International Scholars Journals

Advances in Agriculture and Agricultural Sciences ISSN 2756-326X Vol. 10 (5), pp. 001-008, May, 2024. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Real-Time Oil Palm Fruit Maturity Prediction: A Simulation-Based Approach

Mohd. Hudzari Razali[1]*, Wan Ishak Wan Ismail[1,2], Abd. Rahman Ramli[1], Md. Nasir Sulaiman[3] and Mohd. Haniff B. Harun[4]

[1]Intelligent System and Robotics Laboratory, Institute of Advanced Technology, Universiti Putra Malaysia, Serdang, Selangor, Malaysia.

[2]Department of Biological and Agriculture Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, Selangor, Malaysia.

[3]Department of Computer Science and Information Technology, Faculty of Science Computer and Information Technology, 43400 Universiti Putra Malaysia, Serdang, Selangor, Malaysia.

[4]Crop Physiology, Biological Research Division, Malaysian Palm Oil Board, No. 6, Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia.

Accepted 23 February, 2024

This paper is to introduce the new method of procedure in studying the relationship of the mesocarp oil content with the colour skin of oil palm fruit with respect to its maturity. The procedure started after collecting the fruitlets sample from fresh fruit bunches (FFB) during unripe, until overripe stage. The variety of oil palm is *Pisifera* (Dura X Tenera). The images on each three age categories of FFB were captured at monitoring area with setting image parameter. NIKON coolpix4500 digital camera with tele converter zooming device was used to capture the image. Subsequently, after the end of the capturing session, the fruitlets were pulled from FFB and sent to analyse for oil mesocarp content. The Soxhlet Extractor Soxhlet apparatus is used to determine the oil content of the fruit based on the experiment of standard bunch analysis procedure. The image will be analysed for optical properties of colour, using developed analysis Graphical User Interface (GUI). Using regression analysis of polynomial 2nd order method, it shows that the optical property of oil palm fruit was significant in determining the oil mesocarp fruit with respect to its degree of maturity.

Key words*:* Day estimation for harvesting, hue digital value, maturity prediction, mesocarp oil content, oil palm optical properties.

INTRODUCTION

All creation and plant need energy to perform its life functions. This energy is received directly from sunlight which was created by Allah. As stated in Al-Quran in surah Al-Mulk, chapter 67 verses 3, more or less, means that Allah makes creation perfect without any defection. For plantation, the light energy is converted into chemical energy via the process of photosynthesis in the presence of chlorophyll, CO_2 and water. For humans, the visible light is the part of the electromagnetic spectrum, as shown in Figure 1. The photon is a packet of light that has wavelength associated with it, so a photon can be thought as both a particle and a wave. The longer wavelength contains the less energy, for example, blue light has short wavelengths and red light has longer wavelengths. Figure 1 shows the electromagnetic spectrum that indicated the variance of colour.

Colour is considered a fundamental physical property of agriculture products and foods. It is usually used for recognizing the maturity stage and harvesting process of agriculture products. In manual harvesting of oil palm, colour is the most important indicator for farmers to determine the maturity of the oil palm fruit called fresh fruit bunches (FFB). The need for ripeness assessment and crop quality control in the oil palm industry is mainly for the evaluation of processing results and to check harvesting discipline. Oil palm trees continuously produce fresh fruit bunches (FFB) and the amount of oil in its fruits

*Corresponding author. E-mail: mohdhudzari@unisza.edu.my, hud47@hotmail.com. Tel/Fax: [06]096275672 / 5633.

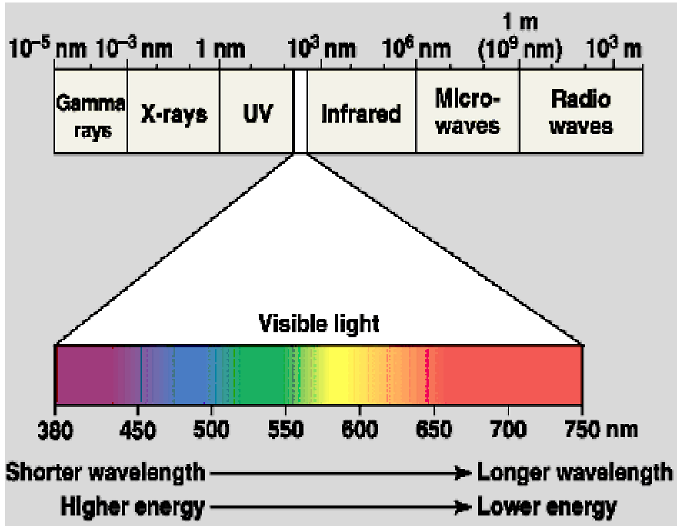

Figure 1. The electromagnetic spectrum (adapted from Simmon, 2004).

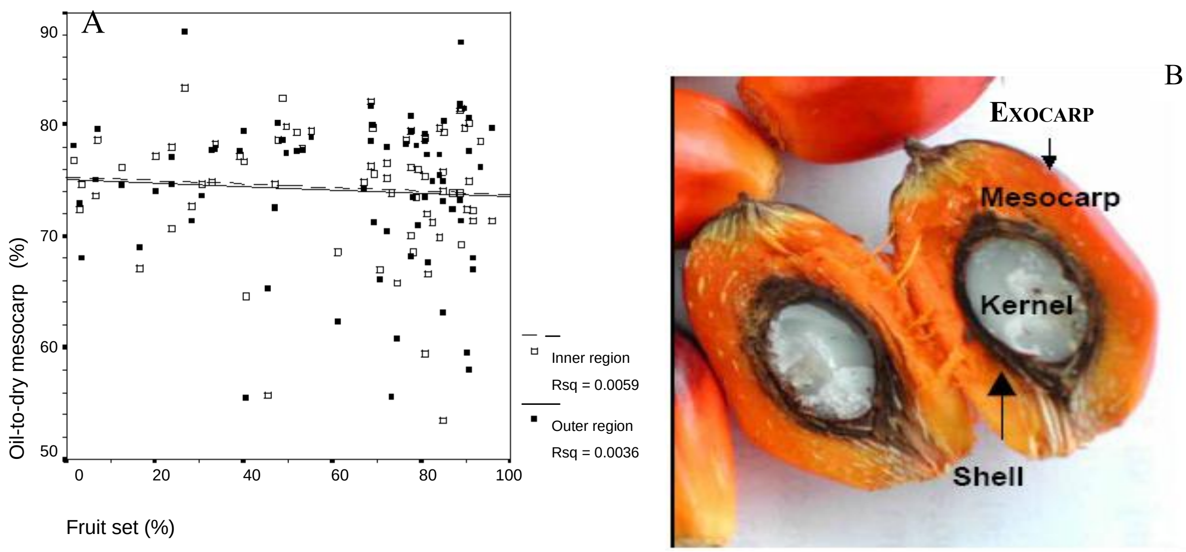

Figure 2. A: the oil to mesocarp (%) for ripe fruit (adapted from Hanif, 2002); B: the mesocarp structure for oil palm fruit.

builds up to a maximum, thereafter, declining due to the hydrolysis of fat to free fatty acid (Southworth et al., 1976). Mature bunches detach fruit progressively and ultimately become rotten and mouldy before breaking-up. In fact, for every 1% of unripe bunches present, the Oil Extraction Rate (OER) will decrease by 0.13%, while the FFA content will increase linearly as the percentage of overripe bunches increases (Siregar, 1976). Therefore, it is imperative that only good quality FFB be selected for harvesting and only ripe fruit be chosen for extraction and refining. Accordingly, the bunch is insufficiently ripe when more than 25% of the outer fruits detach and those with only 12.5 to 25% of outer fruits detached should be considered under ripe (Siregar, 1976). Oil is contained in the mesocarp as well as the endosperm of ripe fruits, Crombie and Hardman (1958) showed that most of the mesocarp oil was synthesized after 120 days from anthesis, and it is likely that oil synthesis in an individual fruits ceases at the time of fruit abscission. Abdul Azis et al. (1984) mentioned that a fruit bunch normally takes perhaps 20 to 22 weeks to ripen. Abscission of the normal ripe (21 or 22 week) bunch should therefore have more oil (> 50% in mesocarp) or 20 to 22% on bunch. Hanif and Roslan (2002), mentioned a maximum bunch weight of 24 kg and mesocarp oil content of 25% were obtained at a fruit set of 90 and 75% respectively as shown in Figure 2a. A minimum fruit set of about 40% sufficed to maintain the total mesocarp

Figure 3. Indicator shows the map of research site near Pekan Bangi, Selangor, Malaysia.

oil per bunch ratio >20%. Normally, the oil content of mesocarp is at mean of 75%. Figure 2b shows the mesocarp structure for oil palm fruit.

Visually, the colour of unripe fruit appears black to reddish black, whereas the colour of fully ripe fruit appears reddish orange. The Palm Oil Research Institute of Malaysia (now MPOB) established four classes of ordinary oil palm, *Elaeis guineesis*, which is used in this study (Jalil, 1994). According to these standards, the unripe class has a purplish black colour, covering more than 90% of fruit's surface. The colour at the base of this fruit appears colourless. Meanwhile, under ripe and ripe classes appear reddish black and reddish orange respectively over the upper half, tending to lighten towards base. Finally, the fruit belongs to the overripe class when it exhibits almost entirely reddish orange colouration.

Hence, the first task to ensure quality in oil milling is to select a good quality FFB for processing, which means, the only right ripe FFB should be harvested. Presently in the palm oil plantation, the ripe FFB will harvest based on color judgments only. Sometimes, the workers will hit and rub the FFB surface using harvesting chisel to ensure its ripeness. The worker may not clearly judge the color of FFB ripeness due to the tree being too tall. The objective of this study is to show the technique and procedure for simulating the degree of oil palm maturity model in outdoor condition by determining its optical properties and oil content. The FFB image will capture at unripe until overripe stage and its fruitlets were simultaneously removed and sent to test by soxhlet extractor for determination of its oil content. The equation model of relationship between oil content and optical properties will be developed. It is envisioned on development of nondestructive method for portable vision system which is to determine the optimum date of harvesting with respect to its oil content. In determining the oil palm ripeness, Wan Ishak et al. (2000) used RGB value for categorised six oil palm fruit bunches tested indoor environment condition. This project was conducted to determine and differentiate between the colours properties of oil palm fruit bunch.

Abdullah et al. (2001) used computer vision model in order to inspect and grade the oil palm fresh fruit bunches. The relationship between oil contents and colour was explored in HSI (hue, saturation and intensity) domain for ripeness determination of oil palm by four major classes: the unripe, the under ripe, the ripe and the over ripe. Idris et al. (2003) mentioned that a strong correlation was found between mesocarp oil content and colour values with R^2 = 0.82 (in second order polynomial regression analysis). Balasundram et al. (2006) investigated the relationship between oil content in oil palm fruit and its surface color distribution. It was found that the surface color of oil palm fruits correlates significantly with total oil content and ripeness which is also found by Razali et al. (2009) and Wan and Hudzari (2010). Hudzari et al. (2008) developed an equation to be used for detecting matured FFB. The vision system was developed to recognize the matured FFB in outdoor environment. The EXTECH Lightmeter was used to capture the intensity of the environment and the software manipulates and computes the compensation value between digital values of RGB component for matured FFB with environment intensity.

METHODOLOGY

The fruits were selected from 3 categories of palm trees aged, 5, 16 and 20 years old. The 5 years old was chosen because it is the initial production of FFB, 20 years is the optimum output while 25 and 30 years old is optimum age for replanting (Azman and Mohd, 2002). Sixty years is the middle age of oil palm production.

Selecting the fruit trees

The experiments for all three categories of oil palm (Tenera: *Elaeis guineensis*) were conducted in a research plot at the UKM-MPOB Research Station in Bangi Lama, situated about 30 km South of Kuala-Lumpur on Latitude 2° 58' 36" N and Longitude 101° 44' 26" E at an average altitude of 66.5 m above sea level . Figure 3 shows the map of research site.

Experimental steps

The image was captured using NIKON digital camera and the picture was automatically saved in the local memory of the camera. The images of fruits were captured with the highest optical zoom and focal length of 155 mm, and to get the fit area of the size of image, which was 640 × 480 pixels, a resolution that suited the window size of the image analysis was made in the developed software. In this experiment, more than 500 images of FFB were captured during unripe until overripe stage, which indicated at least 1 loose fruitlet detached from the bunch. Figure 4a indicates red rectangle for the monitoring area of capturing the FFB image. After finishing the capturing session for the FFB image, 3 fruitlets were removed from the bunch and packed to be sent for chemical analysis to determine its mesocarp oil content. The steps were repeated with a day's interval from fruits at unripe stage until overripe FFB. Figure 4b shows the monitored FFB image during capturing, 4c, d, shows the image of pulling the fruitlet from the bunch, 4e shows weighing of the fruits sample and 4f shows filing the form for data analysis.

Determination of oil content

In this study, nine experiments were conducted on every age categories of *Elaeis guineesis* (*Pisifera).* Three fruitlet samples were removed from bunch on each experiment for 5, 60, and 20 years old oil palm tree as shown in Ffigure 4d and e. With same bunch, three fruits were collected until the FFB reached the overripe stage. The samples were weighed and chopped. The samples were dried at 70°C for a day to remove the moisture content in the fruits. The dry nuts and mesocarp were weighed and blended to get particles before being packed into filter papers (Whatman Cat No 1001 150). The Oil was extracted in soxhlet extractor using hexane as chemical solvent. In case the soxhlet extractor machine is not available, the packing paper will be stored together with silica gel for wet absorption. After that, the remnant fibre and thimble were dried at 70°C for a day to remove the remaining hexane. The samples were weighed and the entire weight of measurements was recorded in the form for mesocarp oil content calculation (Flingoh and Zukarinah, 1989).

Capturing the FFB image

The NIKON Digital Camera and Nikon 3x Tele Converter TC-E3ED were used in this experiment. This type of lens was chosen because this is the highest zooming device for capturing as close as possible, to get full image size of 640 × 480 resolutions. This size was selected to suit the size of image analysis in developed software for histogram analysis which counts the value on every pixel of image captured. During experiments, the camera was set to manual mode to make constant image output. The shutter speed in the camera parameter was set with the exposure value. This parameter value was experimentally suitable to capture the FFB image in the whole day shift. The selected fruits were chosen at the unripe stage which, in overall, appeared to be black until it became overripe, with 50 to 90% fruit detached from bunch.

All the weight measurements will be recorded in the form for mesocarp oil content calculation. Table 1 shows the raw data and calculations to obtain the oil content of oil palm fruits.

Algorithm flow chart

The experiment started with capturing the images of FFB from 19 November, 2008 until 25 January, 2009 which means the FFB from the unripe until overripe stage. The images were taken at monitoring area of FFB and the camera with tripod stand was placed under canopy of oil palm tree in real plantation condition. After the capturing image session was over, 3 fruitlets were removed for chemical test run. These fruitlets must pull outside of the monitoring area as indicated on Figure 4a. These steps will repeat until the FFB gets to the overripe stage. More than 50 images were captured during one photography session.

During running the GUI program, the user choose the picture to be analyzed using VB 6.0. The user needs to insert the FFB image and run in order to get histogram value of luminance for monitored area of image. From maximum value of luminance, the value of hue will be determined. The developed validation GUI will be used to confirm maximum value of hue for overall image. The GUI was shown in Figure 5a and b. In Figure 5a, the green indicator shows the point chosen on the image and also shows that the threshold area is big when compared to the blue indicator on Figure 5b. If the user wants to analyze another FFB image, they have to repeat the same procedure described earlier. Finally, the graph of oil content of mesocarp versus pixel value was plotted automatically in this program.

Development of software analysis

The images captured were inserted and analysed into luminance histogram software to define the maximum luminance value of all maturity stages of FFB image. The hue value of the images will be taken from maximum value on RGB (red, green, blue) histogram and the validation process will manually be proofed by testing on developed threshold image analysis as shown in Figure 5a and b. These histogram methods, which are basically a graphing of the frequency on each intensity of red, green, blue or luminance in an image, are used. The Windows Application Programming Interface (API), which is a collection of dynamically linked libraries (so-called 'DLL files'), contain programming routines to generate the value of red, green and blue component of the image (Hudzari, 2007). The syntax for each of our API function declarations is as follows (Micheal, 1999):

```
Private Declare Function SetPixelV Lib "GDI32" (ByVal hDC As Long, ByVal x As Long, ByVal y As Long, ByVal crColor As Long) As Byte
```

The Hue value was calculated by the following formula (Gonzalez, 1987);

if $B \geq G$;

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

if $B<G$;

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

RESULT AND DISCUSSION

Figure 6 shows the relationship of FFB mesocarp oil content with hue value. The lighting intensity from sunlight was found not to be affected or less affected by the hue value of the FFB's colour skin which was also stated by Wan and Hudzari (2010).

Using trend line analysis of polynomial 2nd order method, the result showed that the hue value of FFB image was highly significant in determining the oil content of oil palm fruit with correlation in equation as;

$$Y = -0.0093X^2 + 4.373X - 440.06 \qquad \text{……… (1)}$$

$$R^2 = 0.9239 \qquad \text{………………………. (2)}$$

Where:

Y = Mesocarp oil content

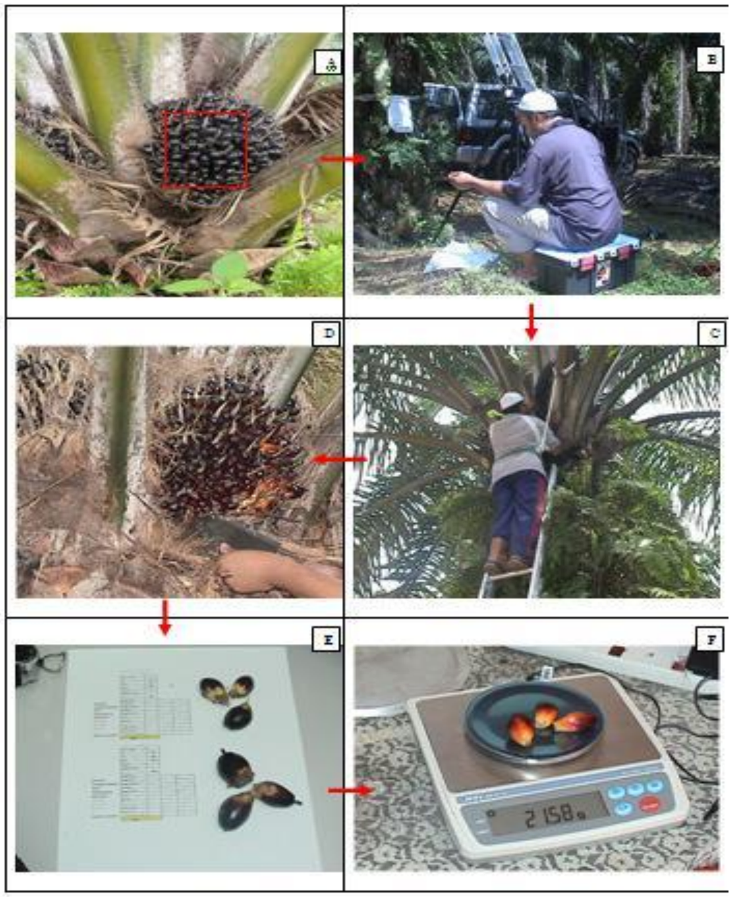

Figure 4. A; indicates red rectangle for the monitoring area of capturing the FFB image; B; shows experiment during capturing the monitored FFB image; C and D; shows the image of removing the fruitlet from bunch; E; weighing the fruits sample; F; filling the data analysis form.

Table 1. The raw data and calculations to obtain the oil content of oil palm fruits.

Expt. No./ Old tree	1/20		
Date	19 Nov. 2008		
Serial no.	2ptg		
Palm no.	99		
Fruit family	Tenera		
Estimation day to ripe	2 month		
Unit	gram		
Sub-sample fruits no.	1	2	3
Sub-sample fruits weight(SFW)	8.18	8.26	6.63
Sub-sample fruits fresh weight (SFFW)	5.07	5.04	2.53
Nut Fresh weight (NFW)	2.91	3.14	3.98
Sub-sample fruits dry weight	1.01	0.96	0.83
Nut dry weight (NDW)	1.21	1.25	1.11
Timber weight (TW)	1.66	1.63	1.64
Sub-sampel + timber (SST)	2.7	2.63	2.47
Post Sochlet + timber Wt.(PST)	2.71	2.65	2.48
Whole dry weight (WDW)	-0.01	-0.02	-0.01
oil to dry mesocarp	-0.96	-2.00	-1.20
Average % oil content In mesocarp		-1.39	

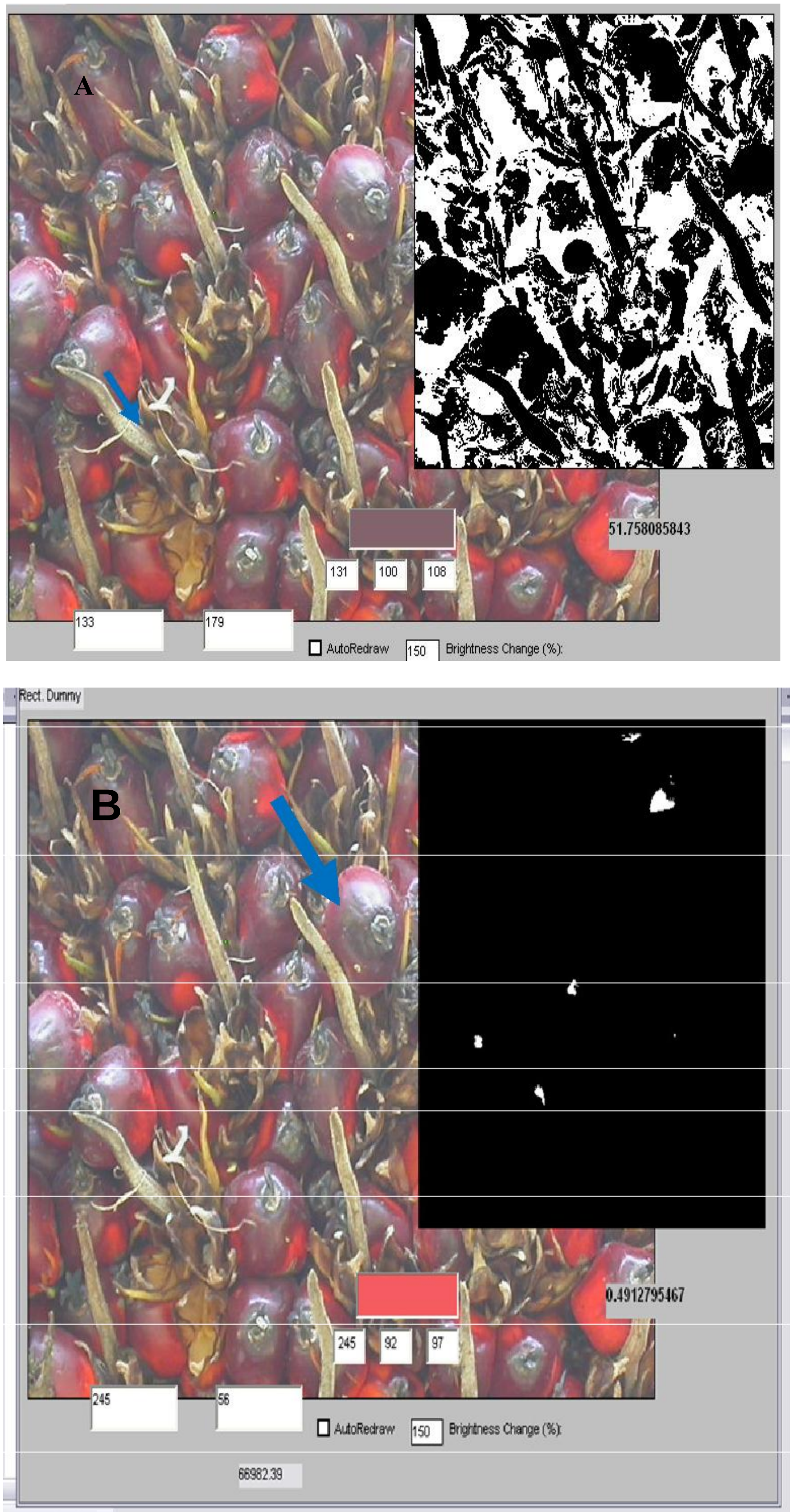

Figure 5. Developed validation GUI for determine the value of hue after being extracted from RGB histogram.

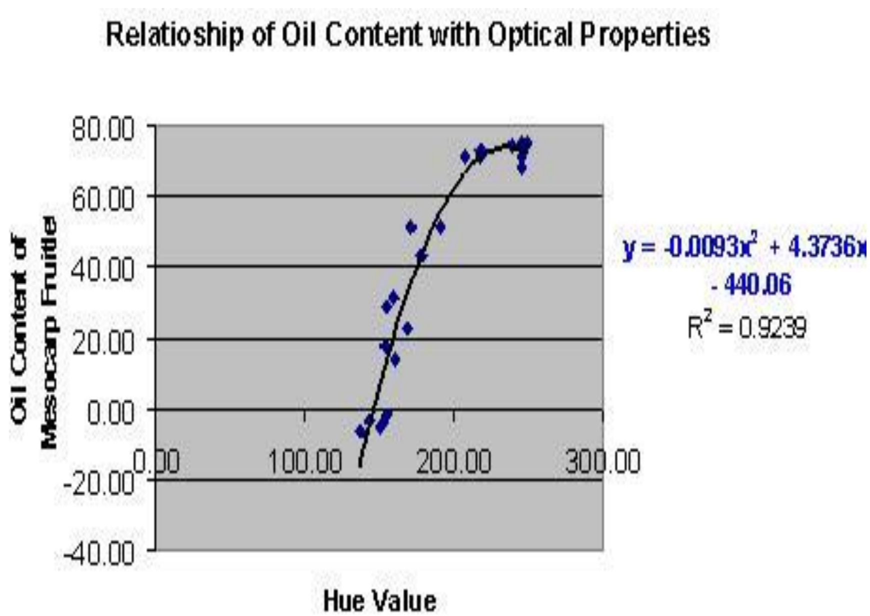

Figure 6. The relationship of FFB oil content with hue value.

X = Hue value
R^2 = Regression Squared

As an experiment, the FFB was signed matured which indicated loose fruit at date of 19 January 2009. From date at fruit unripe on 19 November 2008, it will need 63 days to mature. Let say the Hue value is 200, so the oil content is:

$$Y = -0.0093X^2 + 4.3736X - 440.06$$
$$= -0.0093(200)^2 + 4.3736(200) – 440.06$$
$$= 62.66\% \text{ of oil content}$$

So from experiment:

Fruit is mature means = 0 day or oil content = 74%
At X = 130; fruit will mature in the next 69 days = -3.72%
17.52% oil content; the fruit will mature in the next 41 days

So, from 62.66%, using the triangulation method, the number of days needed for the fruit to be harvested is:

17.52 - 74 /62.66-74 = 41 - 0 /X – 0
-56.48/-11.34 = 41/X X= 8.23

It means that from hue value of the FFB image, the number of days required for harvest is next 8.23 days.

Strong relationships were found between the hue values of fruits image with the oil content of mesocarp FFB with regression correlation > 0.9. The value of R^2 was acceptable. The oil content of fruit in mesocarp and digital value was increased with increasing the stages of maturity which was also found by Abdullah et al. (2002), Idris et al. (2003), Rashid et al. (2004), Choong et al. (2006) and Balasundram et al. (2006).

Conclusions

This experiment was conducted to determine and to model the equation between the hue values of the oil palm fruits image with different stages of maturity after considering the effect of outdoor environment intensity. The maturity stages were confirmed later by oil content determination. This study was carried out on selected unripe fruits and monitored until one loose fruit was found which indicated as a matured FFB. This process took more than two months of monitoring. A strong relationship was found between the hue values of fruits image with oil content of FFB mesocarp. The developed graphical analysis user interface was able to differentiate and give the output result of the hue value for colour component. The procedure in monitoring the image pixel value of different maturity stages of oil palm fruit was initially contributed. For the next, the monitoring will start during pollination stages and monitor until fruit become overripe. There is a challenge, in that it is difficult to recognize the fruit at the end of the pollination (anthesis) process (Mohd. Hamim et al., 2010). Theoretically, the FFB will take 22 weeks to ripe from pollination process (Azis et al., 1984). Insha ALLAH, later, the robust equation will be develop between relationships of digital value and the shape of FFB image with respect to the day of estimation for harvesting and the oil content and to realize the development of portable real time maturity prediction device for harvesting.

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