# The Postharvest Physiology and Biochemistry of the 'Carabao' Mango

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ABSTRACT

*Although the 'Carabao' mango is known for its exquisite flavor, its potential markets are limited by its highly perishable nature. Some postharvest technologies which have been successfully used to extend postharvest life of other tropical fruits were found to induce physiological disorders in this mango cultivar. These technologies include modified atmosphere and low-temperature storage. Moreover, the 'Carabao' mango was found to be susceptible to hyperthermal injury when subjected to the vapor heat treatment, a method of disinfestation which is currently required by the Japanese market.*

*In an effort to understand the postharvest behavior of the 'Carabao' mango, we conducted several physiological and biochemical studies aimed at providing information which can be used for formulating recommendations for handling and storage.*

## INTRODUCTION

The 'Carabao' mango known as 'Manila Super' mango in world trade, is the third most important fresh fruit export of the Philippines. Many of its potential markets remained untapped primarily due to its high perishability. The Philippine draft standard (BPS, 1986) for the 'Carabao' mango describes it as having a "very delicate aromatic flavor" when ripe. This subtle flavor, which depends partly on the acid-sugar balance, is invariably affected when the harvested fruit is subjected to adverse environmental conditions during handling. The Postharvest Horticulture Training and Research Center which specializes in the postharvest biology and technology of perishable crops, has conducted several studies to understand the basis for the perishability and sensitivity to several environmental factors of this important horticultural commodity.

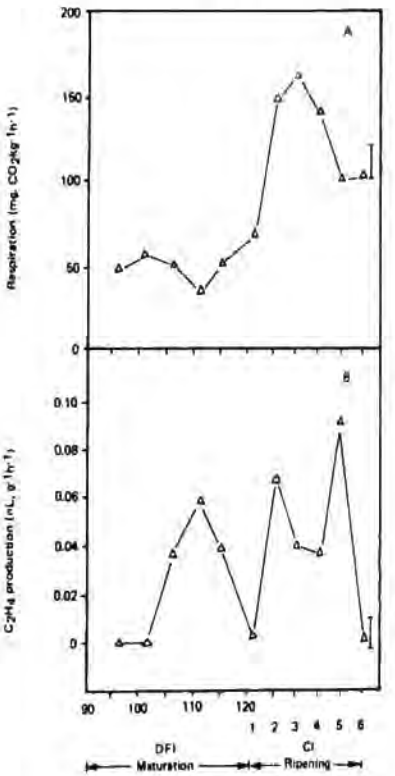
## THE PROBLEM OF PERISHABILITY

The 'Carabao' mango is a climacteric fruit, i.e. it is capable of autocatalytic ethylene production and exhibits a characteristic respiratory peak. The approach to delaying ripening in these fruits has been to: (1) inhibit ethylene production or action or (2) inhibit the changes triggered by this ripening hormone.

The shipment of 'Cavendish' bananas to the Middle East illustrates the first approach. This involves the use of modified atmosphere (MA) storage in sealed polyethylene bags which results in a depletion of $O_2$ and an accumulation of $CO_2$ around the fruit (Kader, 1986). If no ripening has been initiated prior to MA storage, the fruit remains firm and green until the bag is opened and/or ethylene is introduced.

This technology has been tried on 'Carabao' mangoes shipped from Manila to Tokyo in the late 70s. Unfortunately, this fruit did not respond favorably to MA packaging (Mendoza, personal communication), and exhibited progressive softening, albeit an inhibited peel color formation.

One of the subjective indices used to determine whether mangoes are sufficiently mature to harvest is the yellowing of the pulp. Since stimulation of carotenoid biosynthesis is indicated, this led us to hypothesize that ethylene production in the 'Carabao' mango is initiated prior to full maturation. Our results revealed (Cua and Lizada, 1989) that, indeed, ethylene production in the harvested fruit was first detected about 2 weeks prior to harvest maturity (Fig. 1a). It is interesting to note that this ethylene production, which subsequently declines to near zero at full maturation, is not accompanied by the usual marked stimulation of respiration (Fig. 1b). However, it is accompanied by a marked increase in yellow color formation, specifically in the inner mesocarp (Fig. 2a). In this tissue yellowing was also associated with a progressive softening (Fig. 2b).




on (A) and ethylene production (B) in the 'Carabao' during maturation and ripening. Each data point its the mean obtained from ten fruits. Vertical bars nts least significant difference (5%)

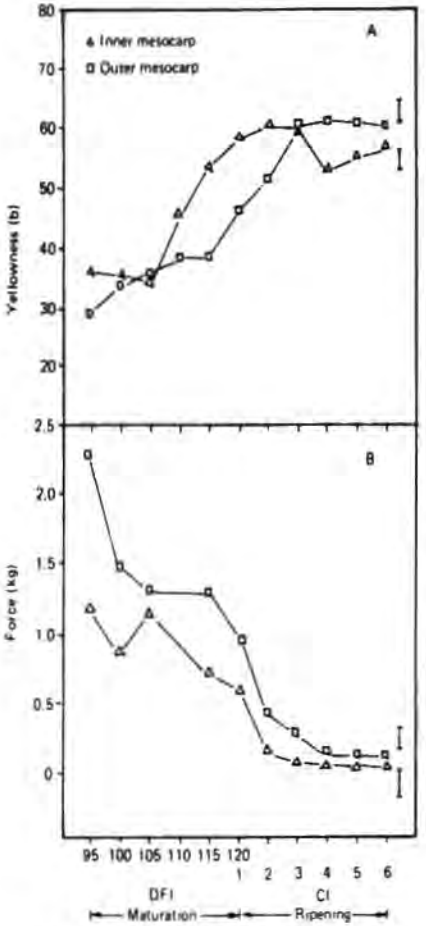
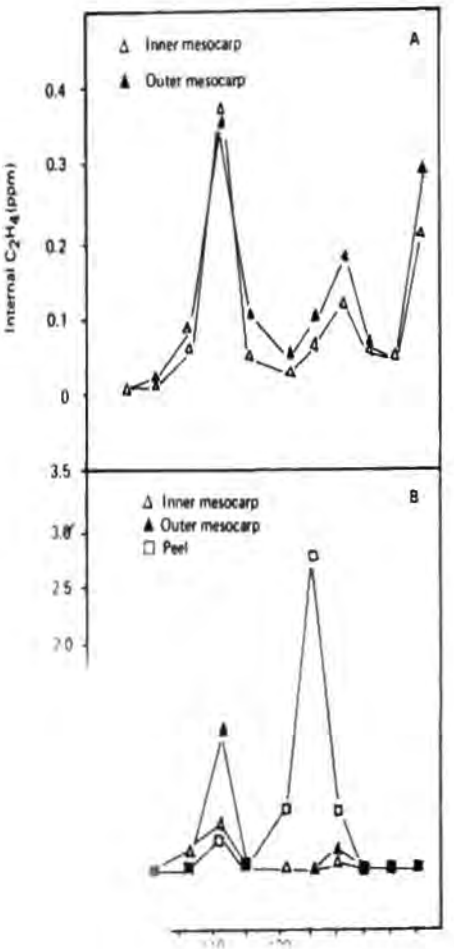
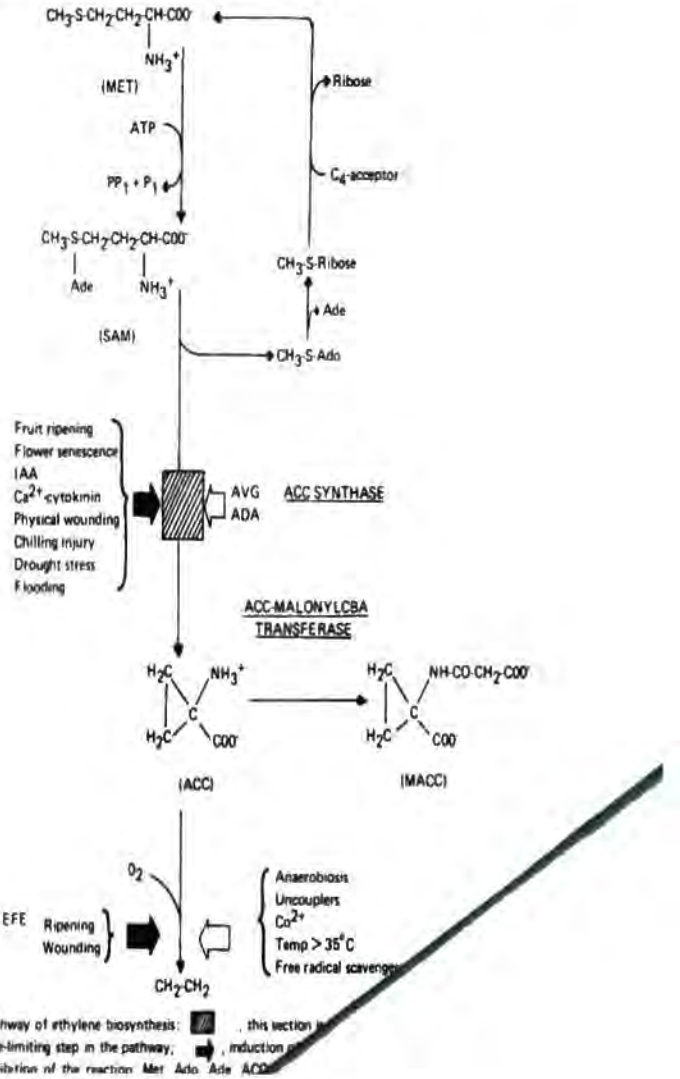



Fig. 2. Changes in the yellow color (A) and pulp rupture force (B) of the mesocarp of the 'Carabao' mango during maturation and ripening. Each data point represents the mean obtained from three fruits. Vertical bars represent least significant difference (5%)


Δ Inner mesocarp
▲ Outer mesocarp
A
Internal $C_2H_4$ (ppm)
0.4
0.3
0.2
0.1
0
3.5
3.0
2.5
2.0
Δ Inner mesocarp
▲ Outer mesocarp
□ Peel
B

120 DFI. The presence of ACC prior to the onset of ethylene production is consistent with the observation that ACC synthase was present throughout maturation. Cua (1989) reported an average activity of 0.03 nmol/g/h in the mesocarp from 95 DFI to full maturity, except at 110 DFI when it rose to ca. 0.1 nmol/g/h. Despite the absence of ethylene production at 95 DFI (Fig. 3), all tissues had measurable EFE activity as well as ACC at this maturity (Fig. 5-7b). This might be due to compartmentation which has been postulated in other studies (Yip et al., 1988; Guy and Kende, 1984).




Pathway of ethylene biosynthesis: , this section in rate-limiting step in the pathway; , induction of inhibition of the reaction. Met, Ado, Ade, ACC

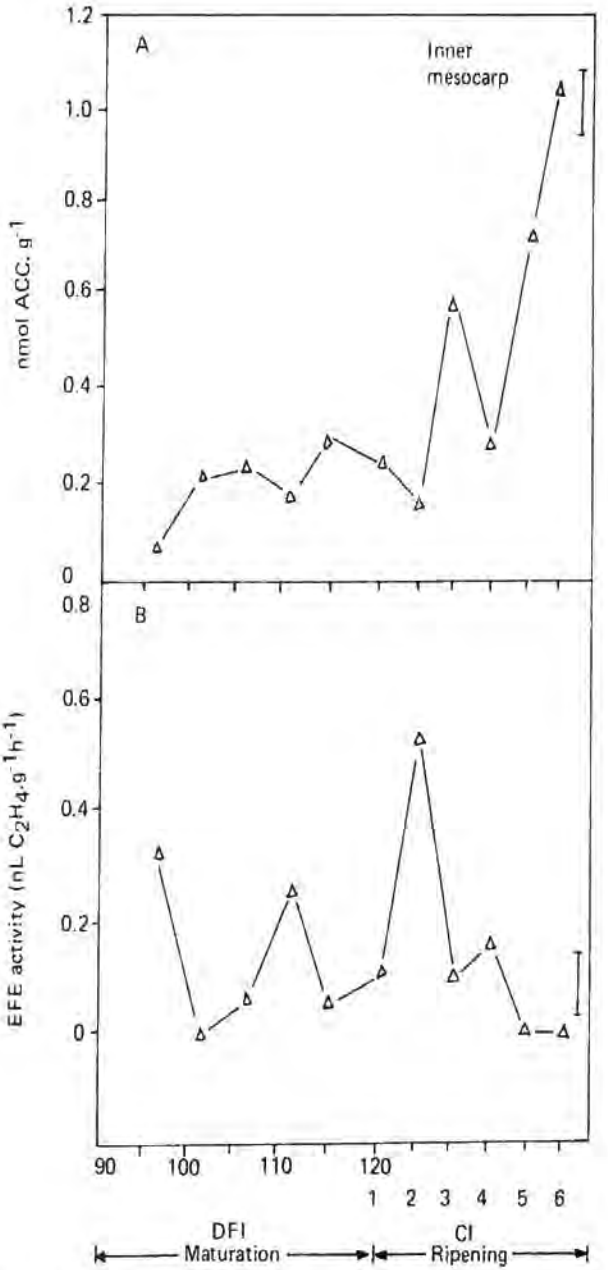



Fig. 5. ACC (A) and the EFE (B) activity in the inner mesocarp of the 'Carabao' mango during maturation and ripening. Each data point represents the mean obtained from three fruits. Vertical bars represent least significant difference (5%).

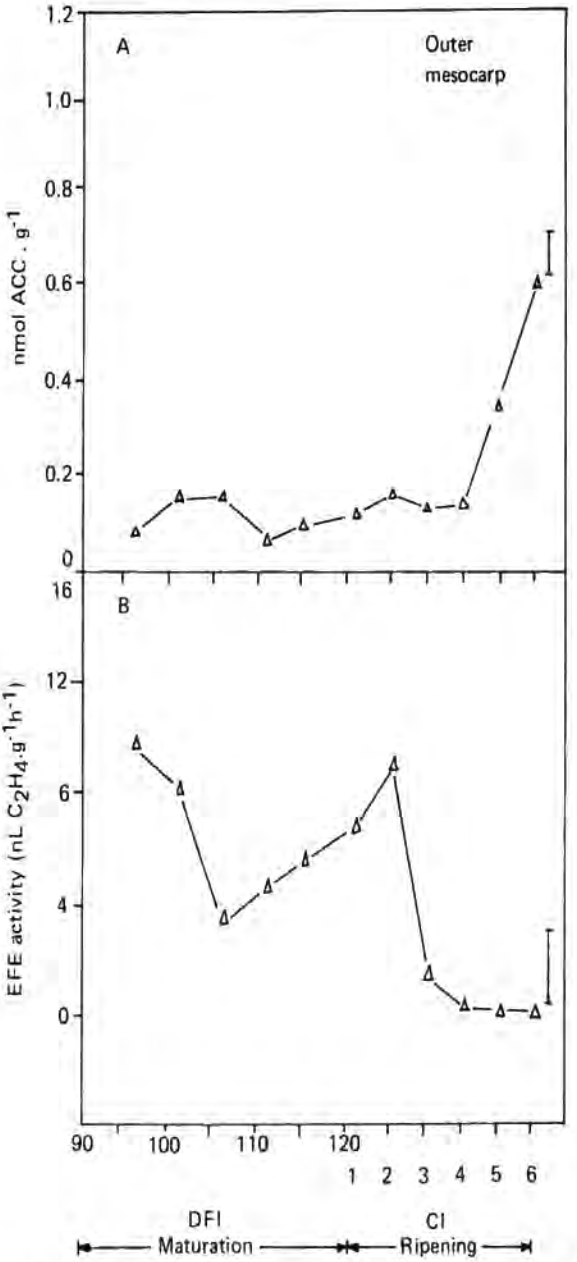



Fig. 6. ACC (A) and the EFE (B) activity in the outer mesocarp of the 'Carabao' mango during maturation and ripening. Each data point represents the mean obtained from three fruits. Vertical bars represent least significant difference (5%).

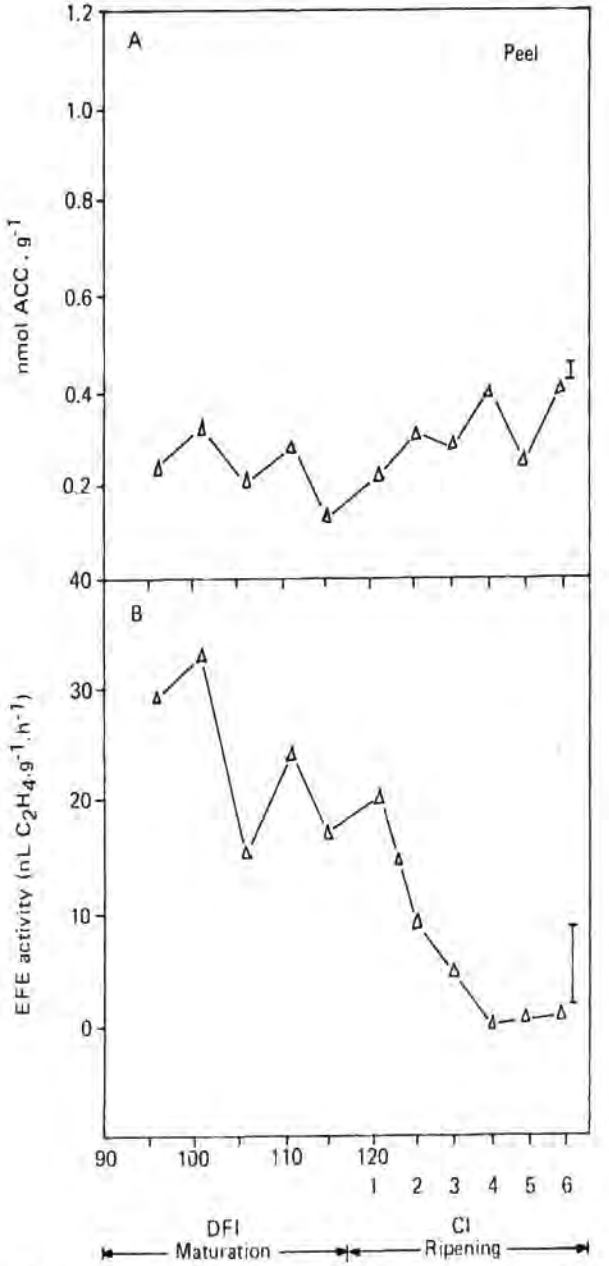



Fig. 7. ACC (A) and the EFE (B) activity in the peel of the 'Carabao' mango during maturation and ripening. Each data point represents the mean obtained from three fruits. Vertical bars represent least significant difference (5%).

Table 1. Effect of MA storage duration on mangoes (PCI 4)[a].

| DAYS IN PEB | FLESH COLOR | INTERNAL BREAKDOWN (SEVERITY) | TSS (°BRIX) | TA (%MALATE) |
|---|---|---|---|---|
| 0 | 5.5 a | 0 a | 18.00 a | 4.68 a |
| 1 | 5.5 a | 0 a | 16.35 a | 0.38 ab |
| 2 | 5.0 b | 1.0 a | 16.20 a | 0.38 ab |
| 3 | 4.5 c | 1.3 c | 15.30 ab | 0.62 b |
| 4 | 4.3 cd | 2.8 d | 10.35 cd | 1.00 c |
| 5 | 4.2 d | 2.9 d | 12.94 cd | 0.94 c |

[a]Mean separation within columns by DMRT, 5%; index for flesh color: 1 = white, 2 = faint yellow, 3 = dull yellow, 4 = bright yellow, 5 = orange yellow, 6 = yellow orange; index for internal breakdown: 0 = none, 1 = less than 25% of cut surface affected, 2 = 25-50% of cut surface affected, 3 = greater 50% of cut surface affected. All determinations were done on three replicates consisting of three fruits each, except for the evaluation of fermented odor which was done on three replicates consisting of five fruits each.

Table 2. Starch and sugar contents in mesocarp of 'Carabao' mango[a]

| FRUIT AND TISSUE TYPE | STARCH (%) | TOTAL SUGARS (%) |
|---|---|---|
| Affected fruits | | |
| Spongy | 6.50 a | 4.8 a |
| Healthy | 0.68 c | 7.5 a |
| Normal fruits | | |
| CI4 | 3.92 b | 12.6 b |
| CI6 | 0.51 c | 23.1 c |

[a]Sugar and starch were determined colorimetrically with phenol reagent. CI4 and CI6 represent the half-yellow and the full-yellow stages, respectively. Mean separation within columns by DMRT, 5%.

In all of our studies related to low $O_2$ exposure, the the 'Carabao' mango recovers if the duration is limited to 2 days even at non-refrigerated temperatures. This has led us to believe that under carefully regulated conditions, controlled atmosphere storage (CA) might effectively retard ripening in this cultivar. This technology is currently being evaluated on Australian and Thai mangoes.

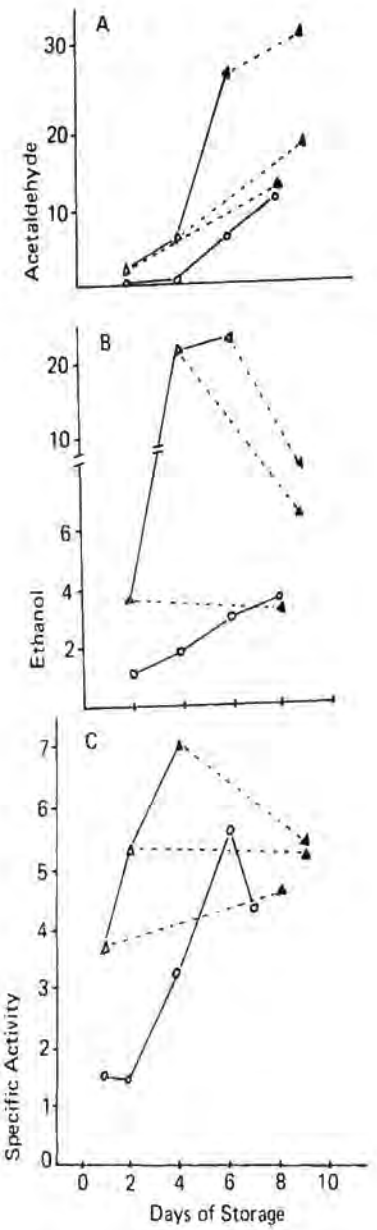



Fig. 8. Acetaldehyde (A), ethanol (B) and alcohol dehydrogenase (C) levels in control fruits (O), fruits subjected to low $O_2$ ( ) and those ripened in air following low $O_2$ treatment ( ). Each value represents the mean obtained from three fruits.

## RESPONSE TO TEMPERATURE EXTREMES

### Hyperthermal Injury

Physical treatments which do not leave residues are increasingly utilized in the postharvest handling of food crops. Thus, for the mango heat treatments are being used for both disease control and insect disinfestation.

If properly applied, a hot water treatment (HWT) at 52-55°C for 10 min effectively controls latent diseases, i.e. anthracnose and stem end rot in the 'Carabao' mango (Lizada *et al.*, 1986; Quimio and Quimio, 1974). However, when the temperature goes up much higher than this range, superficial but unsightly lesions on the peel result. When immersed for 10 min. in water at 50°C, for example, fruits exhibited localized pitting on the peel and discoloration particularly in the vascular bundles on the surface of the fruit (Rimando, 1987).

As with most effects of temperature extremes, a time-temperature interaction is evident in hyperthermal injury. This is the case wih the response of the 'Carabao' mango to vapor heat treatment (VHT), which is currently required by Japanese quarantine for mangoes exported from the Philippines. The treatment results in IB without any evident damage on the peel. Our studies revealed that VHT, which consists in heating the pulp to 46°C and holding it at that temperature for 10 min., elicits an increase in respiration (Table 3; Esguerra and Lizada, 1990), resulting in a decline in $O_2$ to as low as 8% and an increase in $CO_2$ (Cua and Lizada, 1990). The longer the fruits are maintained at an elevated temperature, the greater the severity and incidence of IB (Table 4; Esguerra *et al.*, 1989). The ACC levels decrease, indicating an alteration in the ethylene biosynthetic pathway (Cua and Lizada, 1990).

**Table 3. Effect of VHT on respiration rate in 'Carabao' mangoes*.**

| SOURCE | PCI | RESPIRATION RATE (MG CO2/KG/H) | |
|---|---|---|---|
| | | Before VHT | After VHT |
| Cebu | 1 | 30.88 b | 77.74 a |
| | 2 | 70.07 a | 86.90 a |
| Mati | 2 | 37.50 b | 71.68 a |

* Separation of means obtained before and after treatment by DMRT, 5%. Each mean was obtained from two fruits each.

Table 4. Incidence and severity of IB in fruits withdrawn at different times during VHT*.

| TIME WITHDRAWN (Min) | % DAMAGED FRUITS | | | % SOUND FRUITS |
|---|---|---|---|---|
| | Slight | Moderate | Severe | |
| Approach period 90 min. | 15.8 | 1.8 | 1.8 | 80.7 |
| Holding time 140 min. | 50 | 25.0 | 7.1 | 17.9 |
| After cooling shower 190 min. | 52.9 | 3.0 | 0.6 | 43.5 |

*Fruits were obtained from Bulacan and treated in a commercial VHT unit

Immature fruits are more susceptible to VHT-induced hyperthermal injury (Fig. 9; Esguerra and Lizada, 1990) as indicated by the difference in response between fruits floating and those sinking in 1% salt solution.

Subsequent studies have shown that increasing $O_2$ levels during VHT decreases the incidence and severity of IB (Reyes *et al.*, unpublished). Cooling the fruits immediately after treatment also ameliorates injury (Esguerra *et al.*, 1989).

A very interesting observation (unpublished) that we have made in an effort to minimize VHT-induced injury is that HWT, which is routinely done for disease control, effects an increase in tolerance to high temperatures (Brena *et al.*, unpublished). We are currently investigating the physiological basis for this. Specifically, we are interested in heat shock proteins which are induced at a temperature range of 36-45°C (Mansfield and Key, 1987). The activation of the genes coding for these proteins is accompanied by a repression of normal genes (Tuanguay, 1983).

## Response to Low Temperature

Storage in low temperature presents a potential technology for retarding ripening in the 'Carabao' mango. Being a tropical fruit, however, it is susceptible to chilling injury (CI), which results in deterioration of visual quality and, in severe cases, induces pulp breakdown. CI in the 'Carabao' mango can be observed in fruits stored at 10°C or lower (Nuevo

andLizada, 1986), and is characterized by external symptoms which are identical to those induced by HWT at 59°C.

As with hyperthermal injury, CI is affected by maturity and HWT for disease control (Fig. 10, Agravante *et al.*, unpublished). Immature fruits show a greater susceptibility to chilling temperatures than mature fruits. The response of the 'Carabao' mango to temperatures of 10°C or lower varies as can be seen in Fig. 11. To understand this variability in response will require a consideration of preharvest factors. However, based on experience and documented studies, no CI has been observed at 13.5°C.

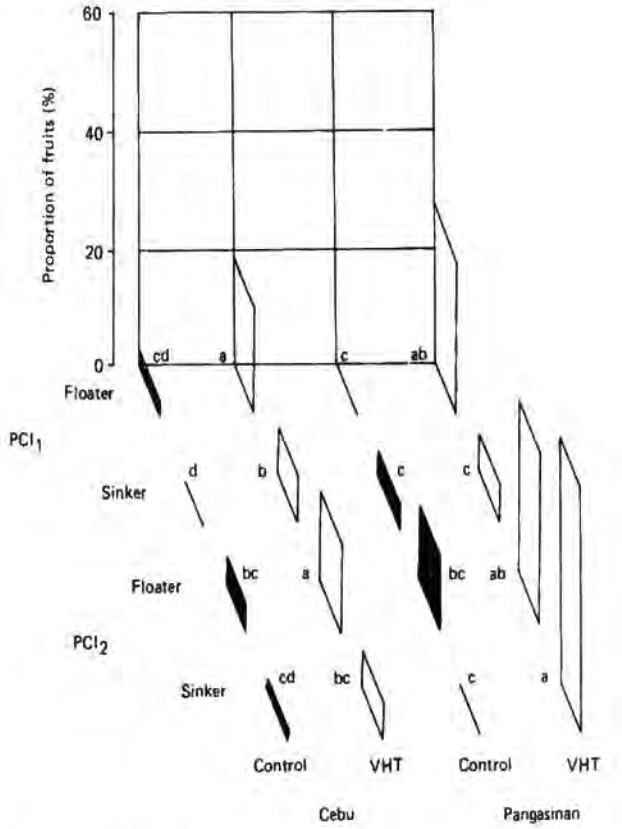



Fig. 9. **Internal breakdown in fruits from two sources subjected to VHT at two maturities and initial PCI. ``Sinkers'' represent mature fruits which sink in 1% salt solution; ``floaters'' immature fruits which float. Each value represents the mean of 37 and 15 fruits for Cebu and Pangasinan fruits, respectively. Mean separation for each location by DMRT, 5%.**

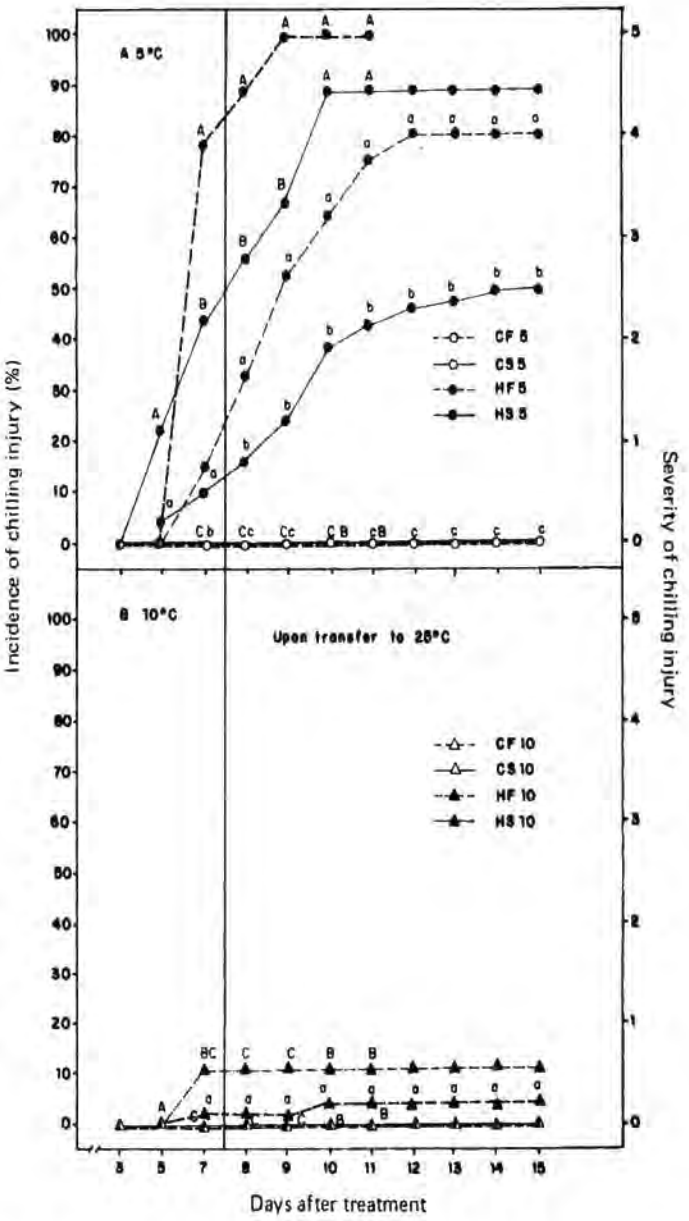



Fig. 10. Chilling injury in fruits stored at 5°C or 10°C. Means separated by upper and lower case letters represent values for incidence and severity, respectively, each taken from three replicates consisting of three fruits each. Separation for each temperature and duration by DMRT, 5%.

## OTHER RESPONSES

Other treatments such as $\gamma$ – irradiation and partial covering of fruits with open plastic bags have resulted in subtle changes in the flavor of the 'Carabao' mango, e.g. loss in intensity of pulp color and flavor. In many of these treatments an increase in acidity is observed. Biochemical studies should provide information on the underlying mechanisms behind these responses. At the PHTRC we continue to conduct these studies to gain insights not only into the etiology of some disorders, but into possible approaches in extending the postharvest life of this commodity. It is our hope that these studies will continue to contribute to the full development of the 'Carabao' mango as an export crop.

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