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Maturity Index and Respiratory Pattern Indicate Optimal Harvesting Time and Post-harvest Handling of *Jatropha curcas* Linn Fruits

Silip, J.J.[1,*], Tambunan A.H.[2], Hambali, H.[2], Sutrisno,[2] and Surahman, M.[2]
[1]School of Sustainable Agriculture
Universiti Malaysia Sabah, Locked Bag No.2073, 88999 Kota Kinabalu, Sabah, Malaysia.
[2]Bogor Agricultural University, Bogor 16680, Indonesia.
[*]*E-mail: silip@ums.edu.my*

Introduction

The main harvesting and post-harvest problem of jatropha is that any single branch the fruits ripens at different times. It leads to laborious and time consuming harvesting as farmers have to select the ripe fruits only or fruits have to be harvested manually at regular intervals (Heller, 1996; Biswas et al., 2006). Therefore, this problem has been highlighted in many publications that may jeopardise the economic viability of production of this crop (GEXSI, 2008; Hambali, 2008). Jatropha fruits are still harvested by hand in small and plantation scale farms. Mechanical harvesting of jatropha is considered to be impossible due to the non uniformity of fruit ripening.

In many crops, maturity or ripening index is developed as measurement that can be used to determine or estimate when the particular commodity is mature and ready to be harvested. High CJCO content and fruit color changes after elapsed days from full bloom have been recommended as indication of harvesting time in Jatropha by many researchers; Heller (1996) and Hambali et al. (2007) recommended 90 days after anthesis or black dry fruits; Santoso et al. (2008) recommended 55 days after anthesis or fully yellow fruits, Wanita and Hartono (2008) recommended 45 days after anthesis of yellow fruits and Annarao et al. (2008) recommended 37 days after anthesis or just before drying. Varying and contradict recommendations indicate a need for development of maturity index in this crop.

In general, fruits can be classified as either climacteric or non-climacteric based on their respiration pattern during ripening. Climacteric fruits display a characteristic peak in respiratory activity during ripening. It is interesting to note that climacteric fruits, such as banana, tend to ripen rapidly. It has led to the regulation of respiration as a possible target of biochemical manipulation of shelf life. In contrast, non-climacteric fruits, such as pineapple, simply exhibit a gradual decline in their respiration during ripening. They have to be harvested at optimal stage of maturity on the tree. However, no information is available on the Jatropha's respiration pattern during ripening. Therefore, the main objective of this study was to determine the maturity index and its physico-chemical characteristics and to better understand the fruit respiration pattern during storage.

Materials and Methods

Sample for maturity index study

Jatropha fruits of local variety were obtained from Sabah Land Development Board, Malaysia Jatropha Demonstration Plot at Jatropha Estet Binakaan, Sook, Keningau, Sabah, Malaysia. Five fruits of each of seven maturity indexes were randomly harvested from different trees in the farm. The visual colour characteristics are described in Table 1. Measurement of physical characteristics of fruits, fruit coats, seeds, shells and kernels was made on the next day after harvest.

Samples for respiration study

This study was carried out at Bogor Agricultural University, Indonesia. Two types of sample were used. Samples for no pre-handling treatment were harvested form Bogor University Farm near the laboratory. Samples with pre-handling treatment were brought from Jatropha Plantation at Serang,

Banten, Indonesia. Open air transportation to bring the samples from farm to laboratory took eight hours. Pre-handling interruption before respiration test of the pre-handling fruits was 28 hours. Fruits were kept in the respirometer bottle from the open topside and were kept closed with the lid while inserting neoprene gasket in between. The three storage temperatures used were 27±3 ^{o}C, 15±3 ^{o}C and 7±3 ^{o}C.

Physical characteristics measurement

Fruit coat colour (L, c and h value) of each sample was measured at a single point on the equatorial region of the fruit, seed and kernel using a Konica Minolta Colour Reader (CR-100, Minolta Corp., Japan). Fruit firmness was determined by using penetrometer (WAGNER U.S.A) fitted with 6 mm plunger. Weight of each bunch, fruit, fruit coat, shell and kernel was determined by using a balance.

Carbon dioxide measurement

The gas inside the airtight respirometer bottle of 3300 ml was measured using Infrared Continuous Gas Analyzer Model IRA-107 (Shimadzu, Japan). Gas composition was analyzed at varying intervals depending on the storage temperatures. Preliminary experiment was carried out to determine a suitable interval for measurement of CO_2 and minimum weight of fruit required per respirometer bottle. Gas measurement was stopped when the fruits were fully senesced or black in color.

Calculation of respiratory rates

The respiration rates in terms of CO_2 at given temperature were calculated using the following equation as given by Kays (1991). The amount of gas in milliliters was converted to milligrams to remove the effect of temperature on the volume of gas according to Kays (1991).

$$\text{ml kg}^{-1}\text{hr}^{-1} = \frac{(\Delta\ \%\ \text{x}\ 10)(\text{free space volume of respirometer bottle in liters})}{(\text{product fwt in kg})(\text{time respirometer bottle is close in hours})}$$

Where $\Delta = \Delta CO_2$ or concentration time 2 – concentration time 1

Seed oil extraction and measurement

Seed oil was extracted by using modified portable hydraulic presser. The principal components of the hydraulic presser are screw, disk pressing, pressing chamber, bearing pressing, hydraulic jack, heater and thermostat. The percentage oil yield was later computed from the ratio of mass of oil to the mass of sample before oil extraction.

Results and Discussion

Respiration pattern of jatropha fruit

The respiration data corresponding to different storage temperatures and different samples indicated an upsurge in CO_2 concentration (Figure 1). The result of this experiment confirmed that jatropha fruit is in the class of climacteric fruit. The point of upsurge in the CO_2 concentration was different according to storage temperature. The peak was observed as early at 54 hours at storage temperature of 27+3 ^{o}C but it was only observed at 90 and 116 hours at storage temperature of 15+3 ^{o}C and 7+3 ^{o}C respectively. The present recommendation of harvesting only yellow and black fruit is a waste of time. According to the results, the mature green fruits can be harvested. It is important to note that a must in harvesting a mature fruit is pre-requested in some fruits (avocado and mango) due to the fact that respiratory upsurge was reported inhibited while the fruits are attached to the tree (Kays, 1991).

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The result of this study offers future study on jatropha fruit postharvest ripening treatment and its effect to the quantity and quality of crude jatropha curcas oil (CJCO).

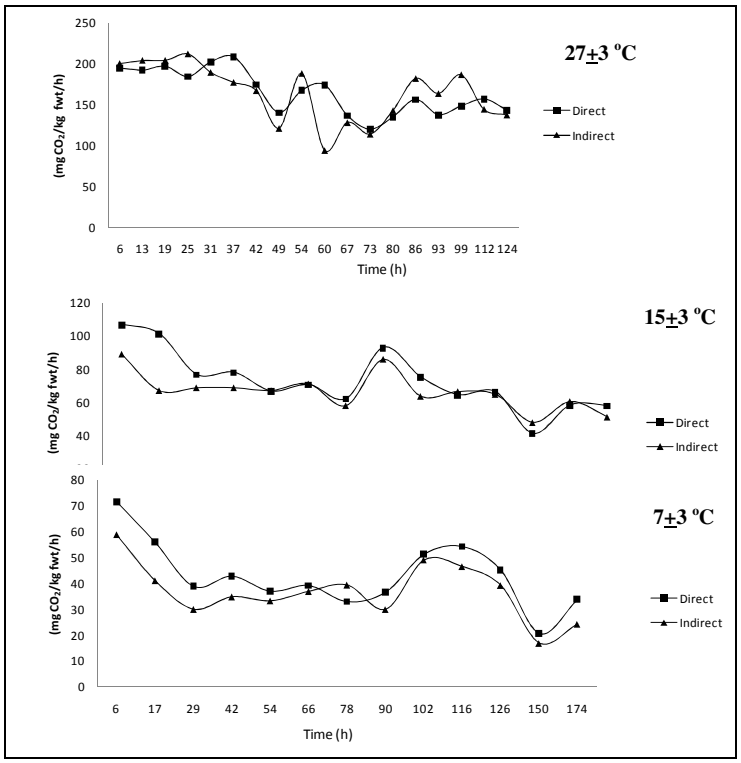

Figure 1. Respiratory rate of jatropha fruit at three different storage temperatures (27±3 °C, 15±3 °C and 7±3 °C) and two different postharvest handling of samples (freshly harvested and 28 hours after harvesting).

Maturity index and physico-chemical characteristics of jatropha fruit

The young and mature fruit showed significant differences in colors (Table 1). Matured fruit or index two showed darker and more saturated green fruit coat color as compared to young fruit which was brighter and had less saturated green color. The color differences between young and matured fruit could be used as physiological maturity indicator for this fruit. Fruit weight was significantly greater in fruits of maturity index 5; i.e. 15.32 g per fruit. Fruits at maturity index 6 and 7 were less than 10 g per fruit. Seeds and kernels of the black dry fruit group were significantly lighter as compared to that of fruits of other maturity indices. A change on firmness value was interesting in this study. Firmness of fruit coats increased when mature green fruits turned to fully yellow fruits but decreased when senescence started. The shell firmness increased with increasing maturity index. However, the kernels of young and matured fruits were much firmer as compared to that of other maturity indices.

CJCO quantity and quality

Result of this study showed that CJCO quantity and quality were different according to different maturity indices (Table 2). The CJCO quantity was different between dry and fresh seeds. High CJCO was found in the dried seeds at maturity index 4, i.e. about 27% as compared to only about 5% in the fresh seeds of similar maturity index. Result of this study indicated the importance of drying before extraction to maximize oil yield. Therefore, this report was not in agreement with most of the harvesting time recommendations, i.e. harvesting the black dried fruit. Instead, harvesting should be carried out at ripening index three, four and five. On the other hand, irrespective of using dried or fresh seeds at any maturity indices, the free fatty acids were less than 2%. It indicated that any of these materials were good for single transesterification processes. It is important to note that if free

fatty acids are found more than 5% in the feedstock by using catalyzed reaction, the material will only form soap and water (van Gerpen and Knothe, 2005).

Table 1. Physical characteristics (color – L, c and h value; weight (g), and firmness (N)) according to seven maturity indexes (1: young fruit, 2: Matured Green, 3: half green and half yellow, 4: fully yellow, 5: half yellow and half black, 6: black wet fruit, 7: black dry fruit) of *Jatropha curcas* L. fruits, coats, seeds, shells and kernels.

Physical Characteristics	Parts	Maturity Index							Sig.
		1	2	3	4	5	6	7	
Weight (g)	Fruits	12.83c[z]	13.41bc	14.28b	15.32a	12.71c	7.98d	02.97e	*
	Seeds	03.18a	03.44a	03.47a	03.72a	03.59a	03.08a	2.23b	*
	Kernels	01.74a	01.76a	01.87a	01.93a	02.05a	01.78a	01.20b	*
Color	Coats (L value)	47.41d	56.78c	60.26b	73.96a	52.36c	25.80e	27.00e	*
	Coats (c value)	30.74d	39.04c	45.43b	55.06a	29.47d	04.66e	06.68e	*
	Coats (h value)	117.10a	113.20a	99.44b	90.72c	67.66d	55.70e	51.00e	*
Firmness (N)	Coats	14.32ab	13.24b	17.36a	16.67ab	10.93bc	07.45c	13.80b	*
	Shells	23.83b	24.42b	34.48ab	35.99ab	42.72a	41.40a	33.90ab	*
	Kernels	06.67b	06.28b	10.79a	11.47a	11.04a	12.00a	11.00a	*

** Significant by ANOVA at 5% level of significance*
[z] Mean for each treatments followed by the same letter at a similar rows are not significantly different at p>0.05 with Duncan's multiple range test (DMRT).

Table 2. Percentage of crude jatropha curcas oil (CJCO) at different maturity indexes of dried and fresh jatropha seeds and free fatty acids (FFA) extracted with modified hydraulic presser.

Maturity Indexes	CJCO (%) of fresh seeds	CJCO (%) of dried seeds	FFA (%) of fresh seeds
Index 2	0.19	17.93	0.59
Index 3	0.97	26.80	0.60
Index 4	4.87	26.76	1.04
Index 5	3.16	24.97	1.08
Index 6	2.02	21.10	0.59

Conclusions

Result of respiration test showed that jatropha fruit is in the climacteric class according to its respiration pattern. The physio-chemical data indicate an optimal seeds oil extraction at ripening index 3 and 4. The percentage of extracted seed oil is higher with drying before extraction. Therefore, the results of this study indicate a possibility to harvest physiological matured fruits followed by ripening off the tree. It is hoped to manipulate the fruit ripening to reduce the cost of harvesting of individual ripened fruits on the tree which was reported laborious and time consuming. However, the result of this study offers future study to confirm the effect of ripening treatment to the harvested mature green fruits and its effect on CJCO quality and quantity.

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