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Original Article

Post harvest ripening of oil palm fruit is accelerated by application of exogenous ethylene

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Abstract

Experiments were conducted with fresh fully mature fruit bunches of Tenera variety oil-palm. Palm fruit bunches were exposed to 0, 250, 500 or 1000 mlL^{-1} ethylene for 24 hours. Each fruit bunch was evaluated in three separate sections: the bottom, the middle, and the top. The exogenous ethylene treatments significantly hastened palm fruit ripening, quantified by an increase in the fruit peel coloring that turns from black to reddish orange. Ethylene treatments also significantly eased detaching the fruit, by reducing the tension force required. Total oil contents of fruit increased with 1000 mlL^{-1} ethylene treatment. Free fatty acids (FFA) in untreated palm fruit, especially in the bottom section, were at their highest levels 2 days after harvest, and the FFA levels were lowered by ethylene treatments. In summary, exogenous ethylene fumigation accelerated the ripening of oil palm fruit, increased oil yield, and decreased the FFA levels.

Keywords: ethylene, FFA, oil palm, oil content

1. Introduction

In oil-palm (*Elaeis guineensis* Jacq.) fruit bunches, the fruitlets do not ripen simultaneously: owing to slight variations in the time of pollination. The fruit ripen first on the bottom, and the ripening ‘front’ progresses towards the top of the bunch (Sambanthamurthi *et al.*, 2000). This asynchronous ripening affects the quality of extracted palm oil. The oil palm is a monocot fruit subject to climacteric ripening with high amounts of lipids accumulated during fruit maturation (Ohlson, 1976; Tranbarger *et al.*, 2011). In oil palm industry, there are various steps involved in the processing crude palm oil from field to mill including: a) reception of the raw material, b) sterilization, c) threshing, d) fruit digestion and e) processing for crude palm oil (CPO). Before sterilization, oil palm fruitlets are split from the fresh fruit bunches (FFB) into smaller pieces by the rotating threshing drum before being relayed to a large cage. The threshing drum aids in the separation of the fruit from the husks; however, a lot of energy is needed and consumed in this process (Ismail *et al.*, 2011). Hence, the application of some plant growth regulators to loosen the fruitlets before they are detached from the bunch in threshing process is helpfulness that fruitlets can be detached more easily.

Ethylene is known as a ripening hormone, and it is widely applied to hasten the maturation of especially climacteric type of fruits: exogenous ethylene application promotes ripening (Lurie, 2000). There are, however, only few past reports on its application to stimulate fruit maturation in oil palm. Suryanto and Bardaie (1994) have reported the application of an ethylene releasing substance (2-chloroethyl phosphonic acid; ethephon) sprayed on the cut spikelets or

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brushed on the cut stalk of a fresh fruit bunch (FFB) just after harvesting. They found that ethephon reduced the detachment force significantly and did not influence the development of FFA. Further, Juntaraniyom *et al.* (1996) have studied the application of acetylene (calcium carbide), and ethephon to stimulate the fruit drop of oil palm. Their ethylene treatments did increase the percentage of fruit abscission. However, they also found increased levels of FFA, and more fruit rot, as side effects of acetylene and ethephon application. Recently, Ismail *et al.* (2011) reported that they used ethephon to loosen the fruitlets before using the vibrational oil palm fruit detaching machine. They also reported that ethephon had no side effects on the fruit components or moisture content of the oil palm bunches.

There is no prior published research on the effects of directly exposing harvested oil palm fruit to gaseous ethylene. In this study, we exposed harvested oil palm fruit to various concentrations of ethylene gas, and report the treatment effects on fruit ripening, total oil yield, and FFA levels.

2. Materials and Methods

2.1 Plant materials

Twelve bunches (one bunch from each of 12 oil-palm trees; each bunch contains approximately 1000 to 1200 fruitlets) of Tenera variety oil-palm were harvested from 11 year-old trees at a commercial field in Songkhla Province, southern Thailand, and then transported within 1 hour to the laboratory at Prince of Songkla University.

2.2 Ethylene treatments

Fruit bunches were subjected to four treatments, namely fumigations with 0, 250, 500, or 1000 mlL^{-1} ethylene. The various concentrations were prepared by diluting pure gaseous ethylene (99.9999% active ingredient). The fumigations were done in a sealed plastic box (1 m x 1 m x 1m) for 24 hours at 30°C. The final concentration of each treatment was measured with gas chromatograph. The oil-palm fruit bunches were sampled from three main sections separately (front, middle and bottom). Nine fruitlets were collected from outer and inner layers of each region, randomly. Results are given as means of 3 replicate samples.

2.3 Data recording

Peel color at the middle of fruit was measured using a hand-held colorimeter (CR-400, Minolta Co., Ltd., Osaka, Japan), with the standard CIE illuminant in the L^*, a^*, b^* mode. The measurement was done at the middle of the fruit. We used a digital force gauge that measures the kg resistance (Force Gauge IPX-800, Bowers) to determine the fruit retention force in each section of the fruit bunch: this was recorded as mentioned in fruit sampling. From the fruit samples, mesocarp was extracted and weighted, chopped and blended to get particulate slurries. The oil was extracted in a soxhlet extractor using hexane as the solvent. Crude oil samples from each treatment were collected at daily intervals, and filtered through No. 2 Whatman filter paper in an oven (90°C), to remove enzymes. Acid values of enzyme-free samples were determined by the AOCS (1989) titration method. The results were calculated from the number of milligrams of KOH necessary to neutralize the FFA in 1 g of sample, and expressed as the equivalent percent palmitic acid.

2.4 Statistics

Statistical analyses of the data were performed using the R environment version 2.12.1. Analysis of variance was performed using the F test, and the least significant differences (LSD) computed at 5% probability for comparing the means between treatments.

3. Results and Discussion

The effects of ethylene gas on fruit abscission are shown in Figure 1. The number of abscised fruit was highest with 1000 mlL^{-1} ethylene treatment. The effect was concentration dependent in the same manner as the observed retention force, which decreased with treatment concentration (Table 1). The ripening was hastened by ethylene treatments, as observed through color change. In the case of Tenera variety oil-palm, fruit peel coloring turns from black to reddish orange. An ethylene treatment at 1000 mlL^{-1} increased the a^* value effectively (Figure 2), and the ripening score reached about 100% values within one to two days after the ethylene treatment (data not shown). The oil palm fruitlets in a bunch ripen in an order from the bottom to the middle and to the top. Thus, the ripening degree decreases with the section of the bunch, from the bottom to the middle to the top.

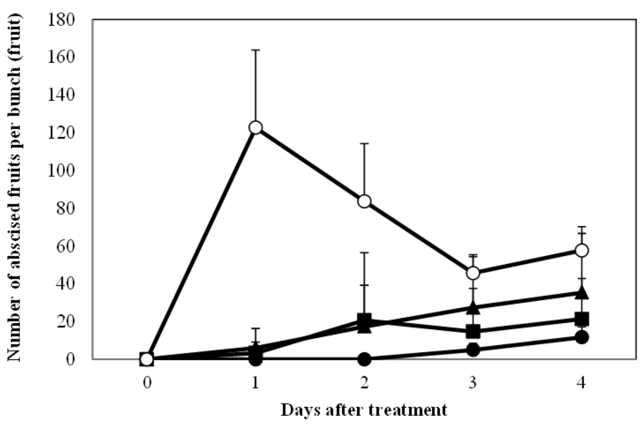

Figure 1. Numbers of abscised fruit with 0 (●), 250 (■), 500 (▲), or 1000 (O) mlL^{-1} ethylene for 24 h after treatments. Vertical bars represent standard errors of means.

Table 1. Retention force of oil-palm fruit after treatments with 0, 250, 500, or 1000 mlL^{-1} ethylene for 24 h.

Treatments	Retention force (N) [1]			
	Days after treatment			
	1	2	3	4
0 mlL^{-1} C_2H_4	239.9 ± 9.6 a	188.2 ± 10.8 c	176.1 ± 11.7 c	164.8 ± 14.5 c
250 mlL^{-1} C_2H_4	232.9 ± 11.3 a	175.3 ± 65.2 c	80.1 ± 36.6 b	78.8 ± 35.5 b
500 mlL^{-1} C_2H_4	216.9 ± 11.8 a	95.8 ± 19.3 b	80.7 ± 23.5 b	57.9 ± 22.7 b
1000 mlL^{-1} C_2H_4	220.9 ± 24.8 a	22.7 ± 13.2 a	9.9 ± 2.7 a	8.4 ± 2.2 a

[1] Means followed by different letters within a column are significantly different at P=0.01 by LSD

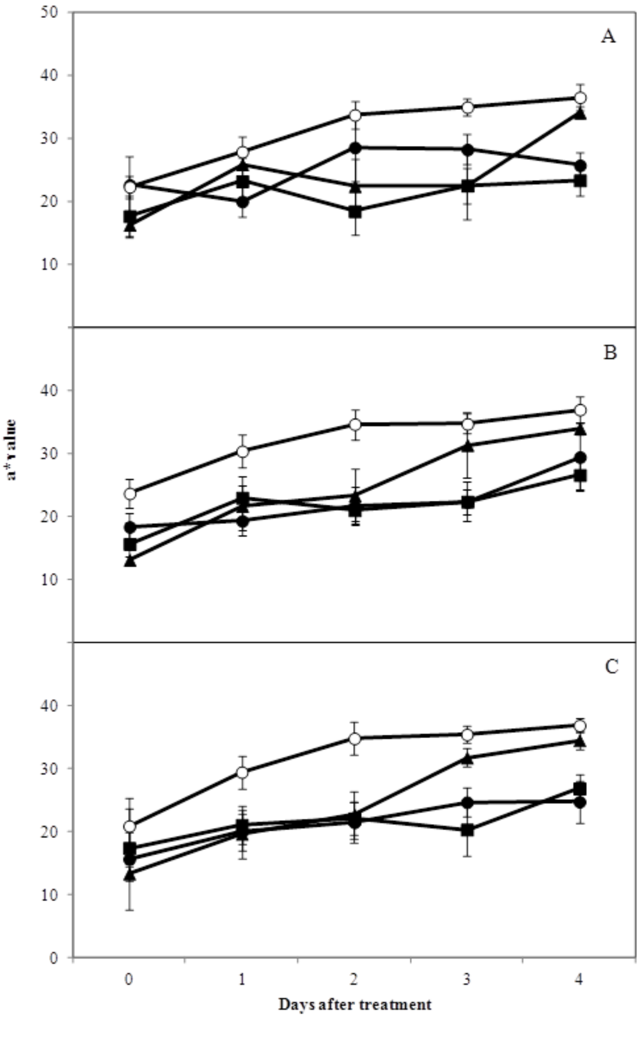

Figure 2. Peel colour (a* values) of oil palm fruitlets at the bottom (A), the middle (B) and the top (C) of the bunch after treated with with 0 (●), 250 (■), 500 (▲), or 1000 (O) mlL^{-1} ethylene for 24 h. Vertical bars represent standard errors of means.

Oil yield of ethylene treated fruit was not affected by ripening stage or the different sections. However, 1000 mlL^{-1} ethylene was the most effective concentration for increasing oil yield (Table 2). These increases of oil content in palm fruit match the reports of Oo *et al.* (1986) and Sambanthamurthi *et al.* (2011): an apparent increase of oil content after harvest, while the fruit ripens, is a consequence of desiccation.

The level of FFA is a major determinant of oil quality and the increase in FFA levels in fruit palm oil is attributed to the action of a lipase enzyme (Sambanthamurthi *et al.*, 2011). Free fatty acids were investigated and the results are summarized in Table 3. The FFA percentage did not meet the commercial standard that allows a maximum of 5% FFA in crude palm oil, with any of our treatments: also the control fruit exceeded this limit by three fold (two days post harvest, after which the level decreased slightly). The ethylene treated fruit did have a lower FFA than the control fruit, but still exceeded the standard limit by two fold. Moreover, the FFA content of treated fruit was almost constant through the time observed. The 500 and 1000 mlL^{-1} of ethylene were the most effective treatments against postharvest increases of FFA levels in oil palm fruit. It is possible that oil palm fruit's ripening is accelerated early by the ethylene fumigation. Normally, lipase activity is first observed at 16 weeks after anthesis (WAA) and reaches a maximum level at 21 WAA and then declines after 21 WAA, harvest stage (Sambanthamurthi *et al.*, 2011).

The result of fumigation with gaseous ethylene resembled the reported using calcium carbide and ethephon, as it also stimulates oil-palm fruit drop with a significant increase in FFA level (Juntaraniyom *et al.*, 1996). In addition, FFA level in the overripe fruits may also caused by microbial infection (Sambanthamurthi *et al.*, 2011; Togoe *et al.*, 2012). However, we found no fruit rot after any of our ethylene treatments. Possibly this difference was caused by the dry condition of the fumigation treatment, whereas the calcium carbide gave off heat and ethephon was a wet treatments that gave more favorable condition for micro-organisms causing

Table 2. Total oil contents of oil-palm fruit after treatments with 0, 250, 500, or 1000 mlL^{-1} ethylene for 24 h.

Treatments	Total oil content (%) [1]			
	Days after treatment			
	1	2	3	4
0 mlL^{-1} C_2H_4	40.6 ± 1.7 b	36.2 ± 18.1 b	35.0 ± 1.2 bc	34.3 ± 6.5 b
250 mlL^{-1} C_2H_4	44.6 ± 2.5 b	33.4 ± 0.9 bc	29.3 ± 4.5 c	38.9 ± 1.9 b
500 mlL^{-1} C_2H_4	56.2 ± 5.6 a	29.0 ± 0.4 c	28.3 ± 0.4 c	37.8 ± 1.9 b
1000 mlL^{-1} C_2H_4	53.6 ± 1.2 a	45.3 ± 0.4 a	68.6 ± 0.8 a	68.6 ± 1.8 a

[1] Means followed by different letters within a column are significantly different at *P*=0.01 by LSD

Table 3. Free fatty acids of oil-palm fruit after treatments with 0, 250, 500, or 1000 mlL^{-1} ethylene for 24 h.

Treatments	Free fatty acids (%) [1]			
	Days after treatment			
	1	2	3	4
0 ppm C_2H_4	7.8 ± 0.5 a	15.1 ± 2.4 b	14.6 ± 0.6 b	13.2 ± 1.5 b
250 ppm C_2H_4	8.7 ± 0.1 a	14.4 ± 0.6 b	12.8 ± 0.4 b	12.2 ± 1.0 b
500 ppm C_2H_4	7.7 ± 0.4 a	11.8 ± 0.4 a	9.7 ± 0.2 a	9.5 ± 0.3 a
1000 ppm C_2H_4	6.4 ± 0.8 a	10.4 ± 0.4 a	8.1 ± 0.4 a	7.5 ± 0.5 a

[1] Means followed by different letters within a column are significantly different at *P*=0.01 by LSD

fruit rot.

In conclusion, postharvest 24 h exposure to 250, 500 or 1000 mlL^{-1} ethylene stimulates fruit abscission and ripening of oil-palm fruit, increased oil yield and decreased the FFA levels. No harmful side-effects were observed. The use of ethylene gas to detach the fruitlets from the bunch will further improve the efficiency in the mill.

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