Ripeness Inspection of Oil Palm Fruits by Applying Hardness Test Technique

Thiensak Chucheep[1,2], Narissara Mahathaninwong[1,2], Suphatchakorn Limhengha[1,2], Duangrudee Petchui[3] and Pattraporn Templong[3]

[1]*Industrial Management Technology Division, Faculty of Science and Industrial Technology, Prince of Songkla University Surat Thani Campus, Surat Thani, Thailand*

[2]*The Center of Excellence in Materials Engineering (CEME) and Intelligent Automation Research Center (IARC), Faculty of Engineering, Prince of Songkla University Hat Yai Campus, Songkhla, Thailand*

[3]*Formerly Student, Industrial Management Technology Division, Faculty of Science and Industrial Technology, Prince of Songkla University Surat Thani Campus, Surat Thani, Thailand*

Keywords: Hardness Technique, Indenting Technique, Palm Ripeness.

Abstract: The objective of this study was to investigate whether the ripeness of oil palm fruits could be estimated based on their hardness. The hardness was examined by indenting with a steel ball on the exocarp of the fruit with the required indentation force (kgf) measured. Five steel balls with diameters of 4, 6, 8, 10, and 12 mm were tested on CIRAD and COMPACT varieties of oil palm, with the fruits in unripe, under-ripe, and ripe stages. The results reveal that, on using five ball indenters, the average hardness of unripe oil palm fruit differs from those of under-ripe and ripe fruit, on both CIRAD and COMPACT varieties. In contrast, the average hardness of under-ripe and ripe stages did not differ, while the hardness in three stages oil palm fruits reflects the oil and moisture percentages. Oil percentages in the COMPACT oil palm fruit in unripe, under-ripe, and ripe stages were 27.71%, 75.11%, and 76.78%, respectively, and for CIRAD variety of oil palm these were 59.42%, 76.67%, and 75.79%, respectively. The empirical dependence of hardness on oil content was $y=-1.47x^2+11.20x+55.36$ for the COMPACT oil palm and $y=-1.90x^2+3.21x+77.49$ for the CIRAD oil palm.

1 INTRODUCTION

Indonesia and Malaysia have been the largest palm oil producers in the world, and Thailand is the third in the global rankings. Oil palm is an important economic crop in Thailand and it has been mostly cultivated in the southern parts of the country, because of suitable climate with abundant rainfall. Oil palm cultivation has expanded to the North, Northeast and Central regions of the country during 2008-2012 because the government planned to increase and support palm oil production for developing alternative energy supplies (Petchseechoung, 2017). Nowadays, Thai oil palm agriculture faces a slump in the price of oil palm fresh fruit bunch (FFB), and this price is set without consideration of FFB grade in terms of oil extract yield. There is a lack of incentives to develop higher yielding oil palms. Farmers may also harvest the FFB before the ripe stage, although the ripe stage gives the highest oil extraction yields. It is important to provide ripe fruits to mills for oil extraction in order to produce high quality crude oil. The overripe and unripe FFB in the mills reduces quality of extracted oil. On the other hand, agricultural product quality conventionally plays a fundamental role in nearly all food industry quality assessments. Generally, skilled workers grade the oil palm FFB subjectively, mainly visually with color criteria, to determine the prices paid to the farmers. Oil palm fruit as unripe are usually black and turn reddish brown when they reach the ripe stage (Makky, 2016). However, human errors often occur in the grading, especially for workers with less experience.

Various techniques have been studied to determine the ripeness of oil palm fruit or their maturity stage. Near infrared image for classifying oil palm fruit was proposed by Kassim *et al.* (2014). Hue, Saturation and Intensity (HSI) approach was proposed by Shabdin *et al.* (2016) for ripeness detection of oil palm fresh fruit bunches. On the other hand, the ability of oil palm fruits to resist

Chucheep, T., Mahathaninwong, N., Limhengha, S., Petchui, D. and Templong, P.
Ripeness Inspection of Oil Palm Fruits by Applying Hardness Test Technique.
DOI: 10.5220/0009981500002964
In *Proceedings of the 16th ASEAN Food Conference (16th AFC 2019) - Outlook and Opportunities of Food Technology and Culinary for Tourism Industry*, pages 279-283
ISBN: 978-989-758-467-1

compressive load has been investigated, and is related to their ripeness. Azli *et al.* (2009) investigated the relation between forces (injection) with the ripeness level of palm oil fruit. Keshvadi *et al.* (2011) determined the relationship between palm oil development in mesocarp and kernel and mechanical properties of fresh fruit bunches during the ripening process of Tenera clonal variety of oil palm (*Elaeis guineensis*) and found that compressive load of fruit grown for 8 weeks significantly increased till 16 weeks, but after that, it had a downward trend. In addition, the oil content in fruit clearly still increased from 16 weeks to 20 weeks. From these results, the firmness of mesocarp against compressive loads is associated with the ripening process of oil palm fruits. Unfortunately, the relationship between compressive strength and oil yield of oil palm fruits has not been investigated.

Therefore, this work aimed to measure the ripeness of oil palm fruits by using a hardness test, and determine the relationship between compressive strength and oil yield.

2 MATERIALS AND METHODS

2.1 Test Samples of Oil Palm Fruits

The study was performed in June of 2019. The samples (Figure 1) were oil palm fresh fruits (*Elaeis guineensis*) of COMPACT and CIRAD varieties from a private farm (32,000 m^2) in Muang district, Surat Thani province, Thailand. All samples were taken from 8 year old plants and represented the three stages of unripe, under-ripe and ripe, as estimated by farmers visually based on color criteria. Samples of each stage were collected from the middle region of each oil palm fresh fruit bunch (FFB). The number of fruit sampled from each bunch was ten. All measurements were done at room temperature.

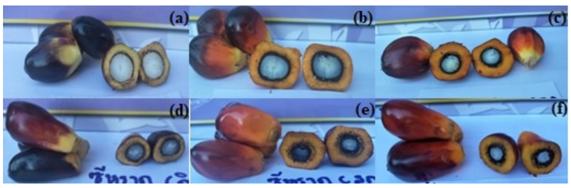

Figure 1: Oil palm fresh fruit samples of COMPACT variety in (a) unripe, (b) under-ripe, and (c) ripe stages; and of CIRAD variety in (d) unripe, (e) under-ripe, and (f) ripe stages.

2.2 Testing Methods

The testing apparatus designed and implemented had a sample holder, five alternative indenter tip sizes, and a load cell, as shown in Figure 2 (a)-(c). Figure 2 (d) and (e) show the sample holder fixed on a load cell and readout connection to the load cell. The testing apparatus schematic is shown in Figure 3. Oil palm fresh fruit samples were placed on the sample holder and the indenter with steel ball tip for various diameter 4, 6, 8, 10, or 12 mm was loaded. The indenter tip was compressed against the middle of an oil palm fruit to a depth of 2 mm from outer mesocarp surface. The compressive force curve was recorded during the test over 15 seconds, as shown in Figure 4, and the peak compressive force represented the strength or hardness of oil palm mesocarp. This testing method is based on a common hardness testing technique. The size or depth of indentation is measured at a constant compressive force in a typical hardness test, while this work controlled the depth of indenting instead of the compressive force (kgf).

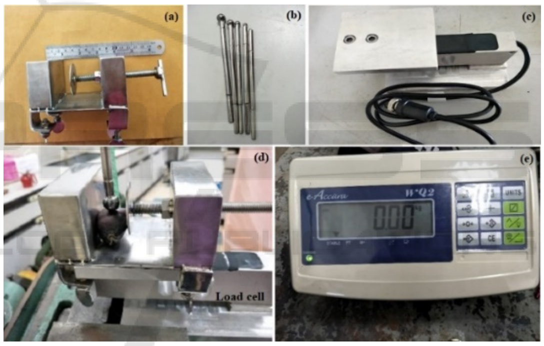

Figure 2: (a) Specimen holder, (b) five sizes of steel ball indenters, (c) load cell, (d) setup of the experiment, and (e) load cell readout.

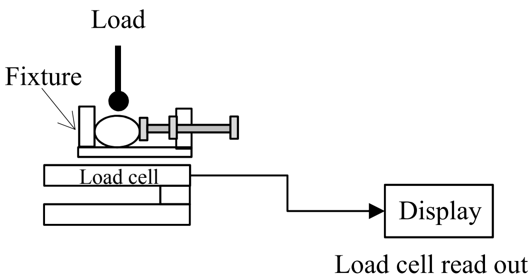

Figure 3: Schematic diagram of the testing set up (not to scale).

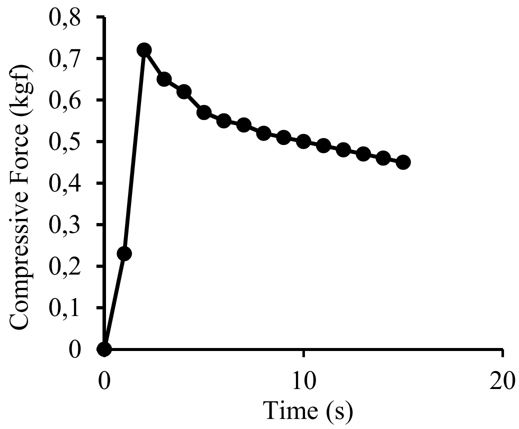

Figure 4: Compressive force recorded during testing.

2.3 Mesocarp Oil Yield and Moisture Content Measurements

Oil palm fruit samples (400 g) were collected from the middle of each FFB (the same FFBs as in ripeness testing), as shown in Figure 5 (a), and 250 g mesocarp of oil palm fruits was collected. The chopped samples were dried at 60°C for two days to remove water in the mesocarp, as shown in Figure 5 (c). The dried samples were then sent for analysis of oil yields to Surat Thani Oil Palm Research Center. Moisture of oil palm mesocarp was measured from 5 g of fresh mesocarp, which was chopped up and then dried at 60°C for two days. The mesocarp moisture content was determined as follows:

$$\% \text{ Moisture} = \frac{\text{(fresh weight-dried weight)}}{\text{(fresh weight)}} \times 100\% \quad (1)$$

Figure 5: Sample preparation for mesocarp oil yield measurement.

3 RESULTS AND DISCUSSION

The average compressive forces of oil palm fruits (COMPACT and CIRAD variety) were higher in the unripe stage than in under-ripe and ripe stages, for all steel ball sizes, as shown in Figures 6 and 7.

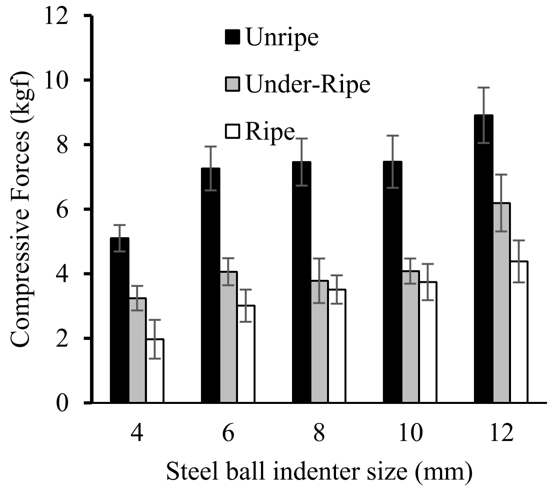

Figure 6: Average compressive forces of three stages of COMPACT oil palm fruits, tested with five indenter tip diameters.

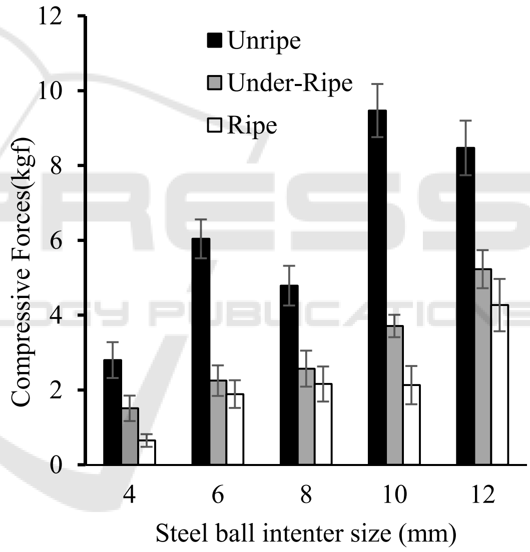

Figure 7: Average compressive forces of three stages of CIRAD oil palm fruits, tested with five indenter tip diameters.

The average compressive forces of COMPACT oil palm fruits in unripe stage were 5.10±0.41, 7.26±0.68, 7.46±0.73, 7.47±0.81 and 8.91±0.86 kgf with steel ball diameters of 4, 6, 8, 10 and 12 mm, respectively. The CIRAD oil palm fruits in unripe stage had average compressive forces of 2.80±0.48, 6.04±0.52, 4.79±0.53, 9.47±0.71 and 8.47±0.73 kgf with steel ball diameters 4, 6, 8, 10 and 12 mm, respectively. The average compressive forces for both COMPACT and CIRAD oil palm fruits decreased notably for the under-ripe stage. The COMPACT oil palm fruits had average compressive forces of 3.24±0.38, 4.06±0.42, 3.78±0.69, 4.08±0.39 and 6.19±0.88 kgf for 4, 6, 8, 10 and 12 mm diameter indenters, respectively. For CIRAD, the average compressive forces were 1.51±0.34, 2.25±0.41, 2.57±0.48, 3.71±0.30 and 5.23±0.51 kgf for 4, 6, 8, 10 and 12 mm diameter indenters, respectively. However, there was mostly no difference in average compressive forces between under-ripe and ripe stages, for either oil palm variety, when indented by steel ball sizes of 6, 8 or 12 mm. The 4 mm ball diameter could distinguish oil palm fruits between under-ripe and ripe stages for both COMPACT and CIRAD varieties. In addition, the 4 mm steel ball diameter gave the lowest average compressive forces among the steel ball sizes tested. These results match an investigation by Azli *et al.* (2009) who found that compressive resistance of oil palm fruits grows significantly from unripe stage to under-ripe stage. Mesocarp oil yield and moisture content of COMPACT and CIRAD oil palm fruits of unripe, under-ripe and ripe stages were determined, with results summarized in Table 1. The oil yield was low in unripe stage but increased significantly for under-ripe and ripe stages. The investigation of Keshvadi *et al.* (2011) also found that oil yield of oil palm fruits (Tenera species) increased significantly during ripening for 16 to 20 weeks. The oil palm moisture varied inversely to oil yield. The oil yields of oil palm fruits in unripe stage were 27.71% for COMPACT and 59.42% for CIRAD. Both oil palm varieties had 75-76% oil yields for under-ripe and ripe stages. It could be seen that oil yield of oil palm fruits in under-ripe stage was not different from that of ripe stage. On the other hand, the hardness of oil palm mesocarp was measured in terms of compressive force and the results from testing with a 6 mm diameter steel ball indenter was selected, as shown in Table 1.

Table 1: Mesocarp oil yield, moisture content, and compressive forces.

Variety	Stage	Mesocarp oil yield (%)	Moisture content (%)	Force (kgf)
COMPACT	Unripe	27.71	53.33	7.26±0.68
	Under-ripe	75.11	32.33	4.06±0.42
	Ripe	76.78	28.08	3.01±0.50
CIRAD	Unripe	59.42	83.71	6.04±0.52
	Under-ripe	76.67	27.86	2.25±0.41
	Ripe	75.79	23.71	1.89±0.37

The compressive force results with this indenter were associated with mesocarp oil yield, more so than with the other indenter sizes tested. The oil yield increased in accordance with the ripening, while the compressive strength of mesocarp in the oil palm fruits decreased. Oil yield was almost stable after the under-ripe stage, and so was the hardness of oil palm mesocarp. This is in line with Keshvadi *et al.* (2011) who state that it is difficult to recognize the fruit maturity stage.

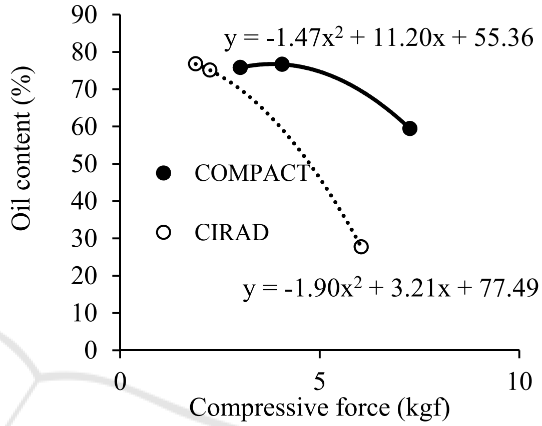

Figure 8: Relationship between oil content and compressive force on indenting COMPACT and CIRAD oil palm fruit with a 6 mm diameter steel ball.

Relationship between oil yield and compressive force on indenting COMPACT and CIRAD oil palm fruits can be seen in Figure 8, with least squares regression fits to the data.

4 CONCLUSIONS

The ripeness inspection of oil palm fruits by a hardness test was investigated, and the outcomes found were:

(1) The compressive indentation force be can used to estimate the grade of oil palm fresh fruits, distinguishing between unripe and either under-ripe or ripe stages. However, this is unable to distinguish between under-ripe and ripe stages.

(2) The compressive force measured is associated with mesocarp oil yield.

(3) The empirical relationships between oil content and indentation force depended on variety: $y=-1.47x^2+11.20x+55.36$ for COMPACT oil palm fruits and $y=-1.90x^2+3.21x+77.49$ for CIRAD oil palm fruits.

ACKNOWLEDGEMENTS

We would like to express our gratitude to Prince of Songkla University, Surat Thani Campus, The Center of Excellence in Materials Engineering (CEME) and Intelligent Automation Research Center (IARC), Faculty of Engineering, Prince of Songkla University Hat Yai Campus for granting financial support to this project. In addition, the authors would like to thank Assoc. Prof. Dr.Seppo Karrila for commenting on the manuscript.

REFERENCES

Azli, A.R., Shahril, K., Nor Hayati, S., Sukarnur, C.A., 2009. Novel Method of Grading Fresh Fruit Bunches (FFB) of Oil Palm Fruit. *Conf Sci Soc Res.* March 2009:1-8.

Keshvadi, A., Endan, J.B., Harun, H., Ahmad, D., Saleena, F., 2011. The Relationship Between Palm Oil Index Development and Mechanical Properties in the Ripening Process of Tenera Variety Fresh Fruit Bunches. *Res Jour App Sci Eng Tech*. 3(3): 218-226.

Kassim, M.S.M., Ismail, W.I.W., Teik, L.H., 2014. Oil Palm Fruit Classifications by using Near Infrared Images. *Res Jour App Sci Eng Tech*. 7(11): 2200-2207.

Makky, K., 2016. A Portable Low-Cost Non-Destructive Ripeness Inspection for Oil Palm FFB. *Inter Conf Food Agric Nat Reso 2015*. Agric Agricul Sci Proc 9: 230-204.

Shabdin M.K., Shariff, A.R.M., Johari, M.N.A., Saat, N.K., Abbas, Z., 2016. A study on the oil palm fresh fruit bunch (FFB) ripeness detection by using Hue, Saturation and Intensity (HSI) approach. *IOP Conf. Ser.: Earth Environ. Sci. 37*: 1-10.

Petchseechoung, W., 2017. Thailand Industry Outlook 2017-19 Oil Palm Industry. *Krungsri Res. June 2017*. Bangkok: Krungsri Bank: 1-8. https://www.krungsri.com/bank/getmedia/ac87c171-db74-442b-ae29-5b69572896ca/IO_Oil_Palm_2017_EN.aspx [Aug 30, 2019]