Pertanika 6(3), 44–47 (1983)

Climacteric Nature of the Carambola *(Averrhoa carambola* L.*)* Fruit.

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Key words: *Averrhoa carambola;* **fruit; respiration; carbon dioxide; ethylene; climacteric.**

RINGKASAN

Belimbing manis (Averrhoa carambola *L.) telah ditentukan sebagai jenis buah bukan "climateric". Tabiat pemingkatan karbon dioksid oleh buah-buah "climacteric" pada peringkat buah masak tidak ketara bagi buah-buah belimbing manis yang mempunyai peringkat kematangan yang berlainan. Demikian juga buah belimbing manis yang dirawat dengan ethrel tidak menunjukkan pertambahan segera karbon dioksid ataupun puncak etilean.*

SUMMARY

The carambola (Averrhoa carambola *L.) is determined to be a non-climacteric type fruit. The characteristic upsurge of carbon dioxide exhibited by climacteric fruits during the ripening process was not evident in carambola fruits of differing maturity. The ethrel treated fruit showed no sudden sharp increase in carbon-dioxide nor an ethylene peak.*

INTRODUCTION

The work of Kidd and West (1930) on the respiratory activity in apple fruit ripening led Biale (1960a) to classify fruits according to their respiration patterns. Accordingly, fruits are classified as climacteric or non-climacteric in nature. Climacteric fruits are characterized by those which show a sharp increase in respiration during the time of ripening. After reaching a climacteric peak the respiration then falls off again, terminating in senescence, physiological breakdown and/or microbial invasion of the fruit. Biale (1960b) and McGlasson (1970) demonstrated that climacteric fruits would respond to ethylene treatments, that is, the fruit would show autocatalytic production of ethylene. The respiratory pattern of non-climacteric fruits, in contrast to the climacteric types, remains rather constant without the characteristic upsurge in carbon dioxide evolution during the ripening process. They will not respond to ethylene or ethrel treatments (Pratt and Mendoza, 1980a).

The carambola *(Averrhoa carambola* L.) fruit is reported to be climacteric by Vines and Grierson (1966). On the contrary, Oslund and Davenport (1981) showed that the carambola is non-climacteric. These conflicting reports could have arisen because of the methods used to study the respiratory activity of the fruit during ripening (McGlasson, 1970; Pratt and Reid, 1974; Pratt and Mendoza, 1980). In this study the question of whether carambola is a climacteric or non-climacteric fruit was reinvestigated.

MATERIALS AND METHODS

Carambola fruits (cv. B 10) were obtained from the Research Farm, Malaysian Agriculture Research and Development Institute at Serdang. The fruits were harvested at approximately four, six and eight weeks after fruit-set. The fruits are green when unripe, turn yellow when ripe and orange when over-ripe.

The respiratory pattern of the fruits was studied by both the continuous (Claypool and Keefer 1942) and static system (Broughton *et al.,* 1977). The response of carambola to ethrel treatments (Burg and Burg, 1962; McGlasson 1970; Reid and Pratt, 1970) was also studied.

Respiration rate in the dynamic or continuous system was measured by passing a known volume of air of approximately 1 ℓ/hr/100 g of fruit

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through a low pressure manometer flowboard into a glass bottle of approximately 3.65 ℓ in volume. The inlet flow rate into the bottle was controlled by the manometer height and the size of the capillaries. The outlet air from the bottle was equilibrated with a dilute mixture of sodium bicarbonate and bromthymol blue (Claypool and Keefer, 1942). The percent transmission of the sample solution was measured in a spectrophotometer (Spectronic 20) at 617 nm (Pratt and Mendoza, 1980a). The percent CO_2 present in the solution was then obtained from a prepared standard curve, and was subsequently converted to mg. $kg.^{-1}$ hr^{-1}. Carbon dioxide determination was done daily until the colour of the fruit reached the orange (over-ripe) stage or began to rot.

In the static method a single 8-week old fruit was sealed in a 3.65 ℓ volume glass bottle with a rubber stopper carrying a closed-end rubber tube. At the end of 20 hrs. 1 ml gas samples were drawn from the bottle for CO_2 determination. The CO_2 content was determined by using a Varian Series 1420 gas chromatograph equipped with a thermal conductivity detector and a stainless steel column (150 x 0.3 cm) of 80 to 100 mesh Porapak R operated at 35°C. The bottle was flushed with humidified air for 4 hrs. and resealed each time a sample of gas was drawn. The determination of CO_2 was repeated daily for 18 days until the fruits turned orange at which stage they were considered to be over-ripe.

The response to ethrel of eight-week old carambola fruits was studied. The fruits were dipped in a 100 μ/ℓ ethrel for 10 mins. The pH of the ethrel solution was 2 which was within the limit of 4 as recommended by de-Wilde (1971). A single fruit was then placed in a 3.65 ℓ glass bottle in which a continuous supply of air was passed. The respiration rate and ethylene (C_2H_4) emanation of the fruit were measured daily until they were ripe. CO_2 was measured using a Varian Series 1420 gas chromatograph as described above. Ethylene content was measured by a varian 1440 gas chromatograph fitted with a flame ionization detector and a column (180 x 0.3 cm) packed with 100 to 120 mesh Porapak T operated at 100°C. Ethylene values are expressed as μℓ kg^{-1} hr^{-1}.

The above studies were conducted at a temperature of 20°C with four replications per treatment.

RESULTS AND DISCUSSION

The rate of respiration of four, six and eight-week old fruits studied by the dynamic method as determined by the amount of CO_2 evolved is as shown in *Figure 1.* In all cases the respiration rate increased as time progressed. No sudden sharp rise in CO_2 was detected during the period when the fruits changed from green (unripe) to orange (over-ripe) stage, except for the four-week old fruit. The marked increase in CO_2 evolved by the four-week old fruits occurred after the 13th day at which time the fruits had already begun to rot. It is suggested that decay micro-organisms observed on the fruits could be the cause for the rise in CO_2, rather than the ripening process itself.

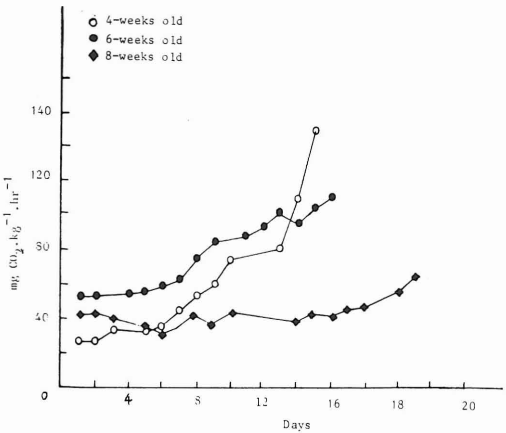

Fig. 1. Respiration rate of 4, 6, and 8-week old carambola fruits in the dynamic system.

The absence of a CO_2 peak in the respiration curve of the carambola fruit observed in this study differs from that obtained by Vines and Grierson (1966). Vines and Grierson (1966) followed the respiration pattern of the fruit which was stored at 60° and 70°F for 17 days. The respiration curves obtained were typical of climacteric type fruits such as apple or avocado. Oslund *et al.,* (1981), on the contrary, demonstrated that the respiratory rates of carambola at various stages of ripening did not markedly change over time in storage. This is similar to what was observed in this study.

The use of fruits of different maturity to ascertain their climacteric nature is important as reported by numerous workers (Biale, 1960a; Mizuno and Pratt, 1979; and Smock and Neubert, 1960). In apples it has been shown that fruits picked after the normal harvest time would have passed through the climacteric phase (Smock and Neubert, 1960). Mizuno and Pratt (1979) in their study on the respiration pattern of water melon concluded that it was not climacteric in nature. However, in a subsequent study they determined that water melon, is in fact, a climacteric fruit. The difference arose because in their early study they had used fruits which were either too immature or over-matured to show the respiration pattern characteristic of climacteric fruit. The measurement of the respiratory activity of carambola fruits in this experiment was done at different stages of maturity as indicated by the colour change from green to orange. Thus, if carambola is a climacteric fruit, the characteristic upsurge in respiration rate would have been detected during the ripening process of the fruits.

Figure 2 shows the respiratory activity of the eight-week old fruit as observed by the static method. The initial respiration rate was 35 mg $CO_2.kg^{-1}.hr^{-1}$ and fell to 15 mg $CO_2.kg^{-1}.hr^{-1}$ on the sixth day. Thereafter, the rate of respiration remained constant. The colour of the skin of the fruit had changed from green to orange when the experiment was terminated on the eighteenth day. The respiratory pattern of the carambola fruit observed in this experiment is similar to that studied by the dynamic system.

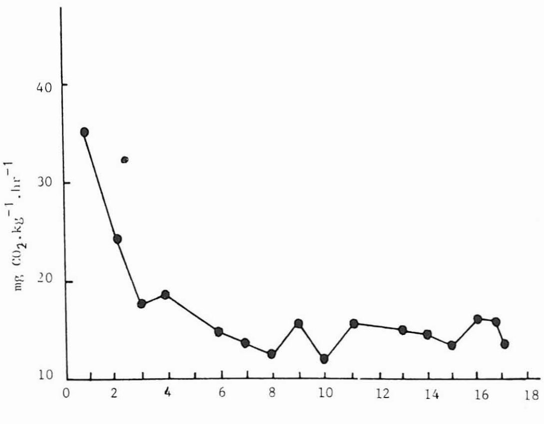

Fig. 2. Respiration rate of eight-week old carambola fruits in the static system.

The CO_2 and C_2H_4 emanations of ethrel-treated carambola fruits are illustrated in Figure 3 (A) and (B) respectively. The three-day moving average plot was used so that curves obtained for CO_2 and C_2H_4 evolved would be smooth and not jagged. Also, the plotting of the gas readings derived for a single representative fruit would not broaden the peaks if there were any. This method of using a moving average plot has been used successfully in the study on the respiration pattern of star-apple (Pratt and Mendoza, 1980a) and winged-bean (Data and Pratt, 1980).

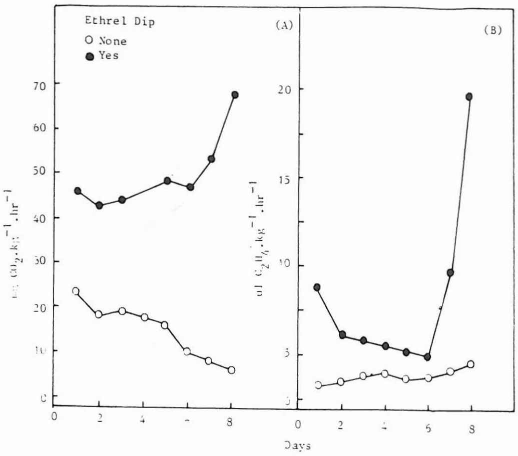

Fig. 3. Three day moving average plot of carbondioxide (A) and ethylene (B) evolution of a ethrel-treated carambola fruit.

No sharp rise in CO_2 was observed in both the non-ethrel and ethrel treated fruits. Fruits which were not dipped in ethrel solution showed a steady decline in respiratory activity. The increase in CO_2 evolution exhibited by the ethrel-treated fruits after the sixth day was due to decay of the fruits. By the eighth day the fruits were over-ripe and began to rot at which time the experiment was terminated.

Pratt and Mendoza (1980b) found that respiration measurements of fruits alone were not satisfactory to determine that the cashew apple was climacteric. They showed that the cashew apple is non-climacteric by the data on C_2H_4 emanation from C_2H_4-treated fruits which tended to be low and fairly steady until decay appeared. Similarly, in this study C_2H_4 emanation from the ethrel-treated carambola fruits was fairly constant with no drastic changes being detected until the sixth day. Thereafter, the C_2H_4 evolved increased markedly which is attributable to rotting of the fruits. The absence of C_2H_4 peaks indicated that carambola do not respond to C_2H_4 treatment as climacteric fruits do (Biale, 1960b, MgGlasson, 1970). Lakshminarayama (1973) demonstrated that mango, a climacteric fruit, when treated with C_2H_4 or ethrel produced a typical C_2H_4 peak. Such a response was not obtained with star-apple dipped in ethrel by Pratt and Mendoza (1980a) which led them to conclude that it is not a climacteric fruit.

CONCLUSION

The characteristic upsurge in CO_2 exhibited by climacteric fruits was not detected in the respiratory activity of carambola fruits of varying stages of maturity during the ripening process. The respiration rate was rather constant with no sharp increase in CO_2 at any time period prior to decay. Furthermore, the carambola fruit when treated with ethrel showed no sharp rise in CO_2 or an C_2H_4 peak during ripening. It is concluded that the carambola fruit is a non-climacteric fruit. This is in agreement with the results of Oslund and Davenport (1981), but not with those of Vines and Grierson (1966).

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(Received 8 July 1983)