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Oil Palm Physical and Optical Characteristics from Two Different Planting Materials

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Abstract: This study discovers the uniqueness of physical and optical characteristics of the oil palm Fresh Fruit Bunches (FFB) and is based on two different *tenera* planting materials namely PORIM SERIES 1 (PS 1) and PORIM SERIES 2 (PS 2). Three methods have been done to determine the characteristics which are as follows; 1) manual approach by measuring the weight, length, width and circumference of oil palm FFB, 2) machine vision technique for color information extraction and 3) multi-band portable, active optical sensor system to determine the chlorophyll and anthocyanin content. A total of thirty bunches were standardized into a ripe grade and have been used as samples in this study. The results showed that each planting material produces different physical and optical characteristics. The correlation between the weight and linear dimensions of oil palm FFB was found to be 80%. This study gives very important information in helping researchers on the development of future non-contact and non-destruction oil palm FFB grading equipment and system.

Key words: Oil palm FFB, optical sensor, physical characteristics, RGB digital number, *tenera*

INTRODUCTION

Tenera is well-known as commercialised oil palm type. *Tenera* itself has variations of its own varieties and their physical as well as optical characteristics depends on planting material type that was developed by any research centre, private or government agencies. Selection of planting material is a critical factor and will affect the characteristics of the produced oil palm Fresh Fruit Bunches (FFB). Oil palm can be divided into two species which are *Elaeis oleifera* and *Elaeis guineensis.* However, only *Elaeis guineensis* was used commercially used in Malaysia. There are three types of *Elaeis guineensis* which are *pisifera*, *dura* and *tenera*. *Pisifera* was a pollen type meanwhile *dura* have a thicker shell and a lesser oil content compared to *tenera* which is a hybrid between *pisifera* and *dura*. Tenera has a high oil content, therefore this type was suitable for planting material for commercialization purpose (Hai, 2002).

High palm oil demands and limited land in Malaysia lead researchers to find alternative ways in increasing oil palm production. One of the best ways is to create new planting material which produces high oil content (Breure, 1986). Even though the main planting material is *tenera*, it has a lot of varieties. This could happen because of the *pisifera* and *dura* type may be a different origin, genetic and selection criteria (Breure, 2006). The different type of *dura* and *pisifera* may affect the varieties of *tenera* during the hybrid process. There are many types of *dura* and *pisifera* in the world which are also known as parent material (Lim, 2003, Teo *et al*., 2004). A hybrid between different parent materials produce large variety of planting material (Esnan *et al*., 2004).

The planting material directly influences the quality of oil palm FFB. Research on planting material will be a continuous process until the researchers can get a high quality oil palm FFB. As the main oil palm research institution in Malaysia, Malaysian Palm Oil Board (MPOB) has produced approximately 13 variations of planting material and each of them had their own special or unique characteristics. Table 1 shows 13 variations that MPOB has produced. PS 1 and PS 2 as shown in Fig. 1 were widely used in plantations and by smallholders whereas private companies have their own research center and produce planting materials using their own brand name (Basri *et al*., 2004). Selection from the extreme segregants would alter the gene frequency thereby creating new population with greater mean values than the

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Table 1: PORIM Series with their category/characteristics

PORIM Series (PS)	Category/Characteristics
PS1	Development of high yielding and dwarf palms
PS2	Breeding for high unsaturated oil (High iodine value)
PS3	Breeding for high lauric oil
PS4	Breeding for high carotenoid content, E. Oleifera
PS5	*Tenera* with thin shell and high vitamin E
PS6	*Dura* with big size and high bunch index
PS7	Very High Bunch Index
PS8	Very High Vitamin E content
PS9	Bactris Gasipaes
PS10	Long Bunch
PS11	E. Guineensis with high carotene content
PS12	High content of Oleic Acid
PS13	Less content of Lipase

Table 2: Oil palm FFB ripeness categories

Total no. of empty fruitlets socket	Mesocarp color		
	Yellow	Yellowish orange	Orange
0	Unripe	Unripe	Ripe
0-10	Unripe	under ripe	Ripe
> 10	Unripe	Ripe	Ripe

Table 3: Classification of oil palm FFB regarding ripeness condition

Categories	Descriptions
Ripe	10-50% of fruits detached from bunch
Over Ripe	50-90% of fruits detached from bunch
Under Ripe	1-9 fruits detached from bunch

original parents (Okoye *et al*., 2009). Most of the researchers and graders classified oil palm FFB by looking at its colours. Each maturity stage has specific changes of colours. The exocarp color is green changing to orange at maturity in *virescens* types, and orange with brown or black cheek colors in the *nigrescens* types (Esnan *et al*., 2004). Each variation will have different ripeness behavior.

The accuracy of oil palm FFB grading system depends very much on their physical and optical characteristics. This study determined the differences of oil palm FFB physical and optical characteristics from two prime planting material using physical determination, machine vision methods and optical sensor. We also made a discovery on how the planting material will have an effect on oil palm FFB physical features.

MATERIALS AND METHODS

This study was conducted at Faculty of Engineering, Universiti Putra Malaysia on June 2010. The samples of oil palm Fresh Fruit Bunches (FFB) were freshly collected from MPOB/UKM Research Station, Malaysia. Thirty samples of oil palm FFB were collected according to two *tenera* planting material but three variations which were PS 1 *nigrescens*, PS 1 *virescens* and PS 2. PS 1, Deli *duras* cross with Nigerian *pisiferas* had special characteristics such as slow increment (20-45 cm/yr), high yield (30-33 t/ha.yr) and high oil to bunch ratio which is about 28% (Kushairi *et al*., 1999b). Otherwise, PS 2 produced high yield with high iodine value (Kushairi *et al*., 1999a). All the samples that were used in this study were selected to standardize the ripe category.

The experiments were divided into three parts. The first part was the measurement of the physical characteristics. This is being performed by measuring the weight, length, width, circumference and all related axial dimensions of oil palm FFB and fruitlets. The second part is the collection of oil palm FFB surface color information using red, green and blue digital number technique. Finally, an evaluation process using a multi-band portable, active optical sensor system; comprising of four spectral bands, 570, 670, 750 and 870 nm, to detect oil palm FFB physical characteristics.

Grading standard: Malaysian Palm Oil Board (MPOB) has already established the oil palm FFB grading standard guidelines (MPOB, 2006). The same guideline was used in this research. Each category has different characteristics as summarized in Table 2. The important factor was mesocarp color. If the color is orange it can be classified as ripe otherwise if the color is still yellow or yellowish orange, it can be unripe or under ripe (Abdul *et al*., 2009). The number of empty fruitlet sockets can help to assist in a more accurate classification. Somehow researcher and plantation side also defined oil palm FFB categories based on the number of fruit that is detached form a bunch. If more than 10% of oil palm fruit from total of fruit in one bunch detach, it will be categorised as ripe (Choong *et al*., 2006). The others description is shown as in Table 3.

Physical properties determination: The oil palm FFB physical properties that were measured are weight, size, shape, spehericity and aspect ratio. We also measured individual fruitlets physical properties by selecting 10 fruitlets at random from each bunch as samples. Additional measurements for the fruitlets were volume, true density, bulk density, density ratio and porosity. Previous physical properties study had been done to the *tenera* and *dura* fruitlets but not as a whole bunch and specific variations of *tenera* (Owolarafe *et al*., 2007).

Size determination: Linear dimensions which are (a) length, (b) width, and (c) thickness were measured for each ten oil palm FFB samples from each group using measuring tape. A reading to 0.1 cm was collected. 100 fruitlets collected from each category were measured as the same linear dimension using vernier caliper reading to 0.01 mm. The circumference measurements were then collected as additional information.

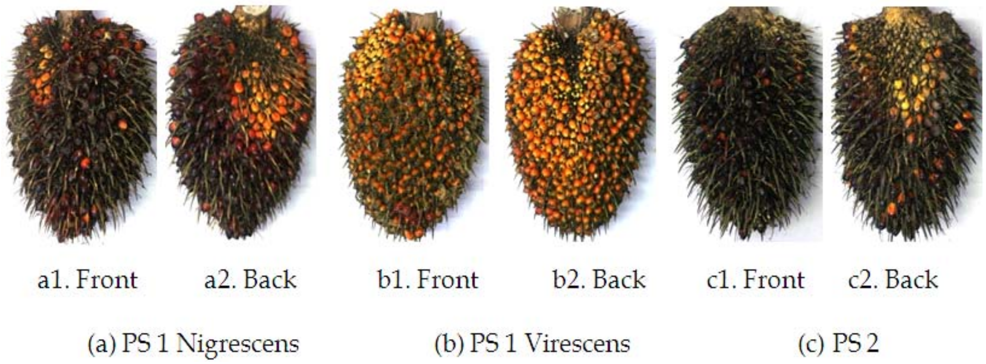

Fig. 1: Tenera varieties with front and back oil palm FFB images (a) PS 1 Nigrescens (b) PS 1 Virescens (c) PS 2

Shape determination: Sphericity index and aspect ratio is normally used to determine a non-uniform shape. As recommended by Mohsenin (1978) and based on linear dimension details, sphericity index S_c of oil palm FFB was calculated using this formula:

$$S_c = \frac{(abc)^3}{a} \times 100 \quad (1)$$

While for the aspect ratio R_a, the formula is recommended by Maduako and Faborode (1990) which is as follows:

$$R_a = \frac{b}{a} \times 100 \quad (2)$$

Determination of volume and density: The irregular shape of oil palm fruitlets could present a problem in volume and density measurement. In relation to this, the best method to calculate volume is water displacement technique according to Mohsenin (1978). The given formula for volume *v* in m^3 is as follows:

v = weight of displaced water/
weight density of water (3)

The true density ρ_t was then calculated using Eq. (4) below (Owolarafe *et al*., 2007),

$$p_t = \frac{m}{v} \quad (4)$$

where, m is the mass of fruit (in kg), and v is the volume of fruit (in m^3). After that, proceed to bulk density measurement as recommended by Owolarafe *et al.* (2007). An empty cylindrical container of 444.50 cm^3 volume was filled with fruitlets and the bulk weight recorded. This was done in 10 replications for each variety. Using Eq. (4) above, the bulk density (ρ_b) was then calculated for each of the replications.

Determination of density ratio and porosity: As a continuation of true and bulk density measurement, the density ratio was measured. The density ratio D_r is the ratio of true density to bulk density stated as a percentage as in Eq. (5):

$$D_r = \frac{p_t}{p_b} \times 100 \quad (5)$$

Porosity (*P*) was calculated (Owolarafe *et al*., 2007) as:

$$p = \frac{p_t - p_b}{p_t} \times 100 \quad (6)$$

Reported values of all density characteristics are means of ten replications.

Oil palm FFB and oil palm fruitlets mass determination: The mass of each individual oil palm FFB from all *tenera* varieties were determined by using weight measuring equipment to an accuracy of 0.1 kg. Meanwhile, the fruitlets mass measurement was measured using a digital platform scale to an accuracy of 0.01 g. Each measurement was replicated five times.

Relationship between weight and linear dimensions of oil palm FFB: The correlation between weight and linear dimensions of oil palm FFB was introduced to see the relationships between these two. All samples were used in these correlation findings. The technique used was by measuring the degree of linear relationship between all parameter. Since both back and front of oil palm FFB is symmetry, we only consider one part of the calculating linear dimensions. If the result shows that both variables are highly correlated, the value of an individual on one variable can predict or estimate the other one variable. The oil palm FFB weight estimation equation was built usin th linear regression.Itcan be simply written as Eq. (6).

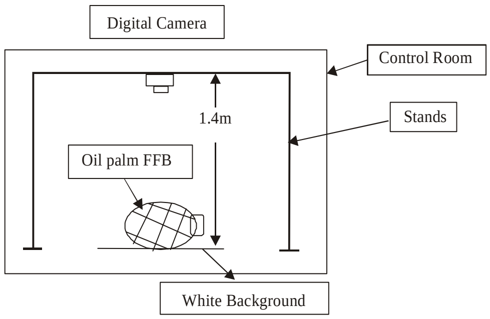

Fig. 2: Equipment setup for data acquisition

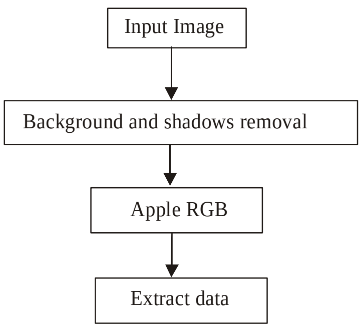

Fig. 3: Flowchart of image processing procedure

$$W = mX + c \quad (6)$$

where, W is the oil palm FFB weight (kg), *X* is a parameter from Eq. (7) and m and *c* are constant value.

$$X = (abd)1/3 \quad (7)$$

where *a* is a length (m), *b* is a width (m), *d* is a thickness (m) and *X* is a linear dimension parameter.The equation can be used in the future to predict automated weight measurement using image analysis technique.

Red, green and blue digital number (RGB) properties: The color features of oil palm FFB was extracted from captured image by image analysis using image processing technique.

Data acquisition: Oil palm FFB was photographed using a digital camera, Canon EOS 10D with discontinued 6.3 megapixel. Fig. 2 shows the equipment setup for the data acquisition. A light source was from fluorescents and controlled by the Lux meter each time an image was taken. The Lux meter is used in photometry for intensity measurement, as apparent by the human eye, of light that hits or passes through a surface. The sample was put directly under the camera to reduce shading effect. Both side of each oil palm FFB was captured to do the analysis.

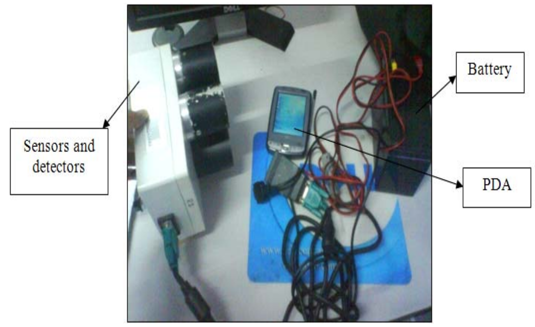

Fig. 4: Four-band optical sensor system

Image processing: Oil palm FFB images were analyzed using Matlab® (ver. 7.6, The MathWorks Inc., Natick, MA) to extract color intensity from the image. In this study, color intensity extraction that has been used were red, green, blue (RGB) space. RGB is the most studied color space because electronic images are often acquired in terms of RGB components (Lee *et al*., 2008). The shadows and background were filtered out using histogram threshold technique. Figure 3 showed the flowchart of image processing procedure.

Mean oil palm FFB image RGB digital number: Mean RGB digital numbers of each *tenera* variety were calculated to do the comparison among its variety.

The percentage RGB intensity and differences of the specimens: The percentage different equation for each particular color is based upon recommendation by Ishak *et al*. (2000):

$$\text{Difference of a (\%)} = (\text{Intensity of a} - \text{Intensity of b}) / \text{Intensity of a} \times 100 \quad (8)$$

where, *a* and *b* are the colors of RGB.
The percentage bands reflectance and differences of the specimens
The percentage different equation for each particular color is upon recommendation by:

$$\text{Difference of c (\%)} = (\text{Reflection of c} - \text{Reflection of d}) / \text{Reflection of c} \times 100$$

where c and *d* are the bands of 570, 670, 750 and 970 nm.

Optical sensor: The hand-held four-band active sensor system shown in Fig. 4 was used as the third method in measuring oil palm FFB optical characteristics. The equipment system consisted of four narrow-band (active optic) light sources and reflectance sensing elements of different wavelengths: two in the visible region (at 570 nm and 670 nm), one in red-edge region (750 nm) and one

Table 4: Oil palm FFB varieties with their physical properties

	Mean value ± Standard Deviation		
Properties	PS 1 (nigrescens)	PS 1 (virescens)	PS 2
Weight (kg)	20.45±4.84	20.91±5.0	418.96±4.9
Length (cm)	47.60±5.95	44.10±6.35	48.30±4.16
Width (cm)	38.20±4.18	37.20±4.09	36.40±2.59
Thickness (cm)	30.70±3.02	31.20±2.28	29.00±3.02
Circumference (cm)	110.8±10.68	110.5±8.3	107.1±8.05
Sphericity (%)	80.64±6.49	84.77±6.76	76.87±3.82
Aspect Ratio (%)	80.93±10	85.54±12.43	75.62±5.19

Table 5: Oil palm fruitlets varieties with their physical properties

	Mean value ± Standard Deviation		
Properties	PS 1 (nigrescens)	PS 1 (virescens)	PS 2
Weight (g)	9.03±2.61	11.04±2.82	11.24±2.52
Length (mm)	34.57±3.54	38.00±3.87	40.64±3.22
Width (mm)	23.65±2.73	25.52±2.53	27.12±2.71
Thickness (mm)	20.95±2.92	22.86±2.58	23.88±2.49
Circumference (cm)	7.40±0.85	8.0±0.69	8.30±0.74
Volume (cm^3)	9.44±2.70	11.72±3.15	11.79±2.57
Sphericity (%)	74.64±5.83	75.70±4.87	81.41±5.38
Aspect Ratio (%)	68.72±7.6	69.03±6.84	74.43±7.59
True Density (kg/m^3)	957.30±81.5	967.83±66.39	1061.01±69.98
Bulk Density (kg/m^3)	818.64±99.28	899.58±96.63	862.35±86.82
Density Ratio (%)	85.5	92.95	81.23
Porosity (%)	14.48	7.05	18.72

Table 6: RGB mean values by different varieties

	Red	Green	Blue
PS1-Nigresen	44.27	36.15	27.10
PS1-Virescens	58.84	41.50	25.20
PS2 42.38	38.48	28.36	

in the near infrared region (970 nm). The band 570 nm and 670 nm represent green and red spectral regions.

The four-band active sensors comprised of their own light source. Thus, calibration for sensors is unnecessary in compensating for the changing light intensity during daytime. All the four bands have epoxy lens type illuminator manufactured by Marubeni America Corporation (Santa Clara, CA 95054). These illuminators are extremely high output power illuminators assembled with a total of 60 high Efficiency Aluminum Gallium Arsenide (AlGaAs) diode chips, mounted on metal stem TO-66 with Aluminum Nitride (AlN) ceramics and covered with double-coated clear silicone and epoxy resin. Sampling frequency was set at 10 Hz and that was also was the average time. All the four detectors were arranged to view the same area. The light is modulated at 10 KHz and then received at the detector along with ambient sunlight. The additional benefit of this system is that it can also be used during nighttime. The sensor system was powered by 12 V DC and was connected to a handheld Personal Device Assistant (PDA) for data acquisition and storage during the data collection. Each bunches were sensed 10 times randomly. It must be ensured that the disctance between the samples and the sensor is not more than 20 cm. All the data were kept in the PDA being transferred to the laptop/PC for further analysis.

RESULTS AND DISCUSSION

Table 4 indicates PS 1 and PS 2 oil palm FFB physical properties with standard deviation. On average, PS 1 is bigger and heavier than PS 2. The average PS 1 *nigrescens* oil palm FFB mass was 20.4 kg, PS 1 *virescens* was 20.4 kg and PS 2 was 18.96 kg. It is interesting to note that there is no significant difference among these three variations. The PS 1 *virescens* sphericity and aspect ratio were found to be 84.77 and 85.54%, respectively. The high sphericity of the PS 1 *virescens* is indicative of the tendency of the shape towards a sphere. The result shows that one interesting trend that can be highlighted is the higher value of sphericity index for the PS 1 variety compared to the value for the PS 2. This gives an indication that PS1 has a higher tendency to have its shape towards a sphere than the PS 2.

The PS 1 *nigrescens* oil palm FFB mean length, width, thickness and circumference were found to be at 47.6, 38.2, 30.7 and 110.8 cm, respectively. The PS 1 *virescens* oil palm FFB mean length, width, thickness and circumference were found to be at 44.1, 37.2, 31.2 and 110.5 cm, respectively. Meanwhile, The PS 2 oil palm FFB mean length, width, thickness and circumference were found to be at 48.3, 36.4, 29 and 107.1 cm, respectively. The uniqueness that was found in this study was PS 2 had longer mean length than PS 1 but the mean width and the mean thickness were less than PS 1. The PS 1 variety is bigger in size than the PS 2 variety. The values for the width, circumference and thickness of the PS 1 variety are higher than the PS 2 variety. Previous study had discussed the importance of these and other characteristic of axial dimensions in determining the aperture size of machines, selection, particularly in separation of materials (Mohsenin, 1978; Ruiz-Altisent *et al*., 2010). The gain dimensions from this study were useful in estimating the size of machine components especially in building an automated oil palm FFB grading system.

A summary of the results of the determined oil palm fruitlets physical parameters of the PS 1 and PS 2 variety is shown in Table 5. Based on the fact that the weight and the size of oil palm FFB is very much affected by the size of fruitlets. The sizes of fruitlets from PS 1 nigrescens were smaller than PS 2. The PS 1 *nigrescens* fruitlets mean's length, width, thickness and circumference were found to be at 34.57, 23.65, 20.95 mm and 7.4 cm, respectively. The PS 1 *virescens* fruitlets mean length, width, thickness and circumference were found to be 38, 25.52, 22.86 mm and 8 cm, respectively. The PS 2

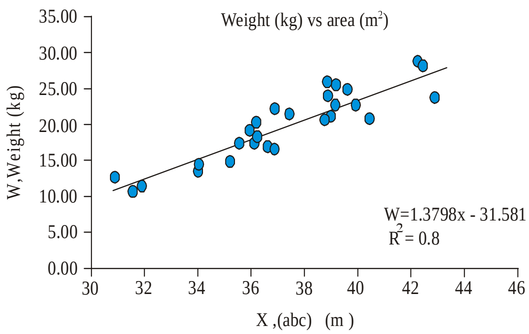

Fig. 5: Linear relationship between weight and interaction length with width

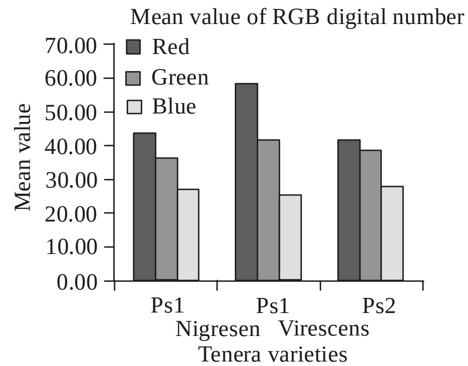

Fig. 6: Mean value of RGB intensity for different *tenera* varieties

fruitlets mean's length, width, thickness and circumference were found to be at 40.64, 27.12, 23.88 mm and 8.3 cm, respectively.

The average fruitlets weight for the PS 1 *nigrescens* was at 9 g whereas for the PS 2 was at 11.2 g. Even though PS 1 fruitlets have less mean weight than PS 2, the mean weight for the PS 1 bunches is higher than PS 2. This could happen because of the total number of PS 1 fruitlets per bunch is much higher than PS 2 which indicates that, although both *tenera* varieties have high yield characteristics, the physical characteristics of oil palm FFB and fruitless however, can be different. High yield oil palm FFB can be considered if a minimum fruitlets set of around 40% because it is sufficient to maintain an oil to bunch ratio of 20% (Haniff and Noor, 2002).

The true density, bulk density, density ratio and porosity of PS 1 *nigrescens* were at 957.3, 818.64 kg/m^3, 85.5 and 14.48% while for the PS 1 *virescens* were 967.83, 899.58 kg/m^3, 92.95 and 7.05% whereas PS 2 were at 1061, 862.35 kg/m^3, 81.23 and 18.72%. PS 2 fruitlets has tendency to sink in water (density 1000 kg/m^3) because the PS 2 true density value, at 1061 kg/m^3 is higher than the density of water. The lower porosity or percentage volume of voids in the PS 1 variety may be due to the higher sphericity and aspect ratio, which ensure a more compact arrangement of the fruitlets. This is probably the best reason why mean mass for the PS 2 fruitlets is heavier than PS 1 variety. It is also due to the high iodine content in PS 2 as mention in (Kushairi *et al*., 1999a) study. Comparing PS 1 and PS 2 fruitlets properties with *tenera* properties which collected from the Teaching Research Farm of Obafemi Awolowo University, Ile-Ife, Nigeria (Owolarafe *et al*., 2007), we found out the PS 1 and PS 2 is more bigger, heavier and higher oil content. This is because Nigerian *tenera* has less percentage of sphericity and aspect ratio with only 64.23 and 56.77%. The high porosity percentage, 38.55% in Nigerian *tenera* indicates that the mesocarp has filled up more voids than the oil content.

Density and specific gravity information is the important factors in much pertinence in agricultural sector. Maturity evaluation, separation from desirable materials, texture and softness of fruits, drying and sorting, separation and grading, design of an equipment and quality evaluation of products that increase in their density as they mature are some examples of the application based on density and specific gravity information (Mohsenin, 1978).

This study also found out that some research on fruitlets cannot be representing the whole bunch. As reported by Owolarafe *et al*. (2007), the high aspect ratio may be deduced that the fruitlets will rather roll than slide on their flat surfaces. Nevertheless, if the aspect ratio value is close to the sphericity values, it may also mean that the fruitlets will undergo a combination of rolling and sliding. But, the oil palm FFB has special features called thorns and it will thwart the bunch from roll or slide smoothly even if on a flat surface. The oil palm FFB density is not the same as their fruitlets density because of in one bunch it has other part such as spikelet, stalk, thorns and parthenocarpic (fruitlets with no kernels) thus directly affecting the density measurement.

There is a high correlation between oil palm FFB mass and the surface area of oil palm FFB. In this case the surface area was calculated by multiplying the length with width. The relationship is high and it is possible to use it as a base for predicting oil palm FFB weight using digital image. As shown as in Fig. 5 the correlation is 80%. The result looks very promising to do the weight estimation by just measuring the width and length of oil palm FFB. The correlation formula derived based on the collected data is determined as follows:

$$W = 1.3798X - 31.518 \tag{10}$$

where, W is the estimated weight in kg and X is the linear dimension parameter. From the captured image, object size can be calculated by measuring the pixel size

Table 7: RGB intensity range by different varieties

Category	RGB intensity range Red	Green	Blue
PS 1 Nigrescens	31.98-61.86	28.73-44.52	21.79-33.30
PS 1 Virescens	44.88-81.69	32.11-53.22	17.90-34.38
PS 2	33.00-58.24	31.56-50.68	24.69-38.19

Table 8: RGB percentage different by different varieties

Category	RGB percentage different Red-green	Red-blue	Green-blue
PS 1 Nigrescens	18.33	38.78	25.04
PS 1 Virescens	29.46	57.17	39.28
PS 2	9.20	33.09	26.31

and the distance between cameras and object accurately. Then, the total number of bunch pixels counted from the detected bunch area was used for the weight estimation. This method had been discussed in previous research (Phorntipha *et al*., 2009; Slamet *et al*., 2007). Due to the irregularities in shape of oil palm FFB, the basis of area only is not enough to obtain high accuracy of weight estimation. Image analysis can measure space between fruitlets or volume to get high accuracy of weight estimation.

Colors are always used in any image retrieval and analysis in view of the fact that colors are easier to work out compared to other features such as shapes, sizes or textures. However, colors are hard to differentiate if comparisons are made between the total pixels of images but the uniformity of histogram always a solution (Mohamad *et al*., 2010). Table 6 shows the mean Red, Green and Blue (RGB) value for each variety. The mean RGB value for the PS 1 *nigrescens* were found to be at 44.27, 36.15 and 27.10, while for the PS 1 *virescens* were found to be at 58.84, 41.50 and 25.20, whereas for the PS 2 were found to be 42.38, 38.48 and 28.36, respectively. PS 1 *virescens* red and green mean values were quite much different from the others. This is because *virescens* variety has different maturity behavior than *nigrescens* and was highlighted in the introduction part. Fig. 6 shows the relationship among RGB mean values and oil palm FFB varieties. The RGB range for all varieties overlapped with each other as shown in Table 7. The PS 1 *nigrescens* RGB percentage differences calculated for red compared to green, red compared to blue and green compared to blue were 18.33, 38.78 and 28.04%, respectively. While for the PS 1 *virescens* RGB percentage differences calculated for red compared to green, red compared to blue and green compared to blue were found to be at 29.46, 57.17 and 39.28% whereas for the PS 2 variety were 9.2, 33.09 and 26.31%, respectively (Table 8).

From Razali *et al*. (2008) studies there were proven fact that RGB model are directly affected by the total amount of light intensity. As mention in Cheng *et al*. (2001), RGB is suitable for color display, but not good for color scene segmentation and analysis because of the high correlation among the R, G, and B components. Once the intensity change, the entire three components will change too. Many researcher change RGB model to the other color space because of this reason. The most popular color space is Hue, Saturation and Intensity (HSI) system. This system will separate color information of an image from its intensity information. Somehow, even though by controlling the light intensity and in control environment, the results of mean RGB for the oil palm FFB in the same category, in this case was ripe is still different from earlier study. Table 9 shows the mean RGB value for the ripe *tenera* oil palm FFB from several previous studies. The comparison indicates that the mean RGB value is not the same for all studies. The best assumption here was each researcher using oil palm FFB from different planting material for their study. The latest finding by the oil palm genome research had successfully detected *virescens* type in nursery stage. It will help farmers to eliminate this variety and focus on *nigrescens* variety (Tan *et al*., 2010). Either *nigrescens* or *virescens*, both are comparable and can produce high yield and high oil to bunch ratio. The major concern here was to develop grading device or equipment and will not successfully distinguish if the planting material variety is not taken into consideration.

Previously researchers had worked with several methods to distinguish different ripeness categories of oil palm fruit bunches which consists of unripe, ripe, under ripe and over ripe without direct contact and non-destructive method. Some of the methods were using red, green and blue digital number (Alfatni *et al*., 2008), hue, saturation and intensity imaging technique (Abdullah *et al*., 2002; Ishak *et al*., 2000; Tan *et al*., 2010), oil palm colorimeter (Idris *et al*., 2003; Tan *et al*., 2004), photogrammetric grading (Jaffar *et al*., 2010), image based modeling (Ishak and Hudzari, 2010), fuzzy regression approach (Nureize and Watada, 2010), Neuro-

Table 9: RGB mean value by different varieties from various studies

Oil palm FFB variety	R	G	B	Reference
Tenera - PS 1 Nigrescens	44.27	36.15	27.10	From this study
Tenera - PS 1 Virescens	58.84	41.50	25.20	From this study
Tenera - PS 2	42.38	38.48	28.36	From this study
Tenera - Unidentify	144.5	73.30	50.40	(Ishak *et al*., 2000)
Tenera - Unidentify	88.00	41.40	52.80	(Alfatni *et al*., 2008)
Tenera - Unidentify	136.33	88.20	62.24	(Jamil *et al*., 2009)
Tenera - Unidentify	92.46	61.76	42.42	(Jaffar *et al*., 2010)

Table 10: Reflectance wavebands mean values by different varieties

Types	Reflectance 570 nm	670 nm	750 nm	970 nm
PS 1 - Nigrescens	0.225	0.530	1.113	0.258
PS 1 - Virescens	0.482	0.766	1.095	0.238
PS 2	0.290	0.591	1.092	0.235

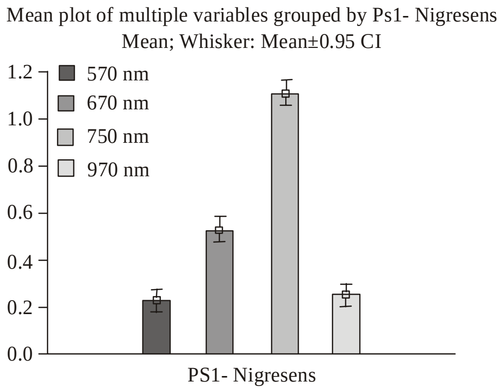

Fig. 7: Mean value of wavebands for PS 1 *nigrescens*

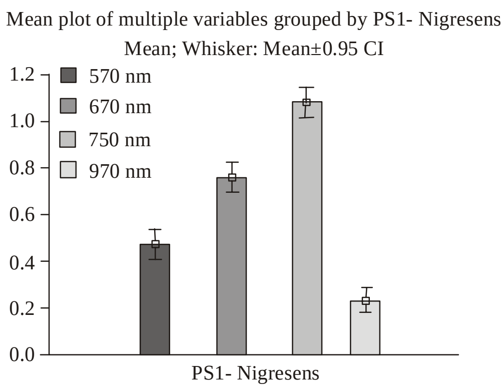

Fig. 8: Mean value of wavebands for PS 1 *virescens*

fuzzy technique (Jamil *et al*., 2009), microwave moisture sensors (Khalid *et al*., 2006), hyperspectral (Osama *et al*., 2010; Phorntipha *et al*., 2009), MRI and Bulk NMR (Sharifudin *et al*., 2010), and others. It gives a very good sign to change from manual grading to automated grading system. Even though they have more than 85% accuracy it is only valid in control environment. If they move to in-field situation, the accuracy can drop to less than 50% (Jamil *et al*., 2009).

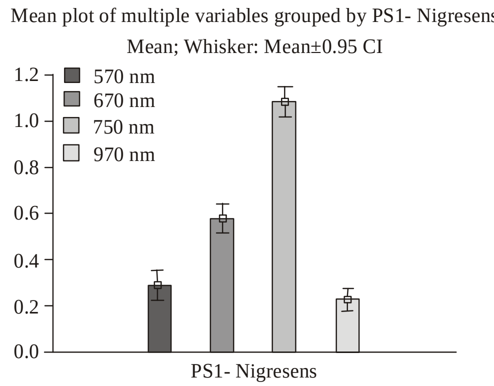

Fig. 9: Mean value of wavebands for PS 2

The optical sensor is the latest non-contact and non-destructive technology. It offers a tremendous advantage to identify or measure oil palm FFB characteristics. The error bar chart of the optical sensor data (Fig. 7, 8, 9) illustrate the mean size of oil palm FFB in each categories, and the 'I' shapes show the confidence interval of these means. The PS 1 *nigrescens* mean reflectance value for 570, 670, 750 and 970 nm were found to be at 0.225, 0.530, 1.113 and 0.258, respectively. While the PS 1 *virescens* mean reflectance value for 570, 670, 750 and 970 nm were found to be at 0.482, 0.766, 1.095 and 0.238 whereas for the PS 2 were at 0.290, 0.591, 1.092 and 0.235, respectively (Table 10). Chlorophyll absorbs in the region of 430 and 670 nm while anthocyanins that was extracted from the skin of oil palm FFB absorbs in the region of 530 nm (Tan *et al*., 2010). PS 1 has a higher reflectance value than PS 2 in this region. That means chlorophyll and anthocyanin content is high in PS 1 oil palm FFB variety when it reaches the ripe condition compare to the PS 2 variety. Table 11 shows the wavebands percentage different between 570 and 670 nm, 570 and 750 nm, 570 and 970 nm, 670 and 750 nm, 670 and 970 nm and 750 and 970 nm for each category of variety. The highest different percentage for PS 1 variety

Table 11: Reflectance wavebands percentage different by different varieties

Category	Wavebands percentage different					
	570 and 670 nm	570 and 750 nm	570 and 970 nm	670 and 750 nm	670 and 970 nm	750 and 970 nm
PS 1 *nigrescens*	57.55	79.78	12.79	52.38	51.327	6.82
PS 1 *virescens*	37.05	55.95	50.70	30.02	68.97	78.28
PS 2	50.93	73.44	18.97	45.88	60.24	78.48

Table 12: Reflectance wavebands range by different varieties

Category	Optical sensor reflectance range			
	570 nm	670 nm	750 nm	970 nm
PS 1 *nigrescens*	0.152-0.384	0.249-0.775	1.067-1.175	0.196-0.293
PS 1 *virescens*	0.358-0.575	0.519-0936	0.933-1.146	0.224-0.335
PS 2	0.150-0.428	0.306-0.777	0.917-1.151	0.15-0.266

was found to be at 570 and 750 nm, 79.78%, respectively. While for the PS 1 *nigrescens* and PS 2, the highest different percentages were at 78.28 and 78.48% in the same column of 750 and 970 nm. The highest different percentage indicates that, there is no relationship or similarity among those wavebands. This is very good information to develop formula, algorithm or indexes for the oil palm FFB grading system. As shown in Table 12, the range for the reflectance value is almost the same. These values demonstrate that we cannot differentiate each variety using the range of reflectance value.

CONCLUSION

In conclusion, this study successfully established the difference of oil palm FFB physical and optical characteristics among 3 varieties from two planting material namely, PS 1 *nigrescens*, PS 1 *virescens* and PS 2. There is no significant difference on physical characteristic of oil palm FFB between PS 1 *nigrescens*, PS 1 *virescens* and PS 2. Somehow, averagely PS 1 is bigger and heavier than PS 2. We also found that the relationship between weight and linear dimensions of oil palm FFB surface is 80%. The RGB mean color intensity for the PS 1 *nigrescens* was found to be at 44.3, 36.2 and 27.6. Meanwhile for the PS 1 *virescens* were at 58.8, 41.5, 25.2 and PS2 were at 42.4, 38.5 and 28.4. From the optical sensor result indicate that each variety had different amount of chlorophyll and anthocyanins contents. This is the best measurement to identify the uniqueness of each variety.

This initial study was only carried out on two different planting materials. It is important to develop a database of oil palm FFB physical and optical characteristics from various and available planting materials. This is the key to help in increasing the accuracy and the efficiency of quality harvesting and the future automated grading system.

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