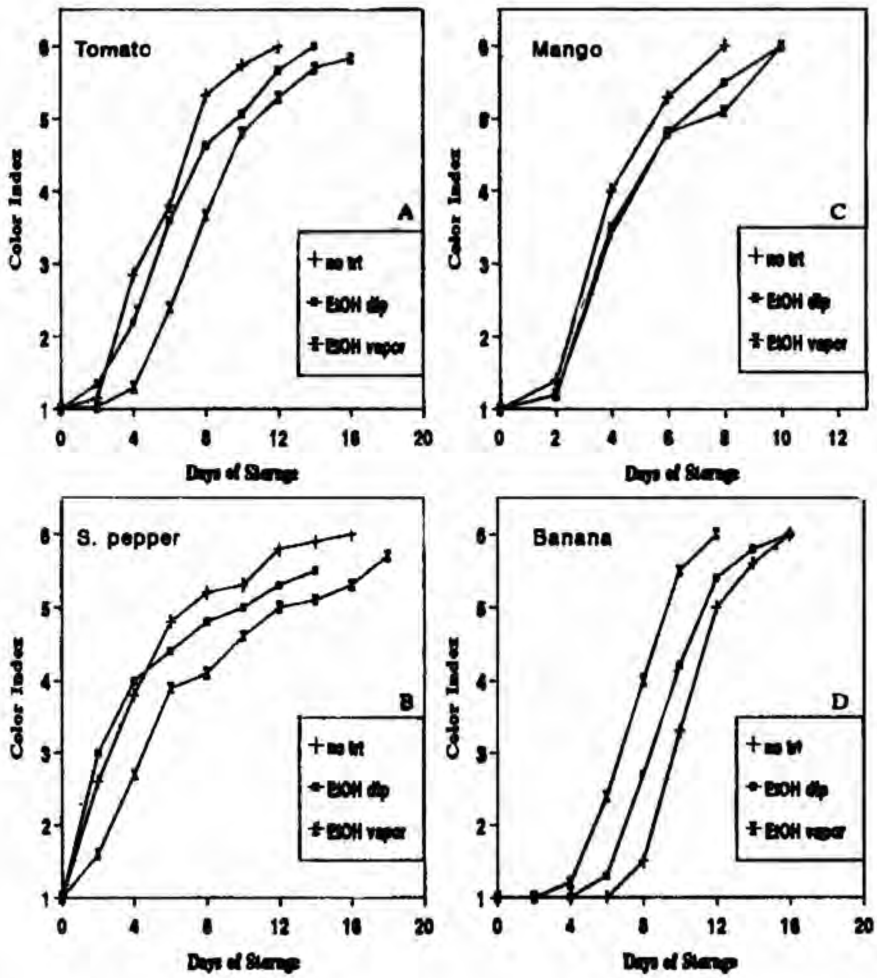

Figure 2. Peel color development of EC-stored vegetables and fruits treated with ethanol vapor or dip.

slowed down ripening manifested as reduced rate of peel color development, except in banana (Figure 2). Vapor treatment was more effective than the dip treatment, particularly in tomato and pepper. The optimum treatment was 1 ml ethanol per kg fruit for 6 hours (vapor) and 40% ethanol for 4 minutes (dip). Use of lower or higher rates of application had no added benefit. In bananas, the ripening period of EC-stored fruits was comparable to that of ambient-stored fruits. Ethanol treatment also promoted ripening (Figure 2D). However, the EC fruits developed better ripe peel color than the ambient fruits (Table 2).

Ripening retardation by EC can be attributed to the cool and humid condition during storage (Table 1). It is well known that metabolic processes proceed at a slower rate at lower temperatures. High humidity is also retardant for ripening (Grierson and Wardowshi, 1978). In bananas, it is surprising that the humid EC condition had no marked inhibitory effect on ripening, contradicting previous reports (Tung et al., 1987; Shukor et al., 1990; Xue et al., 1995). Factors such as ethylene ac. :mulation in the storage chamber may have negated the ripening-inhibitory effect of low temperature and high RH in the EC. Among the fruits and fruit-vegetables used here, banana is the most sensitive to ethylene. On the other hand, the inhibition of tomato, pepper and mango ripening by ethanol concurs with results of earlier studies (Saltveit, 19889; Saltveit and Sharaf, 1992). But again, the response of banana contradicted that obtained in 'Senorita' and 'Cavendish' fruits whose ripening was retarded by ethanol (Esguerra et al., 1993). It can be speculated that the rates of ethanol application used were already excessive for 'Saba' and probably inductive to stress ethylene production and ripening (Hyodo, 1991).

As the rice stage, the soluble solid and acid contents were generally lower in EC-stored fruits than in ambient-stored ones, including that in rambutan (Table 2). This could not possibly be due to respiratory breakdown of TSS and TA components since this process was apparently retarded by the low temperature and high RH condition in the EC. If one examiners Table 3, it can be noted that the degree of weight loss and shrivelling of EC-stored fruits was much reduced compared to that of ambient fruits. These data suggest that the EC fruits contained more water than the ambient ones and that the TSS and TA decrease in EC fruits was not due to chemical breakdown but rather to dilution of the chemical constituents. Supportive to this possibility is the results on the overall flavor which did not change with the decrease in TSS and TA contents (Table 2). The EC and ambient tomatoes, mangoes and bananas had comparable flavor. In rambutan and sweet pepper, EC storage even improved flavor due to increased juiciness.

Shelf Life

The EC increase the shelf life of tomato, sweet pepper, pechay and rambutan by about twice as long as that at ambient or longer (Table 3). Mangoes also lasted in the EC for longer periods of about 2 days more than that at ambient. Shelf life of EC- and ambient-stored bananas did not differ significantly.

Table 2. Ripening characteristics of EC- and ambient- stored vegetables and fruits.

Commodity Parameters	EC	Embient
Tomato		
Ripening period, days	10.8a	8.2b
TSS, °B	5.0B	5.8a
TA, % citrate	0.22b	0.36a
Overall flavor	7.4	7.1
Sweet pepper		
Ripening period, days	16.1a	6.8b
Red-ripe fruits, % of total	97a	45b
TSS, °B	4.6b	6.1a
TA, % citrate	0.43b	0.59a
Overall flavor	6.8	4.8
Mango		
Ripening period, days	10.5a	8.9b
TSS, °B	19.7b	23.7a
TA, % citrate	0.17	0.18
Overall flavor	8.4	8.1
Banana		
Ripening period, days	9.0	8.6
Peel color quality	bright yellow	pale yellow
TSS, °B	11.7	11.9
TA, % citrate	0.40	0.35
Overall flavor	8.2	8.4
Rambutan		
TSS, °B	8.4	8.6
TA, % citrate	0.48	0.54
Overall flavor	6.9a	4.1b

Mean separation within rows by LSD, 5%.

Quality maintenance and shelf life extension by EC storage were due largely to the marked reductions in weight loss and degree of fruit shrivelling or leaf wilting (Table 3). These are expected responses to EC conditions (Table 1). However, disease infection increased at the later part of the storage period and accounted mainly for the quality deterioration of EC-stored tomato, pepper, pechay and mango (Table 3). Prestorage NaOC1 wash significantly minimized disease incidence by delaying symptom manifestation, reducing the number of disease-affected produce, and/or decreasing the severity of infection (Figure 3). A concentration of 0.5% NaOC1 was sufficient for tomatoes and peppers while for pechay and mangoes, 1% NaOC l, but this treatment did not extend shelf life further since the other causes of quality deterioration were not affected.

Table 2. Storage characteristics of EC- and ambient-stored vegetables and fruits.

Commodity Parameters	EC	Embient
Tomato		
Shelf life, days	26.1a	13.b
Weight loss, %	15.8b	27.2a
Degree of shrivelling	1.5b	
3.4a		
Diseased fruits, % of total	62.7a	14.3b
Overripe fruits, % of total	37.3	36.7
Sweet pepper		
Shelf life, days	22.1a	8.1b
Weight loss, %	12.0b	38.9a
Degree of shrivelling	1.2b	3.7a
Diseased fruits, % of total	69.7a	4.0b
Overripe fruits, % of total	31.3a	0.0b
Pechay		
Shelf life, days	5.1a	2.3b
Weight loss, %	14.0b	37.5a
Degree of wilting	1.0b	3.9a
Degree of yellowing	4.6a	1.6b
Chlorophyll loss, %	63.0a	5.3b
Degree of decay	3.3a	1.0b
Mango		
Shelf life, days	11.5	10.3
Weight loss, %	13.7b	20.5a
Degree of shrivelling	1.6b	3.0a
Discased fruits, % of total	60.4	53.3
Disease severity	2.9a	1.8b
Banana		
Shelf life, days	11.5	10.3
Weight loss, %	9.5	12.0
Degree of shrivelling	1.5b	2.7a
Overripe fruits, % of total	100	100
Rambutan		
Shelf life, days	5.8a	3.2b
Weight loss, %	9.7b	19.0a
Degree of browning	5.0	5.7

Mean separation within rows by LSD, 5%.

In rambutan, browning of spinterns was the primary cause of quality deterioration which was inhibited by EC (Table 3 and Figure 4). In another experiment, ascorbic acid as an antioxidant was tried but did not influence browning symptom

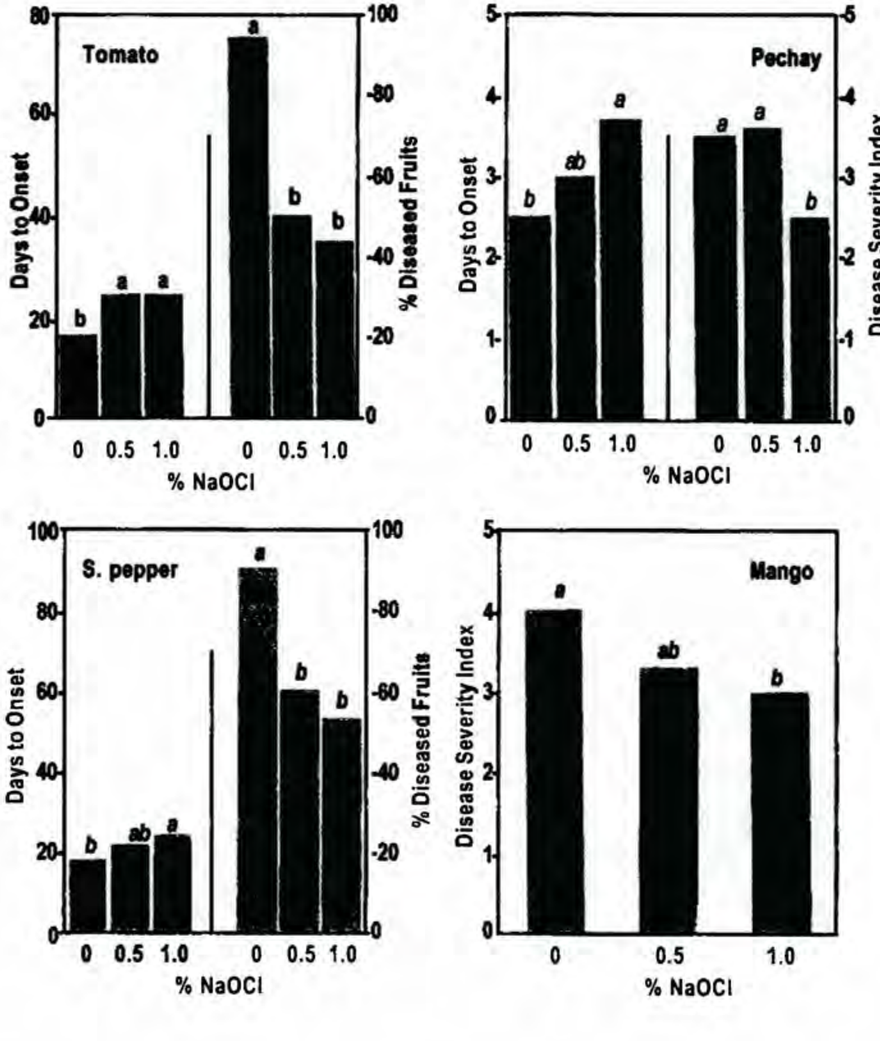

Figure 3. Disease incidence during EC storage of NaOCl-treated and untreated vegetables and fruits.

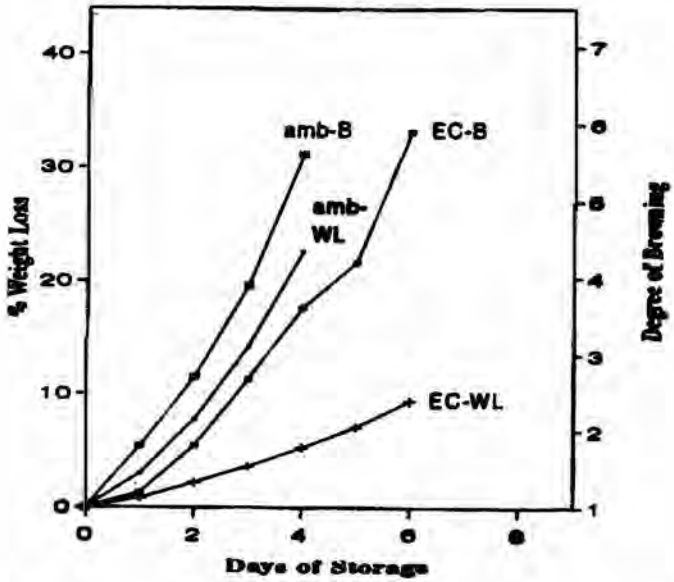

Figure 4. Weight loss and degree of browning of rambutan fruits during EC and ambient storage.

development (results not shown). From this result and that presented in Figure 4, it can be deduced that pericarp browning was primarily due to water loss. In bananas, overripening caused the fruits to deteriorate. As presented earlier in Table 2, banana ripening proceeds at comparable rates at ambient and EC condition and as a result, the fruits turned overripe and reached the end of their shelf life at comparable periods. Beneficial effects of EC storage included only reduced weight loss and shrivelling in addition to improved peel color of ripe fruits.

CONCLUSION

Storage in the simple box-type EC was very effective in prolonging the postharvest life of tomatoes, sweet peppers, pechay, mangoes and rambutans. Two major limitations were disease development and unretarded ripening. Disease incidence can be minimized by NaOCl washing while fruit ripening can be slowed down by treatment with ethanol. In bananas, the EC and ethanol treatment did not retard ripening and as a consequence, shelf life was not prolonged. Treatments that can inhibit banana ripening need to be developed to extend fruit shelf life during EC storage. The combined application of disease and ripening control measures should (also be looked into as a strategy to further extend shelf life of EC-stored produce. More importantly, larger scale trials need to be done to establish the economics of the process and the commercial viability of the technique.

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