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MATURATION OF MALAYSIAN FRUITS. II. STORAGE CONDITIONS AND RIPENING OF BANANA (*Musa sapientum* L. var "Pisang Emas")*

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RINGKASAN

Perubahan-perubahan fisiologikal ke atas Pisang Emas telah diukur semasa ianya dalam proses sedang masak (ripening) dan dalam penyimpanan. Buah-buah pisang telah diuji dalam beberapa suhu dan keadaan penyimpanan yang berbedza. Kadar pengeluaran carbon dioxide and ethylene telah diukur. Telah didapati bahawa suhu lebih kurang 20°C adalah yang paling sesuai untuk penyimpanan dan suhu kurang dari 11°C memberikan kesan yang buruk kepada buah-buah pisang. Keadaan udara yang lembab dan pembuangan carbon dioxide mempercepatkan kemasakan buah, manakala keadaan udara yang kurang lembab memberi kesan buruk ke atas mutu buah. Masa penyimpanan akan bertambah dengan pembuangan ethylene yang dikeluarkan. Keadaan penyimpanan yang disyurkan adalah seperti berikut: suhu lebih kurang 20°C ethylene hendaklah dibuang dan kandungan kelembapan udara lebih kurang 85% semasa di dalam simpanan.

INTRODUCTION

According to a study carried out by the Federal Agricultural and Marketing Authority of Malaysia (F.A.M.A. 1968), the potential of the bananas as an export commodity and a money earner is very great. Moreover, compared to other local and imported fruits, it is one of the cheapest and most popular. Eleven vitamins have been reported present in the fruit, amongst which are vitamins A, B_1, B_2 and C (SIMMONDS, 1966). The calorific value is surprisingly low, about $4J.g^{-1}$ (SIMMONDS, 1966) and does not therefore pose excessive dietary problems. Coupled with their year round availability, they become one of the most desirable of Malaysian fruits. In this communication, factors affecting the storage and ripening of a common local variety, Pisang Emas, are reported as part of a continuing series of investigations aimed at elucidating optimal storage conditions to preserve fruits both for use in this country and for export.

EXPERIMENTAL

Fruit – a local variety of *Musa sapientum* Pisang Emas (Family: Musaceae; Order: Zingerberales) (HULME, 1970), obtained from the Malaysian Agricultural Research and Development Institute (M.A.R.D.I.), Serdang, Selangor was used throughout. Fruits were picked green, sixty days after anthesis. In these studies, two 'fingers' from the second 'hand' were enclosed in a jar. Vaseline was applied to the cut ends to prevent dehydration and fungal infection. Results are means of at least three replicates.

(a) Effect of Temperature

Two bananas were incubated in modified 'Fowlers Vacola' jars as described by BROUGHTON, HASHIM, SHEN and TAN (1977). Temperatures used were 6°C, 11°C, 20°C and 28°C (± 1°C). Carbon dioxide and ethylene were measured daily followed by a three hour period of aeration with carbon dioxide free air (see BROUGHTON *et al.*, 1977).

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(b) Effect of Humidity

High humidities were achieved with wet filter papers, low humidities with self indicating silica gel. The silica gel was replaced periodically and the fruits exposed to a stream of wet or dry air as the case may be for three hours per day after measurement of carbon dioxide and ehtylene.

(c) Effect of Carbon Dioxide Removal

Carbon dioxide was removed from the chamber with self indicating soda lime pellets. After incubation, ethylene was measured and the fruits aerated with carbon dioxide free air for three hours.

(d) Effect of Ethylene Removal

Ethylene was removed by placing potassium permanganate inside the chamber. In this case only carbon dioxide was measured as described below.

(e) Determination of Carbon Dioxide and Ethylene

These were assayed by titrimetry and gas chromatography respectively as described previously (see BROUGHTON *et al.*, 1977).

(f) Determination of Reducing Sugars

Levels of reducing sugars in the fruits were measured as follows. Ten grams of pulp was homogenised with a mortar and pestle in 5 ml of 10% (w/v) trichloroacetic acid. Then, the homogenate was centrifuged at 10,000 x g for 20 min and the supernatant assayed for reducing sugars by the Somagyi – Nelson method (SOMAGYI, 1952).

RESULTS

"Pisang Emas" displayed the characteristic climacteric type and respiration *(Fig. 1)*. The carbon dioxide peak preceeded the ethylene peak at 28°C but at the other temperatures, the order was reversed *(Fig. 1 and 2)*. Both the carbon dioxide and ehtylene peaks occurred sooner and were of greater magnitude at higher temperatures. Bananas ripened fastest at 28°C, had normal colour and flavour but by the eighth day fungal wastage began to occur. On the other hand, bananas stored at 20°C ripened more slowly but had the same good quality and taste. Storage life was also prolonged. Fruits held at 6°C and 11°C showed no signs of ripening. At these temperatures the banana skin turned dark green with dark brown mottling. Accordingly, 20°C seemed to be a good temperature for storage and further attempts at extending the storage life of the fruit were carried out at this temperature.

When carbon dioxide was removed from the chamber, the ethylene peak was brought forward by about four days compared to the control fruit *(Fig. 3)*. The fruit took only six days to ripen compared to the controls which took nine days. When ethylene was removed instead, the carbon dioxide peak occurred at about the same time as in the control fruit *(Fig. 4)* but the fruits took a very much longer time to ripen (more than twenty days).

Banana respiration in both the high and low relative humidity treatments showed a similar pattern *(Fig. 5)*. In the high relative humidity treatment, the fruits remained turgid, smooth, ripened evenly, developed a nice yellow colour and were of good flavour. At low relative humidities however, the fruits became shrunken and wrinkled; the peel tended to turn black and the pulp was soft. Ripening of the fruits was faster at the higher relative humidity.

Levels of reducing sugars seemed to increase as the fruits ripened but later decreased during the overripe phase *(Fig. 6)*.

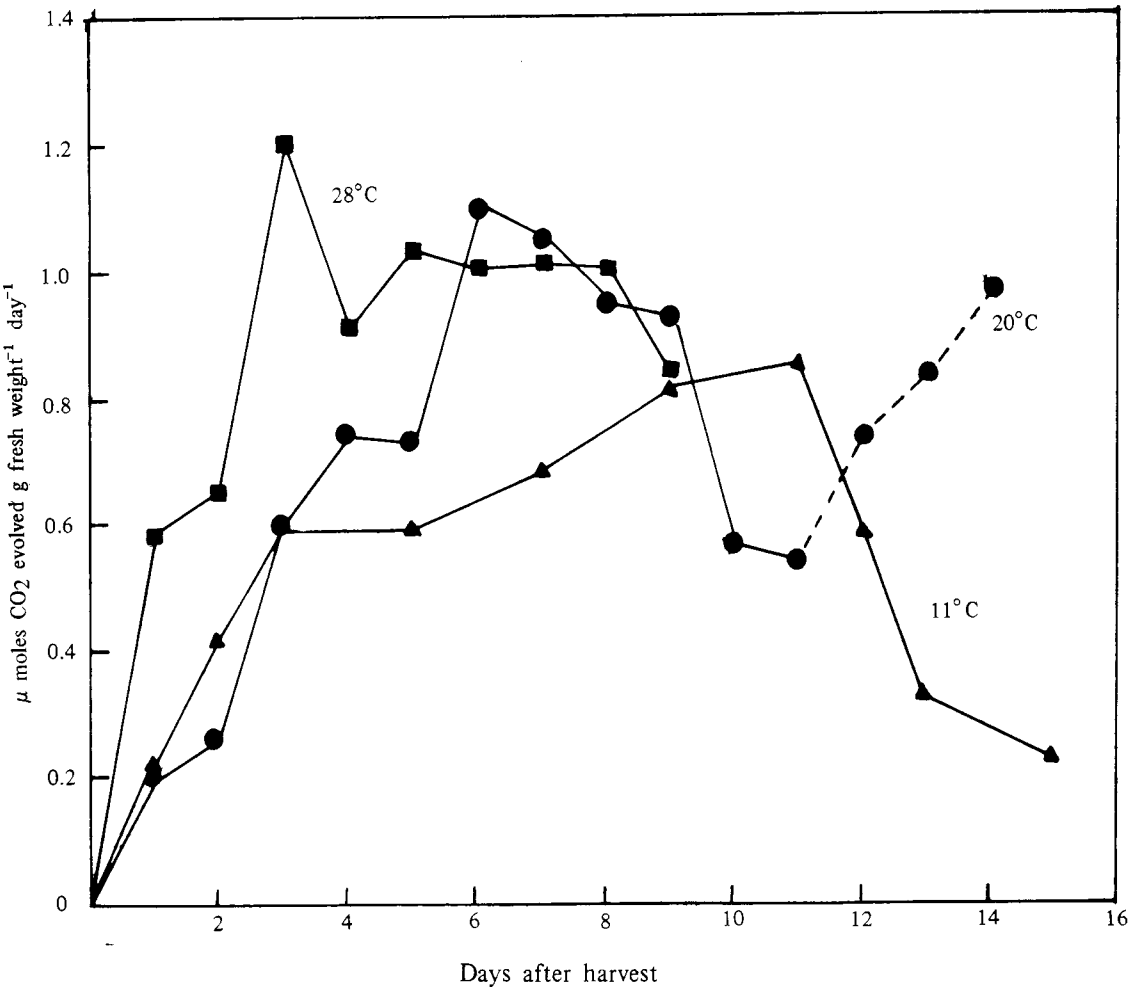

Figure 1. Rate of carbon dioxide evolution by Pisang Emas stored at different temperatures. Fruits were placed in gas-tight containers (Fowler's No. 31, Fowlers – Vacola, Hawthorn, Victoria, Australia) and stored at 11°C, 20°C and 28°C. Daily aeration of the fruit and determination of the amount of carbon dioxide evolved, were performed as described in the text.

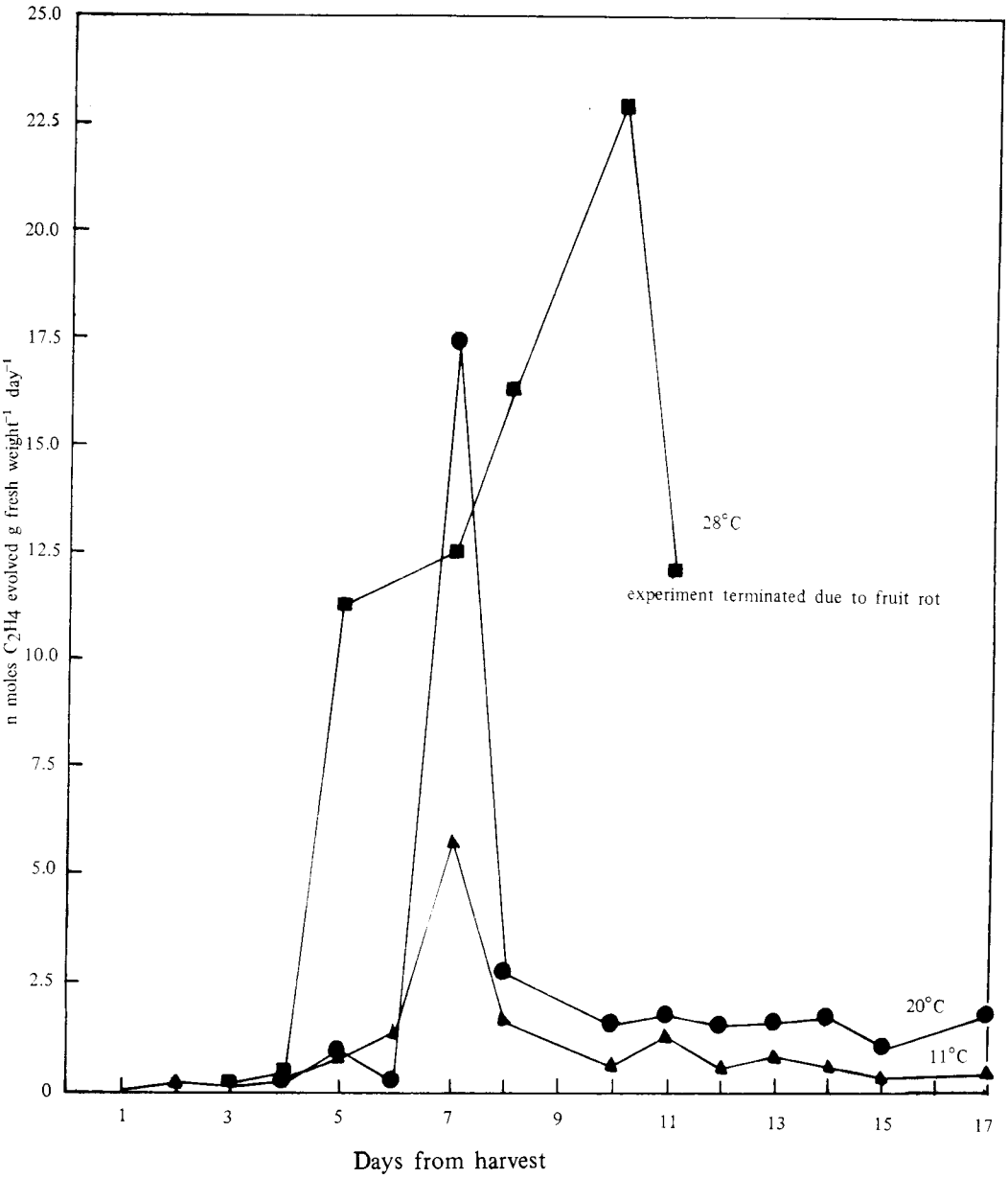

Figure 2. Rate of ethylene evolution by Pisang Emas stored at different temperatures.

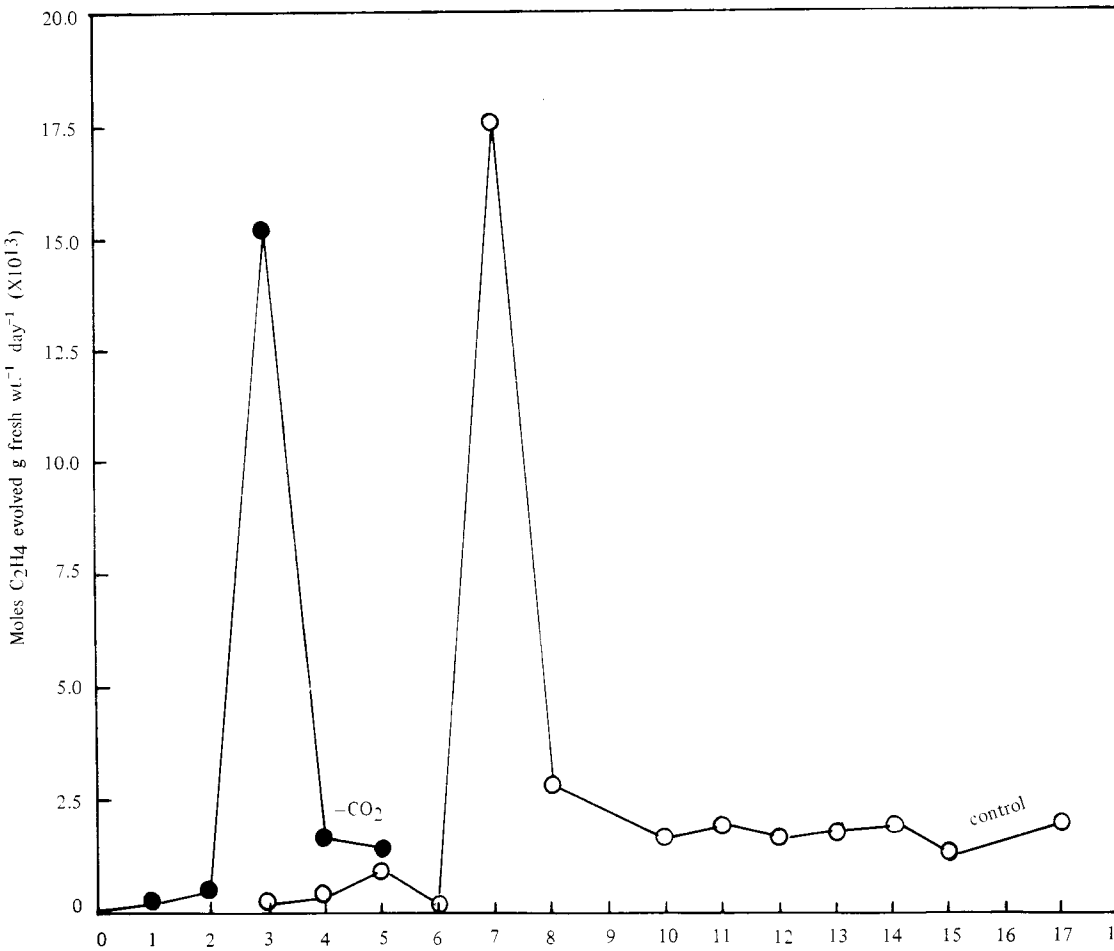

Figure 3. Effect of removal of carbon dioxide on ethylene evolution by Pisang Emas stored at 20°C. Sampling of the gaseous phase for ethylene and daily aeration of the fruit was performed as described in the text.

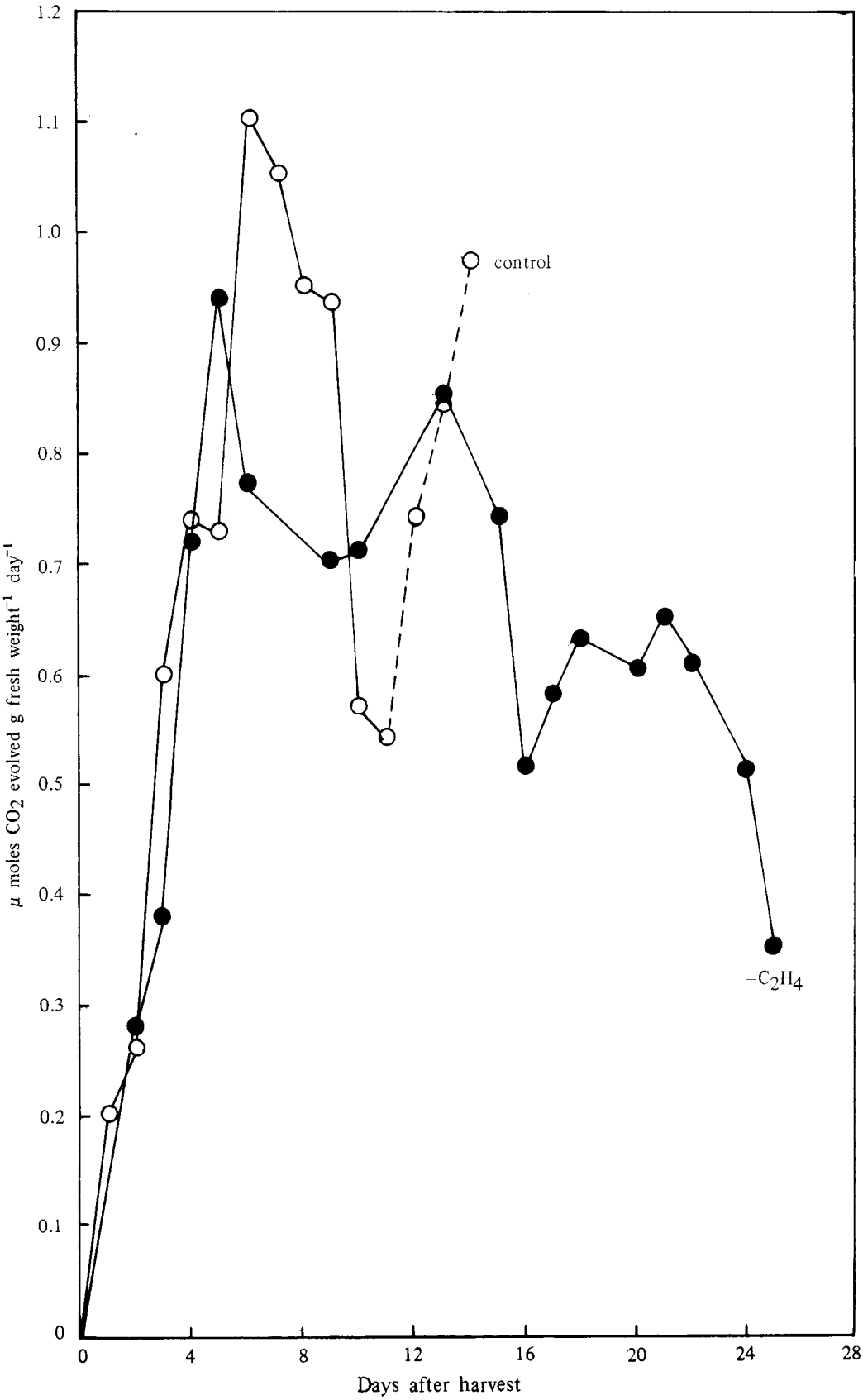

Figure 4. Effect of removal of ethylene from the respiration chamber on the rate of carbon dioxide evolution by Pisang Emas stored at 20°C. Measurement of carbon dioxide evolved and daily aeration of the fruits were performed as described in the text.

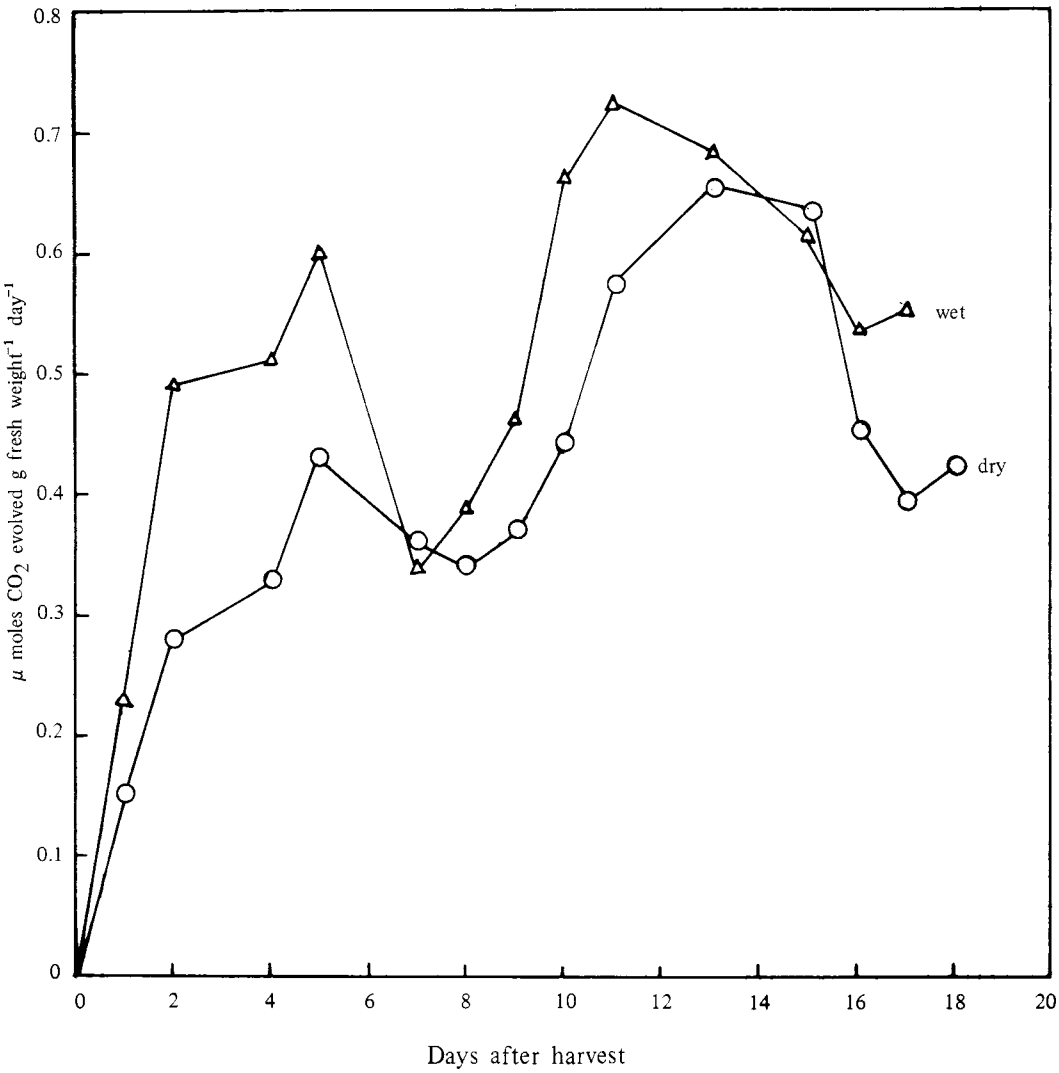

Figure 5. Effect of different humidities in the respiration chamber on the rate of carbon dioxide evolution by Pisang Emas stored at 20°C.

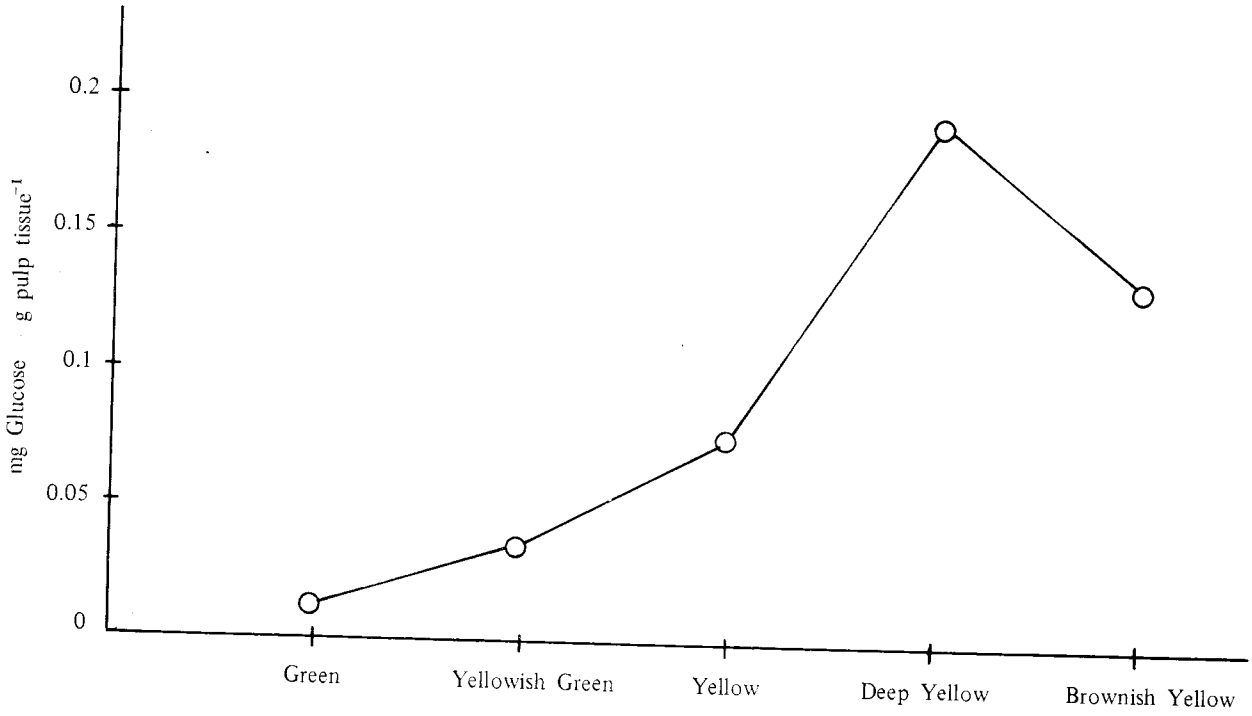

Figure 6. Changes in the reducing sugar content of ripening Pisang Emas. Fruits of different stages of ripeness were used. The technique for determining the reducing sugar content is described in the text.

DISCUSSION

"Pisang Emas" was found to ripen normally between 20°C and 28°C. At 28°C ripening was fast and the shelf life short. At 20°C ripening was gradual with a longer shelf life. At lower temperatures (6°C and 11°C), the fruits failed to ripen. GANE (1936) showed that "Gros Michel" bananas ripen normally between 13°C and 30°C. He also showed that chilling occurred at 11.6°C. WU (1976) found that the "Pisang Embun" and "Pisang Rastali", another two local varieties of banana, ripen normally between 15°C to 25°C (see BROUGHTON and WU, 1979). Thus most varieties of banana have an almost similar ripening temperature range. The rate of respiration and ethylene evolution followed actual ripening closely at all temperatures. An effect of temperature was therefore to stimulate evolution of both carbon dioxide and ethylene.

Most fruits do not ripen if the ethylene in their vicinity is completely removed. FORSYTH, EAVES and LIGHTFOOT (1969) stored apples for 189 days at 3.3°C under low ethylene levels. SCOTT, BLAKE, STRACHAN, TUGWELL and MCGLASSON (1971) found that bananas stored in polyethylene bags remained green for 8–18 days at ambient temperatures. Exogenous ethylene has been shown to accelerate ripening in other bananas (BROUGHTON and WU, 1979).

Removal of carbon dioxide hastened the ripening process without detrimental effects on the flavour of the fruits. On the other hand, when carbon dioxide was allowed to accumulate, ripening was delayed. BURG and BURG (1965) explained this by proposing that carbon dioxide competitively inhibits binding of ethylene to the receptor site thus rendering the ethylene ineffective. No trails were carried out to find the safe range of carbon dioxide levels but 5% (v/v) appears satisfactory. Many workers have shown that carbon dioxide may be injurious to fruits at certain concentration (see for example TOMKINS, 1959).

Bananas maintained at high relative humidities ripened normally while those at low relative humidities tended to shrivel and turn black, although under both sets of conditions the fruit did exhibit the respiratory climacteric. This is not always the case since HEARD and HULTIN (1969) found that a number of varieties of banana, maintained at relative humidities less than 80% did not exhibit a climacteric rise in respiration.

WARDLAW, LEONARD and BARNELL (1939) showed that the increase in reducing sugar content in bananas was due to the hydrolysis of starch. The level of reducing sugar in "Pisang Emas" increased as the fruits ripened and decreased with post ripening. Similar changes were reported for "Pisang Embun" and "Pisang Rastali" (BROUGHTON & WU 1979).

Table 1 shows clearly that the best ripening and storage temperature is 20°C as the ripening was gradual and the shelf life longer. Removal of ethylene also helps to extend the shelf life of the fruits. On the other hand removal of carbon dioxide or allowing the ethylene produced to accumulate enhanced ripening.

TABLE 1. EFFECT OF THE VARIOUS TREATMENTS ON THE CLIMACTERIC, ETHYLENE PRODUCTION, FINAL TASTE AND APPEARANCE OF PISANG EMAS

Treatments	Days to reach C_2H_4 peak	Days to reach CO_2 peak	Days to ripen	Fruit appearance and taste when ripe
Temperature:				
6°C	–	–		Fruits failed to ripen; peel turned brown
11°C	7	11	–	Fruits failed to ripen; peel turned brown
20°C	7	6	9	Uniform ripening; yellow; good taste
28°C	9	3	5	Uniform ripening; yellow; good taste but short storage life.
Humidity:				
High		10	6	Uniform ripening; yellow; good taste
Low	–	12	7	Fruits were shrivelled; peel turned black, pulp soft; taste astringent.
Removal of CO_2	3	–	6	Uniform ripening; yellow; good taste
Removal of C_2H_4	–	4	20	Uniform ripening; yellow; good taste

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SUMMARY

Physiological changes were measured during the ripening and storage of a local variety of banana – the "Pisang Emas". Fruits were subjected to different temperatures and storage atmospheres, and their rate of carbon dioxide and ethylene evolution measured. Temperatures of

about 20°C prolonged the storage life of the fruits while temperatures below 11°C were detrimental causing chilling injuries. High humidity and removal of carbon dioxide enhanced ripening while low humidity adversely affected fruit quality. Storage life was prolonged by the removal of the ethylene produced. Recommended storage conditions are: temperature of about 20°C, removal of ethylene and about 85% relative humidity in the storage atmosphere.

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