Hue Optical Properties to Model Oil Palm Fresh Fruit Bunches Maturity Index

Wan Ishak Wan Ismail
Professor,
Department of Biological and Agriculture Engineering,
Faculty of Engineering, Universiti Putra Malaysia,
43400 UPM, Serdang, Selangor, Malaysia.

and

Mohd. Hudzari Razali
Special Graduate Research Assistant,
Institute of Advanced Technology, Universiti Putra Malaysia,
43400 UPM, Serdang, Selangor, Malaysia.

ABSTRACT

Harvesting of the oil palm fresh fruit bunches (FFB) at correct stage of ripening is important in maximizing the quality of oil of the oil palm FFB. A non-destructive and real time simulation method is necessary to predict the FFB maturity stage while on the tree. Three colors form the basis for the RGB-colorspace and it can also be transformed into one common basis for the color space in HSI. In the HSI coordinate system, a color is described by its hue (average wavelength), saturation (the amount of white in the color), and intensity. This color space makes it easier to directly derive the intensity and color of perceived light. Furthermore it can be used as an optical property of digital value. The experiment was conducted to determine the Hue optical properties of the three categories of Fresh Fruit Bunches (FFB) namely unripe, underripe and ripe. Nikon Coolpix 4500 digital camera with tele-converter zooming and the Keyence vision system were used to capture the FFB images in actual oil palm plantation. The relationship of the oil content for mesocarp oil palm fruits with the digital value of Hue was analysed. The lighting intensity under oil palm canopy was simultaneously recorded and monitored using Extech Light Meter Datalogger. Using Analysis of Variance (ANOVA), the ratio of test statistic of F with $F_{critical}$ for experiments under natural environment of oil palm plantation indicated the hue value was the best color digital component to differentiate the maturity level (unripe, ripe and overripe) of FFB in real time oil palm plantation. On the same day, the fruitlets were plucked from FFB and analysed for its oil mesocarp content using the Soxhlet Extractor machine. The calculations to determine the mesocarp oil content was developed based on the ratio of oil to dry mesocarp. The equation model obtained was $Y = -0.0116X^2 + 5.2376X - 514.88$ and $R^2 = 0.884$. Y is the mesocarp oil content, X is the Hue value and R^2 is the Regression Squared respectively. From this finding, the knowledge based method can be developed for communication of management strategy of oil palm plantation by estimation the days harvesting of FFB with the highest oil content and quality in the fruit.

Keywords: Simulation Model, Maturity Index, Mesocarp Oil Content, Oil Palm FFB, Optical Properties, Camera System, Hue Digital Value.

1. INTRODUCTION

Agriculture in Malaysia is still one of the biggest enterprise and the most important sector in Malaysia's economy. In the last 35 years, Malaysia has emerged as the number one producer of palm oil. Currently, Malaysia accounts for about 55% of world palm oil production and about 62% of world exports [1]. As the largest producer and exporter of palm oil and palm oil products, in general, Malaysia plays an important role in fulfilling the growing global need for oils and fats. The Malaysian oil palm industry continues to contribute significantly to the country's economic development and foreign exchange earnings. However, the Malaysian oil palm industry needs more emphasis on its research and development to meet the world challenge and to maintain Malaysia as the top world producer of palm oil. The major problem faced by the oil palm plantation is shortage of labor, which will only be solved with the introduction of appropriate machineries.

Harvesting oil palm fresh fruit bunches (FFB) at the right stage of ripeness is critical to ensure optimum quality and quantity of oil production, and thus profitability of the industry. The most critical process in FFB grading is to categorize the bunches into ripe, under ripe and unripe. The MPOB manual on FFB grading defines a ripe bunch when the mesocarp colour is reddish orange and the bunch has 10 or more empty sockets of detached fruitlets; an under ripe bunch has yellowish orange with less than 10 empty sockets; and an unripe bunch has yellow mesocarp with no empty sockets [2]. A fruit bunch normally takes perhaps 20 to 22 weeks to ripen and those less than 17 weeks old could be classified as unripe or black bunches[3]. The skin color of the fruit bunch will change from black to reddish and orange during ripeness process. The change in the mesocarp colour is due to the accumulation of the carotene pigments, which also corresponds to the oil content of the mesocarp when analysed. Kaida and Zulkifly [4], mentioned that the fruit bunch with 7-11 weeks after anthesis had black color skin, 15 – 17 weeks had black mixed reddish black, after 18-19 weeks had color of reddish orange, at 20-22 weeks had color of reddish orange mixed orange and 21 – 24 weeks will mostly orange of color skin of the fruits.

Kaida and Zulkifly [5] developed the application of microstrip sensor to determine the moisture content which will indicate or approximate the oil content of fresh mesocarp oil palm. This destructive method is not possible to be applied for tall palm trees age 10 years or above. Using non-destructive technique such as vision to determine the oil palm ripeness, Wan Ishak et al., used camera vision to categories six oil palm FFB [6]. Abdullah et al., used computer vision model in order to inspect and grade the oil palm fresh fruit bunches [7]. S.K Balasundram et al., used camera vision to investigate the relationship between oil content in oil palm fruit and its surface color distribution [8]. Idris et al., use colorimeter and found a strong correlation between mesocarp oil content and color values [9]. Advantages of using imaging technology for sensing are that it can be fairly accurate, nondestructive, and yields consistent results. At the moment there was no research carried out vision systems test on actual oil palm plantation for maturity recognition. The advantage of predicting the oil palm fruit maturity in real time oil palm plantation will help harvesters to harvest the oil palm FFB at the correct maturity stage.

Advantages of using imaging vision technology for sensing the maturity stage of agriculture products are that it can be fairly accurate, nondestructive, and yields consistent results [6]. Wan Ishak et al., [9] reported that 6 categories of Oil Palm Fruit Bunches were determined by mean of RGB value and tested indoor environment condition using machine vision technology. This project was conducted to determine and differentiate between the colour properties of oil palm fruit bunch. S.K Balasundram et al., [8], used camera vision to investigate the relationship between oil content in oil palm fruit and its surface color distribution. He found that the surface color of oil palm fruits correlated significantly with total oil content and ripeness.

2. METHODOLOGY

The experiment started by capturing of images of FFB from unripe stage until overripe stage. The NIKON coolpix 4500 digital camera was used to digitally capture fruit images. The camera was set to manual mode and the shutterspeed of the camera was set to 1/8, while the white balance was set using standard white calibrator CR-A74. This parameter value was experimentally suitable for capturing FFB images during day light [11]. The FFB image was photographed from under the canopy of 5, 16 and 20 years old oil palm tree in the actual plantation condition. The position of the camera was fixed within 3 meters from oil palm tree and this was due to fact that the area covered by leaves was within 3 to 7.5 meters radius in length [12]. Figure 1 shows the camera setup during the experiment to monitor the five years old palm tree. The camera was placed at the distance with no obstructions view of the fruits, therefore a clear FFB image. It emulates the visibility of the worker in manual harvesting on plantation. The data logging light meter recorded the light intensity during image capturing. Distances and heights between cameras and fruits and reference point were fixed for all samples.

Figure 1: The camera setup during experiment process
(Small picture: top-left: Nikon Digital camera, down-right- Keyence Vision System).

Figure 2 shows the images of FFB used in the experiment on natural environment setting and experiment under direct sunlight. Picture (A) shows unripe FFB under natural condition, Picture (B) shows ripe FFB under natural condition, Picture (C) shows overripe FFB under natural condition, for experiment on natural environment, Picture (D) shows ripe FFB under direct sunlight, Picture (E) shows unripe FFB under direct sunlight, Picture (F) shows overripe FFB under direct sunlight.

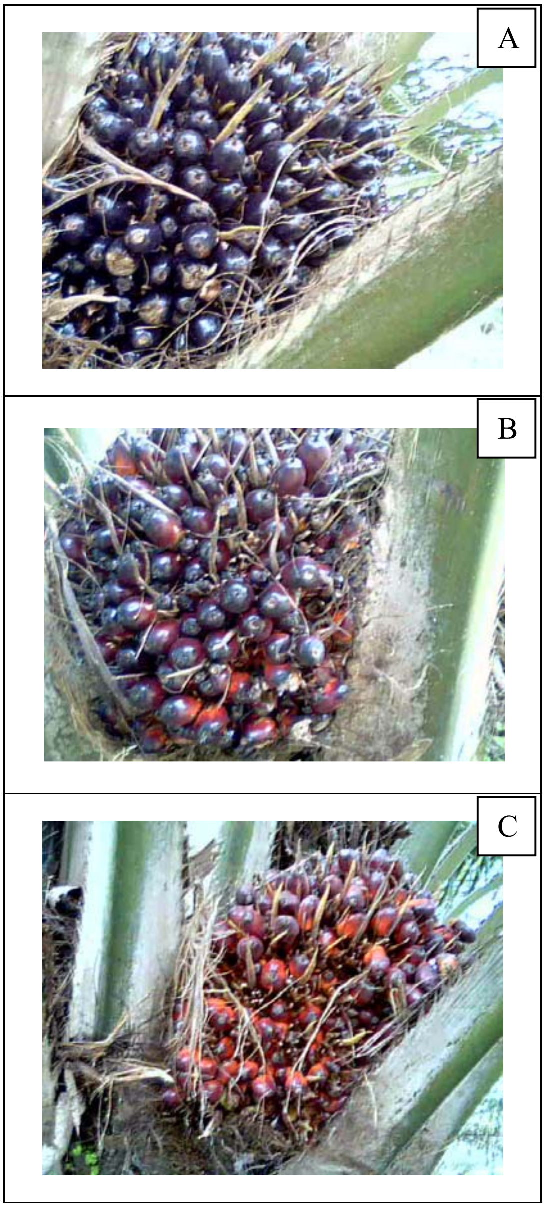

Figure 2: FFB images used in the experiment on natural environment setting and experiment under direct sunlight

This equipment was used to determine the oil content of fruits. The process starts with the samples being weighed and dried at 75^0C in the oven a day before being packed with filter paper. The dry nuts and mesocarp were weighed and blend to get particle before pack into filter papers; (brand of Whatman Cat No 1001 150) and the oil was extracted in soxhlet machine using chemical solvent namely hexane. The remnant fibre and thimble were dried under 75^0C for 3 days to remove the remaining hexane. The samples were weighed. All the weight of measurements was recorded in the form for mesocarp oil content calculation [13]. In this study, three samples of fruits from different stage of maturity were harvested from 5, 16 and 20 years palm tree.

Software Analysis Development

The visual basic programming language version 6 is the platform to develop the software analysis to be used in this project. It contains an excel worksheet programming software and populate it with sample scientific data. Next it will draw a chart and modify the charts location and dimensions [14]. To read and manipulate the pixel value of image, the function of windows API (Application Programming Interface) called GDI32 (Graphic Device Interface: 32-bit version) was applied and the Hue pixel value was determined by the total value (0 to 255) assigned for each colour bands of red, green and blue as calculated here [15];

if $B \geq G$; $H^0 = 360^0 - \cos^{-1}[-0.5[(R-G) + (R-B) / [(R - G)^2 + (R - B)(G - B)]^{0.5} \times 255/360$

if $B<G$; $H^0 = \cos^{-1}[-0.5[(R-G) + (R-B) / [(R - G)^2 + (R - B)(G - B)]^{0.5} \times 255/360$;

where R is red component pixel value, G is green component pixel value, B is blue component pixel value. The embedded histogram application that was developed by software was use to determine the maximum R,G and B pixel value of captured FFB images. This R,G and B value will then be converted to single Hue value as average value for overall FFB images. These histogram methods which basically just a graphing of the frequency of each intensity of red, green, blue or luminance in an image is used [11].

Simulation of Hue Value Determination

The images captured were fed into the software and these images were analysed using RGB histogram module. Figure 6 shows the Hue digital value simulation model. The Hue value of the images obtained from RGB conversion value would then go through validation process by comparing the value obtained from Keyence vision. The histogram method which basically just a graphing of the frequency of each intensity of red, green, blue or luminance in an image is used. The Hue value was calculated from conversion using formula depicted as mentioned.

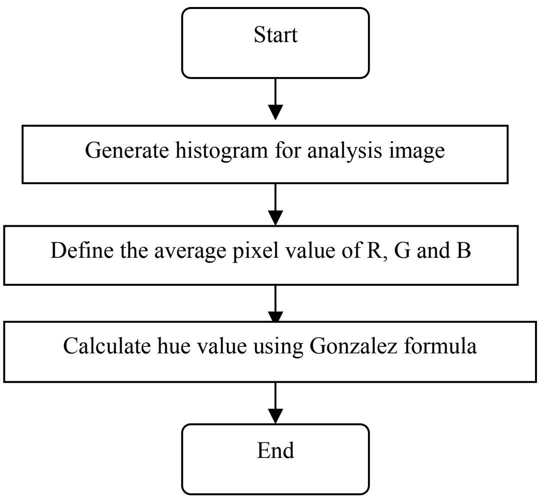

Figure 3: Algorithm flow chart of hue value simulation model

3. RESULTS AND DISCUSSION

The data obtained during the processing of images was analyzed using statitical data analysis software. The ANOVA single factor analysis was executed using Microsoft Excel.

Table 1 shows the significant analysis for Hue color component of oil palm FFB Since the F statistic (*F*) is larger than the critical value (*F critical*), therefore the null hypothesis (h_0) which states that the means of the groups are equal was rejected. From the summary above, the conclusion that can be derived is that the Hue component highly can be used to differentiate between the ripe, unripe and overripe FFB.

Table 1: Analysis for Hue color component of FFB

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Hue (ripe)	10	2449	244.9	47.21111
Hue (unripe)	10	1707	170.7	16.23333
Hue (overripe)	10	63	6.3	18.67778

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*
Between Groups	298209.9	2	149104.9	5446.94
Within Groups	739.1	27	27.37407	
Total	298949	29		
P-value	6.41E-36			
F critical	3.354131			

Table 2 shows the analysis for red color component of the oil palm FFB. Since the F statistic (*F*) is larger than the critical value (*F critical*) as shown in Table 2, the null hypothesis (h_0) which states that the means of the groups are equal was rejected. From the summary above, the conclusion that can be derived is that the Red component also was highly can be used to differentiate between the ripe, unripe and overripe FFB.

From the overall result of ANOVA test, the hue value was highly significant in identifying the optical properties of each of the categories of FFB namely ripe, unripe and underripe. This is shown in Table 3. In general all the test showed that the F value is larger than *F crititical* value and hue was the highest followed by red, green and blue respectively.

Table 2: Analysis for Red color component of FFB

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
RED (ripe)	10	1578.778	157.8778	171.47
RED (unripe)	10	546.1111	54.61111	313.58
RED (overripe)	10	2255	225.5	163.57

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*
Between Groups	148132.6	2	74066.3	342.57
Within Groups	5837.605	27	216.2076	
Total				
P-value	6.51E-20			
F critica0	3.354131			

While for Green color component was resulted, F statistic (*F*) is larger than the critical value (*F critical*) with 27.24 and 3.35 respectively which means the green component can be used to differentiate between ripe, unripe and overripe. The Blue color component is the lowest with 4.61 and 3.35 respectively as shown in Table 3.

Table 3: Statistical Test Result on FFB Optical properties (Outdoor Condition)

Optical Properties\Test Statistic	***F***	***F critical***
Hue	5446.94	3.35
Red	342.57	3.35
Green	27.24	3.35
Blue	4.61	3.35

This result was similar to that of Hudzari et al. and Rashid et al., [11,16], which stated that the optical properties has significant relationship with FFB maturity. Hue has the highest optical properties, is a good mechanism for distinguishing maturity stage of oil palm fruits. The *F* value for Hue on natural environment testing was too high compared to the testing done on direct sunlight and this is due to the fact that the lighting from the sunlight was too intense. The phenomenon was different for the natural environment which was covered with tree canopies.

Figure 4 shows the correlation analysis as a measure of the reliability of relationship between the optical properties of fruit skin, hue (X) and the percentage of mesocarp oil content (Y) values. High correlation of R^2 was founded for a relationship of Hue digital value versus mesocarp oil content with equation of $Y = -0.0116X^2 + 5.2376X – 514.88$ and $R^2 =0.884$. The value of $R^2=0.884$ show high correlated of hue value and the oil content of FFB.

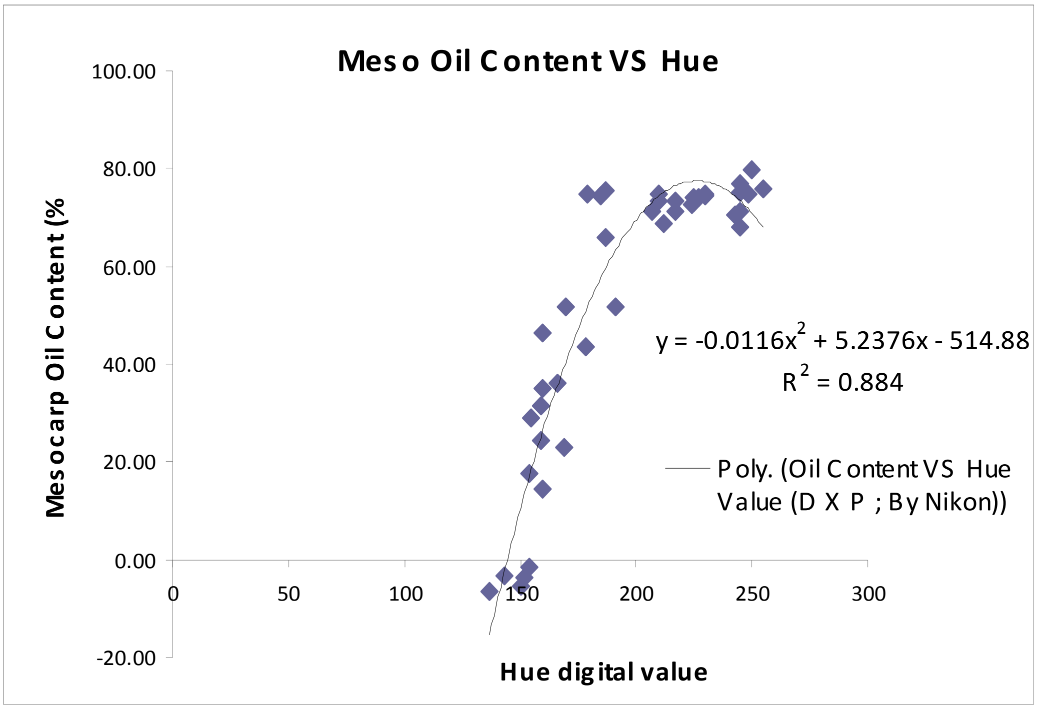

Figure 4. The relationship of optical properties for fruit color versus mesocarp oil content.

The relationship of mesocarp oil content with optical properties for the fruit was illustrated using trendline analysis of polynomial second order method. The result showed that the hue value of FFB image was highly significant in determining the oil content of oil palm fruit.

4. CONCLUSIONS

These experiment were conducted so as to determine and model an equation between the Hue optical properties of the oil palm fruits at different stages of maturity. The maturity stages were based on mesocarp oil content. Finding of the research stated that the optical property has significant relationship with FFB maturity. Hue has the highest optical properties, is a good mechanism for distinguishing maturity stage of oil palm fruits. The hue value was the best color digital component to differentiate the maturity level of FFB in real time oil palm plantation. The variances of lighting intensity were not affecting the Hue value of the target color which also stated by David, Gevers and Smeulders; because this color system separates the color information of an image from its intensity information [17,18]. The experiment conducted in an oil palm plantation had showed good result on significance of optical properties with maturity level. The procedure in monitoring the image pixel value of different maturity stages for real oil palm fruit was determined. The prediction model for harvesting based on Hue's value used in this project is more advanced as compared to the used of Microstrip sensor on previous research. This method is a non-destructive application. This method of work can be used in real time prediction in an actual oil palm plantation.

5. REFERENCES

[1] Malaysian Palm Oil Industry Performance (MPOIP, 2008), **Global Oils & Fats Business Magazine**, Vol.6 Issue 1 (Jan-March), 2007.

[2] MPOB. 2005. **Malaysian Oil Palm Board**, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia

[3] Azis A. A., Mohamadiah Banjari, W Zailan Rosnah Mat Soom, W Omar and Chen Kin W. (1984). Ripeness Standard: Any sign of Loose Fruit and with One Loose Fruit per Bunch as the Minimum Standard. **Proceeding Of The Symposium On Impact Of The Pollinating Weevil On The Malaysian Oil Palm Industry** (pp. 165-176). Kuala Lumpur. Palm Oil Research Institute of Malaysia

[4] Kaida Khalid, Zahariah Zakaria and Wan Daud Wan Yusof, (1996), Variation of Dielectric Properties of Oil Palm Mesocarp With Moisture Content And Fruit Maturity at Microwave Frequencies, **Elaeis**, Vol. 8 No. 2, Pp. 83—91

[5] Kaida Khalid and Zulkifly Abbas (1992), A Microstrip Sensor for Determination of Harvesting Time for Oil Palm Fruits, **Journal of Microwave Power and Electromagnetic Energy**,Vol.27 No.1

[6] Wan Ishak W. I., Mohd. Zohadie B., A.Malik A.H. (2000). Optical Properties for Mechanical Harvesting of Oil Palm, **Journal of Oil Palm Research**, Vol. 11, No. 2, pp. 38-45

[7] M.Z. Abdullah1, L.C. Guan2 And B.M.N. Mohd Azemi (2004). "Stepwise Discriminant Analysis For Colour Grading Of Oil Palm Using Machine Vision", **Trans Icheme**, Vol 77, Part C

[8] S.K Balasundram, P.C Robert, D.J Mulla (2005), Relationship Between Oil Content and Fruit Surface Color in Oil Palm Elaeis guineensis Jacq., **Journal of Plant Sciences** (pp. 217-227), Volume: 1, Issue: 3

[9] Idris O., M.Ashhar K., M.Haniff H. and M. Basri W. (2003), Colour Meter for Measuring Fruit Ripeness, **MPOB Information Series** (p. 195), ISSN 1511-7871

[10] Yud-Ren Chen, Kuanglin Chao, Moon S. Kim, Machine vision technology for agricultural applications, **Computers and Electronics in Agriculture,** 35 (2002) 173-171.

[11] Mohd Hudzari R., Wan Ishak W. I., Abd. Rahman R., Md. Nasir S., and Mohd. Haniff H. (2009), Development of Image Based Modeling for Determination of Oil Content and Days Estimation for Harvesting of FFB, I**nternational Journal of Food Engineering**, Vol. 5, Iss. 1, Article 1

[12] Md. Abdul Awal, (2005b), Image-Based Measurement of Leaf Area Index and Radiation Interception For Modelling Of Oil Palm, **Unpublished PhD Dissertation**, Universiti Putra Malaysia.

[13] Flingoh Ch Oh and Zukarinah Kamurind (1989), Measurement Palm Mesokarp Oil Content by Nuclear Magnetic Resonance Spectroscopy, Porim, **International Palm Oil Development Conference,** (p. 238-241) Kuala Lumpur, Malaysia

[14] Mohd. Hudzari Razali, Wan Ishak Wan Ismail, (2007). Development Of Software Automation For Agriculture Vision System, **World Engineering Congress (Wec07),** 5 – 7 August 2007, Penang, Malaysia

[15] Gonzalez, R. C. and Wintz, P., (1787), **Digital Image Processing**, (Add.-Wesley, Reading, USA)

[16] Rashid Shariff, Nor Aizam Adnan, Radzali Mispan, Shattri Mansor, Rohaya Halim and Roop Goyal (2004), Correlation Between Oil Content and DN Values, Department of Biological and Agriculture, Universiti Putra Malaysia, **GISdevelopment.net**

[17] David Forsyth, (1990), A novel algorithm for color constancy, **International Journal Computer Vision**, 5, 5–36.

[18] Theo Gevers and Arnold W.M. Smeulders (1999), Color-based object recognition. **Pattern Recognition**, 32,453–464