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# Influence of exogenous ethylene on the ripening of banana (*Musa sapientum* cv. Mas)

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Key words: Mas banana, exogenous ethylene, colour score, climacteric pattern, chemical composition

**Abstrak**

Pisang mas yang dituai pada peringkat kematangan 7 minggu dari masa pengeluaran jantung telah didedahkan pada gas etilena yang mempunyai kepekatan sebanyak 0, 0.35, 5, 10 dan 20 μL/L dengan menggunakan sistem aliran udara terus selama 24 jam pada suhu 25°C dan kelembapan bandingan 90–95%. Selepas pengaruhan pemasakan, buah tersebut dibiarkan masak pada suhu yang sama dan kelembapan bandingan 85–90% sehingga warna kulit mencapai indeks 6. Gas etilena pada kepekatan 0.35 μL/L didapati mencukupi untuk merangsang perubahan warna kulit dan menggalakkan pewujudan puncak klimakterik pernafasan. Buah yang telah didedahkan pada gas etilena mencapai indeks warna 6 selepas 3 hari pengaruhan pemasakan manakala warna kulit buah yang didedahkan pada udara biasa masih lagi berada pada peringkat indeks 2. Perubahan warna kulit bagi buah yang telah didedah pada kepekatan sebanyak 0.35 μL/L didapati perlahan sedikit daripada perubahan pada kepekatan yang lain. Walau bagaimanapun, kepekatan gas etilena yang melebihi 5 μL/L tidak menunjukkan perbezaan dalam mempengaruhi kadar perubahan warna kulit. Kadar pembebasan gas karbon dioksida dan etilena oleh buah yang telah didedahkan pada gas etilena menunjukkan corak yang menurun selepas pengaruhan pemasakan. Kandungan jumlah pepejal larut, jumlah kandungan gula dan pH buah masak yang telah mencapai indeks 6 setelah didedah pada udara biasa atau gas etilena tidak menunjukkan perbezaan yang ketara.

**Abstract**

Mas banana of 7 weeks maturity were exposed to 0, 0.35, 5, 10 and 20 μL/L exogenous ethylene for 24 h under a continuous-flow-through system at 25 °C and 95–100% relative humidity. Following ripening induction, the fruit were allowed to ripen at 25°C and 85–90% relative humidity until the peel colour attained colour score 6. An exogenous ethylene concentration of 0.35 μL/L is enough to stimulate peel colour change and enhance the onset of respiratory climacteric peak. Exogenous ethylene-treated fruit attained colour score 6 after 3 days of induction while control fruit were still at colour score 2. In comparing with other concentrations, fruit exposed to 0.35 μL/L exhibited a slightly slower change in peel colour. Exogenous ethylene concentration exceeding 5 μL/L does not further enhance the peel colour change. The carbon dioxide and ethylene production of ethylene-treated fruit showed a decreasing trend after the ripening induction period. Changes in pH, total soluble solids and total sugar content between air and ethylene-ripened fruit at colour score 6 were insignificant.

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## Introduction

Since the early use of smoking to ripen fruit, many techniques which enhance the ethylene effect on the ripening process have been developed. Externally applied ethylene, termed as exogenous ethylene, allows faster and more uniform ripening of most fruit before retail distribution.

Ethylene is an endogenous plant hormone involved in many phenomena of growth regulation and senescence, and its role in fruit ripening appears to be particularly important (Kidd and West 1945; Pratt and Goeschl 1969; Peacock 1972). Broughton and Wu (1979) reported that the application of exogenous ethylene on two banana cultivars, namely Embun and Rastali accelerated the onset of respiratory climacteric and ripening. They also indicated that banana fruit ripened in the presence of ethylene were attractive, possessed a pleasant aroma and were of good flavour. The ripening physiology of banana fruit in relation to exogenous ethylene were also studied by Peacock (1972), Liu (1976) and Marriott (1980).

The concentration of ethylene required for ripening varies with types of fruit and maturity stages. In general, the ethylene concentration used for ripening of fruit ranges from 10 ppm to 100 ppm with an exposure of 24–72 h (Reid 1985). Peacock (1972) reported that a concentration of 0.44 ppm for 1 day to 6 days caused reduction in the preclimacteric period of Giant Cavendish banana. In a similar study, Liu (1976) showed that Gros Michel banana responded to ethylene concentration of 10 ppm with an exposure period of 28 h. In comparison with Anjou pears, Wang and Mellenthin (1972) indicated that a level of 0.46 $\mu$L/L was needed to initiate climacteric rise in respiratory activities and the rate of softening.

The effect of exogenous ethylene application on the fruit ripening behaviour is mainly associated with physico-chemical changes and respiratory pattern modifications. It is important to establish if these changes also affect the final edible quality of ripe fruit.

This study aims to elucidate the effect of exogenous ethylene application on the ripening behaviour of Mas bananas in relation to its respiration pattern and changes in chemical composition.

## Materials and methods

### *Fruit*

Banana plants in a private farm in Bruas (Perak) were tagged randomly from the period of flower emergence in December 1985. Harvesting started after the seventh week of flower emergence. Individual bunches were wrapped in cushioning pads to avoid mechanical injury during transportation to the laboratory in MARDI, Serdang, Selangor.

### *Sampling*

The individual bunches were sectioned with a sharp knife and graded into groups of upper, middle and lower hands, following the method of Abd. Shukor, Abdullah and Ahmad Shokri (1986).

The individual hands were washed with clean water and dipped in 500 $\mu$g/mL benomyl suspension for five minutes to eliminate fungal infection. They were then dried at ambient temperatures (28–32 °C) to remove excess surface moisture.

### *Ripening induction with exogenous ethylene*

Three hands from the upper, middle and lower portions of one bunch were placed in a 20-L plastic container fitted with inlet and exit ports for a gas flow-through system. The lid was firmly closed and the plastic container was connected to gas cylinders supplying 0, 0.35, 5, 10 and 20 $\mu$L ethylene/L air for 24 hours at 25 °C. Eight similarly prepared plastic containers were connected to each gas cylinder. Before entry into the plastic container, the gas was bubbled through water to maintain 95–100% relative humidity. The flow rate was maintained at 1 L/h per 100 g of fruit weight.

***Colour index***

After 24 hours of ethylene treatment, all the containers were opened. Fruit from four plastic containers from each treatment were arranged on the bench in a ripening room of 25 °C and 85−90% relative humidity. Each plastic container represented a replicate. The evaluation of colour score for each treatment was replicated four times. Colour changes of the peel were evaluated daily using the standard colour index developed by Lam, Ahmad Kamari and Wan Rahimah (1983) until a colour index value of 8 was attained. A numerical score of 1 to 8 was assigned to the ripening stages of green (1), trace of yellow (2), more green than yellow (3), more yellow than green (4), yellow with green tip (5), full yellow (6), yellow and lightly flecked with brown (7), and yellow with increasing brown areas (8).

***Carbon dioxide and ethylene measurement***

Three fingers were randomly selected from the upper, middle and lower hands of the remaining four plastic containers. The fruit were then placed together in a 1.5-L respiration jar and ventilated with humidified air as described earlier. Each treatment had four replicates.

One millilitre of the respired gas was collected from the respiration jar with a hypodermic syringe and injected into a Varian 1420 gas chromatograph fitted with a thermal conductivity detector and a stainlees steel column of 150 cm x 3 mm, packed with 80−100 mesh Porapak R for carbon dioxide determination. The carrier gas for carbon dioxide determination was helium with a flow rate of 30 mL/min and a column temperature of 35 °C. For ethylene determination, 1 mL of the respired gas was injected into a Varian 1440 gas chromatograph fitted with a flame ionization detector and a stainless steel column of 180 cm x 4 mm, packed with 100−120 mesh Porapak T. The carrier gas for ethylene determination was nitrogen at a flow rate of 30 mL/min and a column temperature of 100 °C.

The carbon dioxide and ethylene production were measured until the fruit attained a colour score values of 7.

***Chemical composition***

The chemical composition of ripe fruit from the exposed hands which had attained a colour score value of 6 was determined. Ten fingers were taken randomly from each treatment and analysed for total sugar content, total soluble solids and pH following the methods of AOAC (1975). Each analysis was replicated four times.

**Results**

***Colour score***

Fruit treated with exogenous ethylene showed rapid colour change of the peel from green to yellow compared with control (*Figure 1*). There was significant difference ($p<0.05$) in colour score between ethylene-treated and control fruit throughout the ripening period. Fruit treated with 5, 10 and 20 μL/L

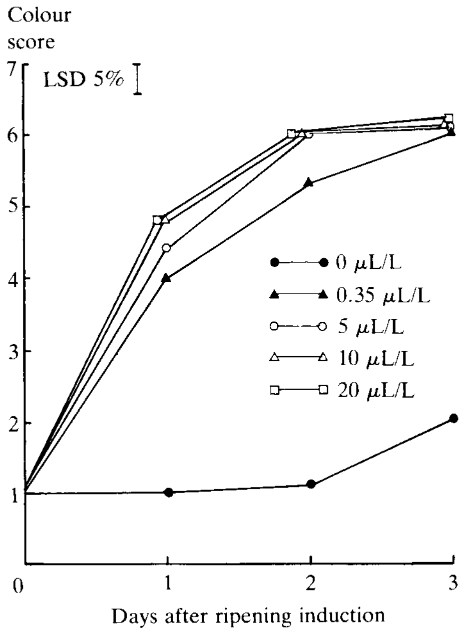


*Figure 1. Colour score of Mas banana after exposure to different concentrations of exogenous ethylene for 24 hours*

exogenous ethylene attained colour score 6 after 2 days of induction and were significantly different ($p<0.05$) from fruit treated with 0.35 µL/L ethylene. However, the colour score of all exogenous ethylene-treated fruit showed no significant difference after 3 days of induction. Control fruit were at colour score 2 after 3 days of induction.

***Carbon dioxide and ethylene production***

Control fruit exhibited a gradual increase in carbon dioxide production which showed insignificant difference throughout the ripening period (*Figure 2*). A decreasing trend in the rate of carbon dioxide production was shown by fruit which had been exposed to different concentrations of exogenous ethylene. Significant difference ($p<0.05$) in the rate of carbon dioxide production throughout the ripening period was only shown in ethylene-treated and control fruit.

Ethylene emanation of exogenous ethylene-treated fruit showed a similar trend as carbon dioxide production throughout the ripening period. The rate of ethylene production of control fruit increased after 2 days of ripening induction and then decreased gradually. With the exception of the second day of the ripening period, the difference in ethylene production rate between ethylene-treated and control fruit was significant ($p<0.05$).

***Chemical composition***

There was no significant difference in chemical composition between control and ethylene-ripened fruit at peel colour score 6 (*Table 1*). The pH, total soluble solids and total sugar content of ripe fruit at colour score 6 ranged between 5.09 and 5.13, 25.8 and 25.9 °Brix, and 18.2% and 18.4% respectively.

**Discussion**

The application of exogenous ethylene (0.35–20 µL/L) to seven-week old mature green Mas banana enhanced rapid and uniform colour change of the peel from green to yellow. Peel colour change was slower in fruit exposed to air. This study indicates that an exogenous

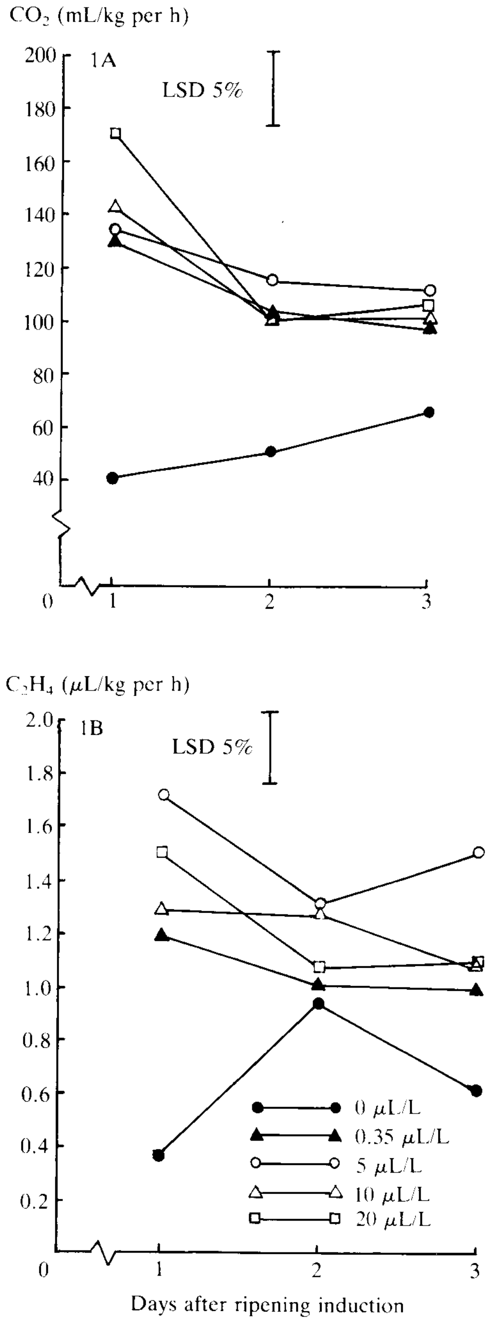


*Figure 2. Carbon dioxide and ethylene production of Mas banana after exposure to different concentration of exogenous ethylene for 24 hours*

Table 1. The chemical composition of Mas banana at colour score 6 induced with five concentrations of exogenous ethylene for 24 hours

| Ethylene concentration ($\mu$L/L) | pH | Total solubc solids (°Brix) | Total sugar (%) |
|---|---|---|---|
| 0 | 5.09a* | 25.9a | 18.4a |
| 0.35 | 5.10a | 25.8a | 18.2a |
| 5 | 5.13a | 25.9a | 18.4a |
| 10 | 5.10a | 25.9a | 18.2a |
| 20 | 5.11a | 25.9a | 18.4a |

*Each value is a mean of 4 replicates. Means with same letters in the same column are not significantly different from each other at 5% level by DMRT.

ethylene concentration as low as 0.35 $\mu$L/L is enough to stimulate colour change of the peel which is associated with ripening. The colour change of fruit exposed to 0.35 $\mu$L/L exogenous ethylene was slightly slower than that of concentrations higher than 5 $\mu$L/L. Exogenous ethylene concentration exceeding 5 $\mu$L/L does not further enhance the peel colour change. In a similar study, Peacock (1972) reported that the green life of Giant Cavendish banana was shortened by exposure to 0.44 $\mu$L/L exogenous ethylene for 1 day to 6 days.

Mas banana is a climacteric fruit and exhibits a typical climacteric type of respiration and ethylene evolution (Broughton and Wu 1979; Abd. Shukor et al. 1986). All the induced fruit were at the post-climacteric stage after 1 day of ethylene treatment. In contrast to fruit ripened with ordinary air, the gradual increase in carbon dioxide production indicated that the fruit were at the early stage of climacteric rise. This finding is supported by the earlier work of Abd. Shukor et al. (1986) which indicated that the respiratory climacteric peak of seven weeks, fruit ripened with ordinary air occured between 3 days and 4 days after harvest. Similarly, Broughton, Chan and Khoo (1978) reported the respiratory climacteric peak of Mas banana ripened at 20 °C and 28 °C at 6 days and 3 days after harvest respectively. It is possible that the climateric peak of ethylene-induced fruit could have occurred during or immediately after the ripening induction period. This suggests that the onset of respiratory climacteric peak tends to occur earlier with fruit which have been induced to ripen with exogenous ethylene.

Although the respiratory climacteric peak of ethylene-treated fruit was not detected, the rate of carbon dioxide production throughout the ripening period was significantly higher than that of control fruit. This suggests that an exogenous ethylene concentration as low as 0.35 $\mu$L/L is sufficient to stimulate rapid rate of carbon dioxide production which is associated with ripening. This concentration is within the range of physiologically active concentration for most climacteric fruit (Rhodes 1980). Biale and Young (1982) reported that the onset of ripening in climacteric fruit is marked by an upsurge in the respiration rate.

The ethylene-treated fruit had a higher rate of ethylene emanation than control fruit throughout the ripening period. Ethylene emanation is closely related to the respiratory activity of climacteric fruit during ripening. Abd. Shukor et al. (1986) reported that the ethylene peak of Mas banana at seven weeks maturity ripened at 25 °C preceded the carbon dioxide peak, while Karikari, Marriott and Hutchins (1979) indicated the increase in ethylene production before the climacteric peak in Ghanian plantain (Musa, AAB group). This study indicated that the onset of ethylene peak of ethylene-treated fruit could have occurred simultaneously with carbon dioxide production.

There were no marked differences in pH, total soluble solids and total sugar content between ethylene and air-ripened fruit at colour score value of 6. This study has established that the application of exogenous ethylene to induce ripening of Mas banana has no resultant effect on the chemical composition of ripe fruit.

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