UNIVERSITI PUTRA MALAYSIA

QUALITY ASSESSMENT OF OIL PALM FRESH FRUIT BUNCHES USING BACKSCATTERING IMAGING

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APPROVAL SHEET

This project report here to entitle “QUALITY ASSESSMENT OF OIL PALM FRESH FRUIT BUNCHES USING BACKSCATTERING IMAGING” was prepared and submitted by AHMAD SHAHID BIN ABDUL HAMID in partial fulfillment of the requirement for the degree of Bachelor of Engineering (Agricultural and Biosystems Engineering with Honors) is hereby accepted**.**

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DECLARATION

I hereby declare that this project is my original work except for quotations and citations, which have been properly acknowledged by the expert. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at University Putra Malaysia or any other institution.

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ABSTRACT

Quality Assessment of Oil Palm Fresh Fruit Bunches Using Backscattering Imaging

By

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June 2019

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Faculty: Engineering

Oil palm one of the important crop in Malaysia by which grading process still conducted using manual and laborious methods. This project investigate the potential of laser light backscattering imaging (BSI) for predicting and classifying oil palm fresh fruit bunches (FFB) at different maturity level. In this study, oil palm at various maturity levels from unripe, ripe and over ripe were acquired by charge couple device (CCD) camera combined with a laser diodes emitting light at wavelengths of 658 nm and 780 nm. The grey level intensity and the size of the backscattering area were extracted from the backscattering images and used as parameters for estimating the quality properties of the oil palm that measured using conventional method. The results of data analysis indicated strong correlations between the BSI parameters and oil palm properties with coefficient of correlation (R^2) over 0.50. Thus, it can be concluded that the BSI could potentially be used for predicting and classifying the maturity level of oil palm.

ABSTRAK

Penilaian Kualiti Tandan Buah Tanaman Minyak Sawit Menggunakan Pengimejan Serak balik

oleh

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Jun 2019

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Kelapa sawit merupakan salah satu tanaman penting di Malaysia yang mana proses penggredan masih dijalankan menggunakan kaedah manual dan makmal. Projek ini menyiasat potensi pengimejan serak balik cahaya laser (BSI) untuk meramal dan mengklasifikasikan tandan buah kelapa sawit (FFB) pada tahap kematangan yang berbeza. Dalam kajian ini, kelapa sawit pada pelbagai peringkat kematangan dari kurang matang, matang dan terlebih matang telah diperolehi oleh kamera pasangan kamera (digabungkan) dengan diod laser yang memancarkan cahaya pada panjang gelombang 658 nm dan 780 nm. Keamatan tahap kelabu dan saiz kawasan serak balik diekstrak dari imej serak balik dan digunakan sebagai parameter untuk menganggar sifat kualiti kelapa sawit yang diukur menggunakan kaedah konvensional. Hasil analisis data menunjukkan korelasi yang kuat antara parameter BSI dan sifat kelapa sawit dengan koefisien korelasi (R^2) lebih dari 0.50. Oleh itu, dapat disimpulkan bahawa BSI

berpotensi digunakan untuk meramalkan dan mengklasifikasikan tingkat kematangan kelapa sawit.

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LIST OF ABBREVIATIONS

L	Lightness
A	Area
B	Blue
CCD	Charged-coupled Device
r	Pearson's Correlation Coefficient
R^2	Coefficient of Determination
BSI	BackScattering imaging
SPSS	Statistical Package for the Social Sciences
CPO	Crude Palm Oil
FFB	Fresh Fruit Bunches

CHAPTER 1

INTRODUCTION

1.1 Overview

Oil palm is the most important economic crop in Malaysia. It was ranked second largest production behind Indonesia (USDA 2013). The planted area covers 5.74 million hectares that contributed to 30% of world total palm oil production in the world (Kushairi et al., 2017; Oil World, 2016). This is due to the increasing world population which is expected to be ten billions in the year 2050 (Barcelos et al., 2015). Thus, to overcome this demand, a larger oil palm plantation and more labors are needed which is expected to be a critically problem due to competition for residential area and modernization (Masani et al., 2013). It is important for the oil palm industry to remain competitive by increasing the yield per unit area as well as producing novel high-value traits such as high oleic acid and minimizing postharvest losses (Parveez et al., 2015a)

One of the obstacles in postharvest processes of palm oil production is grading oil palm fresh fruit bunches (FFB) according to their maturity level. The maturity or ripeness of the oil palm fruits dictates the quality of palm oil produced and overall marketability (Junkwon et al., 2009). The conventional method that currently being practiced of counting the number of loosened fruits per bunch is time-consuming, and labor intensive. These inefficient methods affects the growers' profitability (Jamil et al., 2009; Shaarani et al., 2010).

Therefore, there is a need for a reliable, rapid, and accurate sensing technique for the detection of oil palm FFB maturity.

Agricultural and food commodities are presumed to be semi-transparent or opaque and allow the passage of light at specific wavelengths (Mireei et al., 2010). Absorption, transmittance and reflectance may take place when light photons, or electromagnetic radiation, moves within a semi-transparent or opaque biological system (Qin, 2007). Light reflectance is an intricate phenomenon and can be looked at as steady (specular) reflectance, external diffuse reflectance, and scattering. Light reflection from a polished and smooth surface is called steady (specular) reflectance. The law of reflection proposes that the angle of incidence of light with the surface of a body is equal to the angle at which it is reflected, while external diffuse reflectance takes place at a fixed angle of 45° to the incident beam. This reflectance conveys certain information about the surface of the object such as color and texture (Mireei et al., 2010).

1.2 Problem statement

In palm oil industry, the quality of the oil is depending on the FFB maturity level. The FFB market comprises the producers, namely the estates and the smallholders, dealers and mills. The activities of these three sectors are interdependent in ensuring the quality of FFB produced, handled and processed. The rule of thumb for good quality practices is that, only ripe FFB are harvested and then dispatched to mills within 24 hours after harvesting. If this principle is adhered to, the problem of poor quality FFB in the market should be minimized. However, in the FFB market, this basic principle is not strictly followed. Producers fail to ensure that only ripe FFB are harvested, citing problems of labor shortage; and the FFB dealers fail to acknowledge the importance of minimum handling and dispatching of FFB to the mills within 24 hours

In Malaysia, the palm oil fruit grading is done manually by the labor. It involves a certified tester to take a sample of the fruit bunch and perform visual inspection. However, this kind assessment resulted to high variations as the human's eyes perceive colors differently and this often led to dispute between graders and sellers. Additionally, the analysis also easily influenced by physiological and environmental factors, inducing subjective and inconsistent evaluation results.

1.3 Objectives

The main objective of this study is to evaluate the potential of backscattering imaging (BSI) for detecting the maturity level oil palm FFB namely unripe, ripe and over ripe. The specific objectives are:

I. To measure the color, firmness and oil content of FFB using standard methods namely colorimeter, texture analyzer and soxhlet extraction method.
II. To acquire backscattering images of FFB using laser diode emitting lights at 658 nm and 780 nm
III. To correlate the relationship between parameters obtained from standard methods and BSI.

1.4 Scope of study

This experiment was conducted on oil palm FFB of variety DXP GH 500 (Golden Hope) Sime Darby at three different maturities i.e. unripe, ripe and over ripe. The sample was scanned using backscattering imaging (BSI) with laser diode emitting light at 658mm and 780mm.

CHAPTER 2

LITERATURE REVIEW

2.1 Oil Palm

The oil palm tree or scientifically known as *Elaeis guineensis* is originated from West Africa (Corley and Tinker,2003). Oil palm produces fruits in bunches known as FFB. An oil palm tree produces more than 8–12 bunches per year, each weighing up to 13 kg (Evbuomwan et al., 2013; Jagustyn et al., 2013). The main products of the oil palm industry are crude palm oil (CPO) and palm kernel (PK), which yields another type of oil known as palm kernel oil (PKO), and residue known as palm kernel cake (PKC). The wastes generated from processing FFB are known as FFB wastes. The solid wastes include empty fruit bunch (EFB), mesocarp fibre (MF) and palm kernel shell (PKS), which represent important biomass in the oil palm industry (Kabir et al., 2017)

2.2 Fresh fruit bunches

Based on the standards established by Malaysian Palm Oil Board (MPOB), the oil palm fresh fruit bunches can be broadly classified into three main categories: 'Unripe' with 1–9 fruits detached from the bunch, 'Ripe' with 10–50% fruits detached from the bunch and 'Overripe' with 50–90% fruits detached from the bunch.

The nutrient of palm oil's calories come from fat. Its fatty acid breakdown is 50% saturated fatty acids, 40% monounsaturated fatty acids and 10% polyunsaturated fatty acids. The main type of saturated fat found in palm oil is palmitic acid, which contributes 44% of its calories. It also contains high amounts of oleic acid and lower amounts of linoleic acid and stearic acid.

In fractionated palm oil, the liquid portion is removed by a crystallizing and filtering process. The remaining solid portion is higher in saturated fat and has a higher melting temperature. Figure 1 show the example of different maturity level of oil palm FFB.

(a) (b) (c)

Figure 1: Example of FFB; Unripe (a), Ripe (b) and Over ripe (c)

2.3 Backscattering Imaging (BSI)

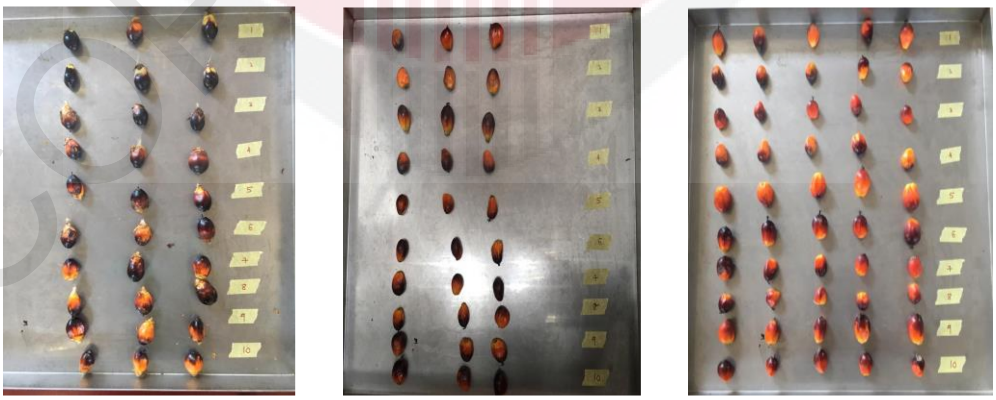
BSI is an innovation of computer vision. It uses the theory of light propagation when the light is reflected and scattered back towards the external surface of the sample upon entering the fruit tissue. In this case, the backscattering photons obtained through light propagation carry useful information associated with the morphology properties of the flesh when interacting with the quality attributes of the fruit sample (Adebayo et al.,2016, Mollazade et al., 2012). Some of the fruit samples that have been tested are bananas (Hashim et al., 2013), apple (Romano et al., 2011), cucumber (Qin and Lu, 2008), papaya (Udomkun et al., 2014), peach (Lu and Peng, 2006) and kiwifruit (Baranyai and Zude, 2009). Lu et al., (2004) reported that the light backscattering imaging system could be a useful technique for determining textural and mechanical properties of the fruit. The fruit and light have great correlation to give much information on the physical characteristics of the fruit as the optical properties are wavelength-dependent. Moreover, the methods developed for processing the backscattering images are computationally inexpensive. The low processing cost suggests that a laser-based system could possibly be developed and applied, especially in real-time sorting/grading machines.

CHAPTER 3

METHODOLOGY

3.1 Sample preparations

The FFB samples were obtained from Taman Pertanian Universiti (TPU), Universiti Putra Malaysia (UPM) Serdang, Selangor. The variety of the samples were DXP GH 500 (Golden Hope) Sime Darby. A total 30 samples of FFB: which were 10 FFB per stage (unripe, ripe and over-ripe) were measured in this study (figure 2). The experiments were conducted immediately samples were conducted immediately once the samples arrived at the Bioprocess Laboratory in the Department of Biological & Agricultural Engineering. Faculty of Engineering, UPM The research workflow was shown in Figure 3. The experiment was started with Image acquisition using backscattering imaging follow by measure the color of FFB using colorimeter, measure the firmness of FFB using texture analyzer, Measure the oil content of FFB using Soxlet extraction and finally, data analysis



(a) (b) (c)

Figure 2: Three groups of FFB sample; (a) unripe, (b) ripe, (c) over-ripe

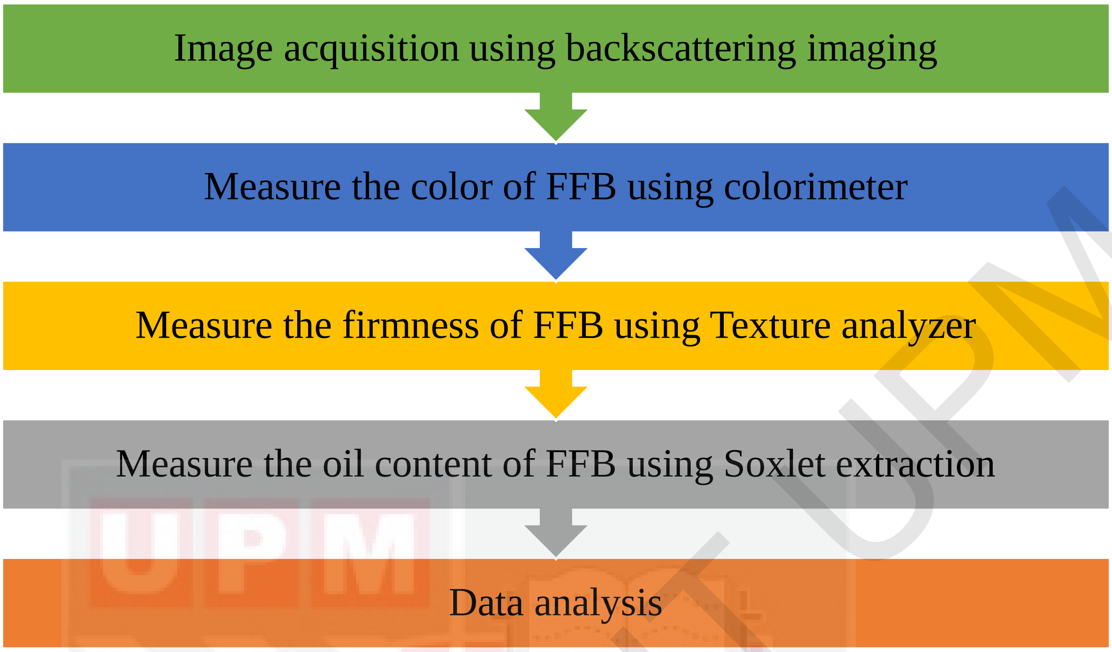


Figure 3: Research Workflow

3.2 Imaging system

The BSI system that used in this study consists of a charge-coupled device (CCD) camera (QICAM Colour Fast 1394, QImaging, Surrey, BC, Canada) with a zoom lens (F5.6 and focal length of 18 mm), a laser diode emitting at 658 nm and 780nm with 30 mW maximal power, and a computer equipped with the Image-Pro Insight 9 software (Media Cybernetics, Inc., USA) (Figure 4). The CCD camera captured backscattering images of 1392 × 1040 pixels with a resolution of 0.073 mm/pixel and 12-bit gray color depth. The portion of backscattering light upon penetrating into the fruit tissue was recorded by the CCD camera and stored on the computer. A frame (930 mm × 700 mm × 700 mm) with a lightproof medium i.e. black cloth was used to avoid interruption from ambient light. A laser diode at 658 nm and

780nm is used as the light source which can distribute light for a selected wavelength. Since the processing of the whole laser-induced backscattering imaging system is quite fast, the image acquisition was set at a short exposure time (10 m/s). The distance from the camera lens to the samples was set at 24 cm in a fixed position at the top of the fruit. The incident angle of the light beam was placed at 22° with respect to the vertical axis. The backscattering images were obtained by placing the sample manually on the sample holder facing the CCD camera.

A total of 60 images per maturity stage with two laser diodes were taken for this study. The images were pre-processed and segmented before backscattering parameters were extracted. The pre-processing was conducted by using Matlab Software to remove background in the image. The image then was converted from gray level image into binary image to reduce the complexity of the data. Image segmentation was carried out using thresholding method to separate the region of interest (foreground) from its background.

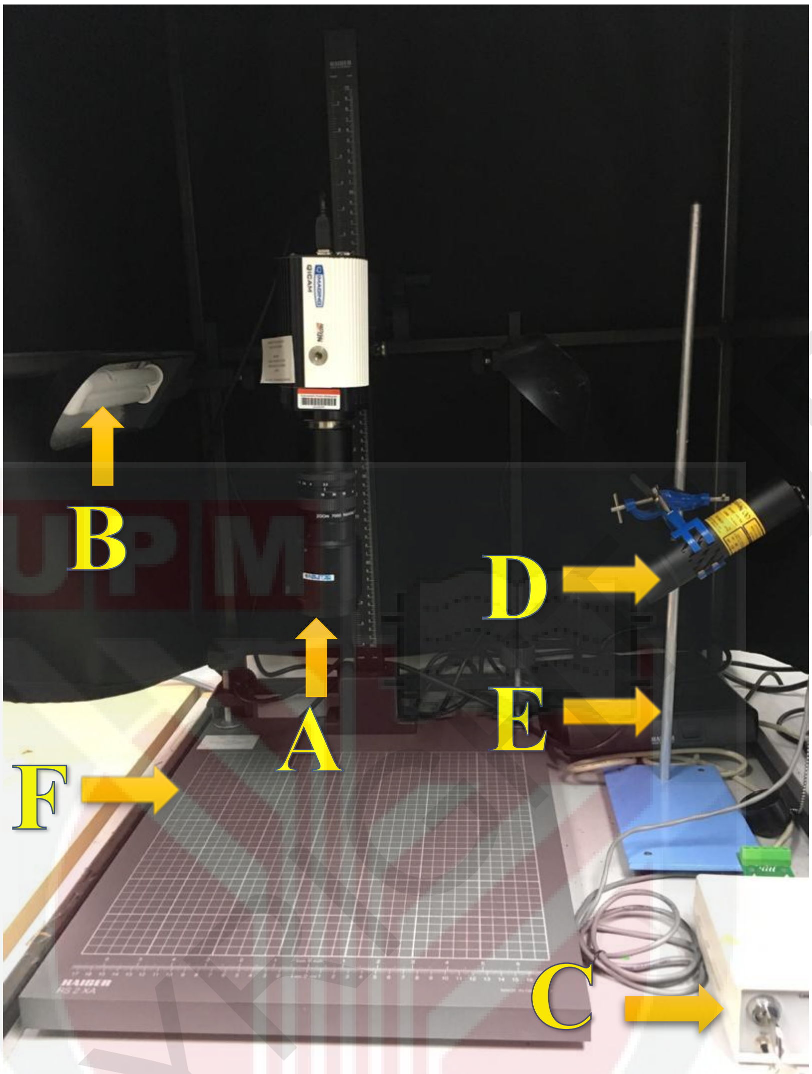


Figure 4: Backscattering imaging system, (A) CCD camera; (B) Halogen lamps; (C) laser diode box; (D) laser light emitter; (E) laser light emitter holder; (F) sample capturing platform

3.3 Backscattering image analysis

Backscattering images obtained at different maturity stages using laser of Wavelength (a) 658nm and (b) 780nm are as shown in Figure 5. The backscattering images were obtained through an image segmentation process using MATLAB software (Version R2016a, The Mathworks Inc., Natick, MA, USA). The region of interest in the image was selected by choosing the threshold value from a histogram profile based on the backscattering image. From the feature extraction of the backscattering image, the pixel value (maximum intensity, minimum intensity, and mean intensity) and shape (area, major axis length, minor axis length, and perimeter) measurements were determine. The mean intensity determine the mean pixel values in region of interest (ROI), the minimum intensity indicated the lowest intensity among the pixel values and maximimum intensity the higher intensity while the perimeter specified the distance calculated around the ROI boundary. The area specified the area calculated for the ROI boundary. The major axis length and minor axis length determined the length measurement of the major and minor axis within the ellipse (Mohd. Ali et al., 2016). The data was then exported to statistical software for further analysis.

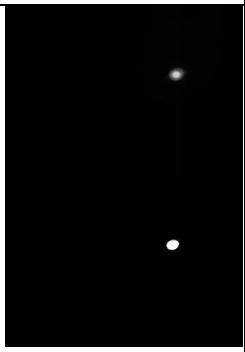
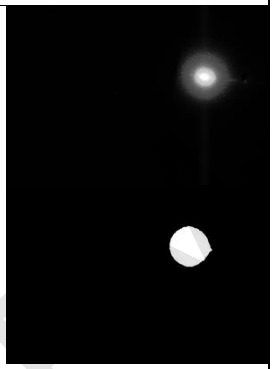
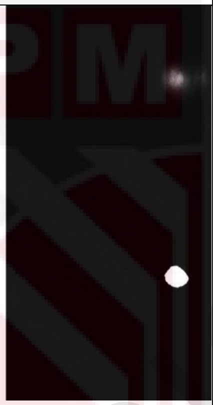
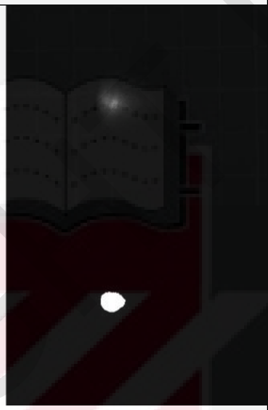
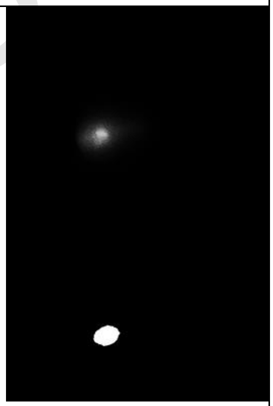
Laser	Unripe	Ripe	Over-ripe
(a) 658nm			
(b) 780nm			

Figure 5: Backscattering images at different maturity level using laser wavelengths 658nm (a) and (b) 780nm

3.4 Color changes

The color assessment was performed using colorimeter (3nH NR 110, China) color reader with diameter of the aperture 8mm (Figure 6). Before measurement, the colorimeter was calibrated by placing the color reader tip flat against the white tile as target color in order to avoid error during the measurement. The color in which results were displayed was changed in L*, a* and b* color space in reflectance mode. The light of colorimeter was penetrated on the same mark positions where the backscattered imaging took place. The color reader showed the reading of the important parameters which were L*, a* and b*. The parameters L* for lightness/darkness, a* for redness/greenness and b* for yellowness/blueness.

Figure 6: colorimeter

3.5 Firmness

The firmness was measured using textural analyzer (TA XT plus) with 2mm Cyl stainless stable micro as shown in figure 7 before measurement, the texture analyzer was calibrated by applying 5kg load force. The specification of the texture analyzer used is as shown in Table 1.

Figure 7: Texture Analyzer

Table 1: Technical specification Texture analyzer

Texture analyzer	TA XT plus Texture Analyzer
Force Capacity	50Kg.f (500N)
Force Resolution	0.1g
Loadcells	0.5, 5, 30, 50kg.f
Speed Range	0.01 – 40mm/s
Maximum Aperture	370mm/590mm
Distance Resolution	0.001mm
Data Acquisition Rate	2000pps

Source: producer – Stable micro system., Ltd

3.6 Oil extraction

Soxhlet extraction (Figure 8) was used to extract oil content of using hexane. The amount used for each sample was 250ml and the total for one cycle oil extraction was about 2.5 liter.

Figure 8: Soxhlet extraction

Prior to extraction process, the sample were cut into small pieces and then, dried in oven at 105 °C for 30 minutes (Figure 9). This drying process was conducted purposely to remove the water content in the samples. After that, the sample was put at desiccator for one day to preserve moisture content. Figure 8 show the Soxhlet extraction system, The Soxhlet extraction was conducted for 8 hours to complete one cycle, the oil palm and hexane were separated using Rotavapor system (Eyela N-1110, Shanghai, China) normally it took about 8-10 minute to separate the hexane and Crude palm oil (CPO) and Finally weigh the Crude palm oil (CPO) was weight to get a value weight of oil content.

Figure 9 shows the prior to extraction process, firstly cut the sample into small pieces. Then, dry at oven, the temperature was set up at 105 °C for 30 minutes. This drying purposely to remove the water content at oil palm. After that, the sample was put at desiccator for one day to preserve moisture content. Figure 8 show the Soxhlet extraction system, The Soxhlet extraction was conducted for 8 hours to complete one cycle, the oil palm and hexane were separated using Rotavapor system (Eyela N-1110, Shanghai, China) normally it took about 8-10 minute to separate the hexane and Crude palm oil (CPO) and Finally weigh the Crude palm oil (CPO) was weight to get a value weight of oil content.

Figure 9: Flow of process Oil Extraction: a) The samples were cut into small pieces: b) Dried in oven at 105° C for 30 minutes; c) Put at desiccator for one day; d) weigh the sample before oil extraction; e) put the sample into thimbles; f) Run the soxhlet extraction for 8 hours; g) Used rotavapor system for separate crude palm oil and hexane h) weight the Crude palm oil

3.7 Data Analysis

The data analysis was conducted using SPSS statistics software (Version 22.0, SPSS Inc., Chicago, USA). The statically analysis was done by investigating relationship of backscattering parameters with oil palm FFB properties. Pearson's correlation was done to determine the linear relationship between the variables. If the Pearson correlation coefficient, r closest to 1, this means that there was a strong relationship between the Standard and BSI methods. Besides that, Linear Stepwise Regression was performed to predict the multiple correlation coefficients, R on how strongly the multiple independent variables are related to the other dependent variables. The coefficient of determination, R^2 value which was the proportion of variance in the dependent variable were used to explain the prediction model of oil palm maturity level estimation. It gave the information on how close the variables to the fitted regression line. The variable that gives the high R^2 value would produce a good model fits of the data.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, all progressive stages of data collected from oil palm FFB at different stage of maturity level were discussed, beginning with the preparation, preprocessing and ending with evaluating the result.

4.2 Physicochemical properties of oil palm at different ripening stage

Table 1 shows the significant variations of color (L*, a*, b*), firmness and oil content values from unripe to over ripe. A significant difference ($p \leq 0.05$) was found in color between the different maturity level of oil palm. The values of L* is higher at ripe which is 44.41 followed by over ripe and unripe. The b* parameters obtained the maximum value ripe stages with 33.10. Meanwhile the value of a* increased by the maturity level, with no overlap between the values, ranging from 16.93 (green) to 58.77 (red). The variations in color changes could be due to the reduction of chlorophyll content and an increased in carotenoid content during the ripening process (Li et al., 1997). As we can see from the (Table 2) the value of ripe samples were the highest followed by unripe and over ripe. On the other hand, oil content for over ripe and ripe was almost similar, with 25.23 for over ripe and 24.60 for ripe.

Table 2: Descriptive analysis results of physicochemical properties of oil palm

Maturity Level	L* ± SD	a* ± SD	b* ± SD	Firmness ± SD	Oil Content ± SD
Unripe	34.62 ± 7.43	16.93 ± 8.05	15.35 ± 13.10	11523.15 ± 5133.58	9.39 ± 4.56
Ripe	44.41 ± 6.45	32.37 ± 5.77	33.10 ± 13.73	13642.87 ± 6934.56	24.60 ± 3.90295
Over Ripe	40.20 ± 5.06	58.77 ± 82.43	31.06 ± 10.88	11173.01 ± 4153.63	25.23 ± 5.71

SD=Standard deviation; statistically significant at $p < 0.05$ differences between means

4.3 BSI parameter at different maturity level

The F-values (ANOVA) of backscattering parameters in the 658nm and 780nm evaluation of oil palm were analyses to obtain the significant effect of the experimental factors at different maturity level and their interactions at $p < 0.05$ (Table 3 and) (Table 4). Based on the results, significant differences were observed for all backscattering parameters of oil palm maturity level, except for the max intensity (658nm) and min intensity (780nm) when subjected to different maturity level. The mean intensity for both laser diodes showed the highest F-values by which 29.914 for 658nm and (35.949) for 780nm, whereas the (658nm) maximum intensity and (780nm) min intensity did not have a significant effect at all the backscattering parameters in terms of maturity level.

Table 3: Analysis of variance (ANOVA) LLBI 658nm parameters with different maturity level oil palm

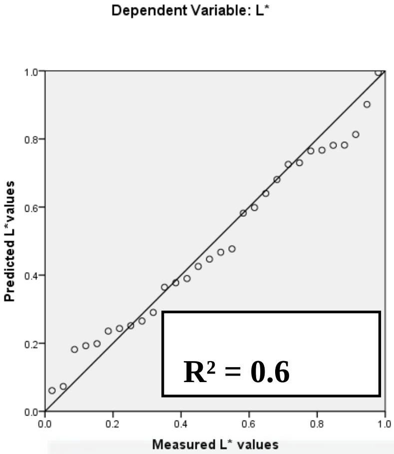
Wavelength 658nm			
Parameter	Mean Square	F - value	P < 0.05.
Area	452958186.359	19.250	.000
Major length	13396.410	25.931	.000
Minor length	11641.992	22.544	.000
Mean intensity	360.864	29.914	.000
Max intensity	99.615	2.262	.124
Min intensity	66.159	25.760	.000
Perimeter	138383.549	25.806	.000

Table 4: Analysis of variance (ANOVA) LLBI 780nm parameters with different maturity level oil palm

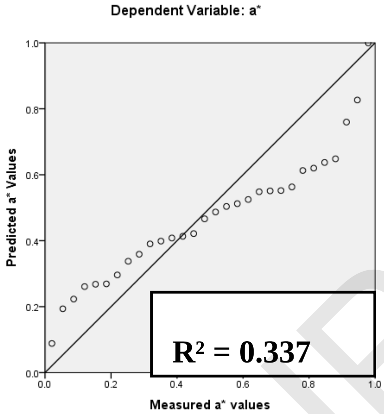
Wavelength 780nm			
Parameter	Mean Square	F - value	P < 0.05.
Area	26236107.448	25.710	.000
Major length	3405.823	22.992	.000
Minor length	315.885	6.968	.004
Mean intensity	985.407	35.949	.000
Max intensity	9853.644	34.234	.000
Min intensity	.848	.577	.569
Perimeter	14370.871	18.305	.000

4.4 Correlation of physicochemical properties and BSI parameters

The result of regression on the BSI (658nm) parameters with physicochemical properties of L*, a*, b*, Firmness and oil content showed that the R^2 value increased as the number of the parameters in the model increased (Figure 10). The best single parameters for predicting the color values of L*, a*, b*, firmness and oil content was mean intensity with R^2 or the regression model being equal to 0.59, 0.51, and 0.72 respectively. On the other hand, the combination of the major length, minor length, mean intensity, min intensity, diameter, area and maximum intensity values gave the highest R^2 with 0.72. for predicting the b* values. The decreased in chlorophyll content and the formation of new color pigments such as carotenoids in ripe oil palm was presumed to be the result of higher b* values. For the regression analysis on the wavelength at (780nm) we can see the R^2 value decreased as the number parameters in the model decreased (Figure 11). As comparison between two laser diodes, 658nm and 780nm. It could be seen that laser 658nm gave a higher value on R^2. This was because the optimal wavelength to measure color is 658nm. Therefore, the laser 658nm performs better than 780nm determining three maturity level of oil palm.



(a)



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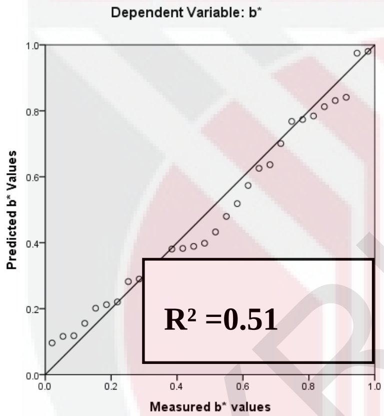

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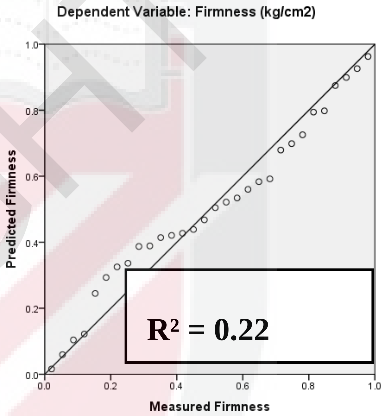

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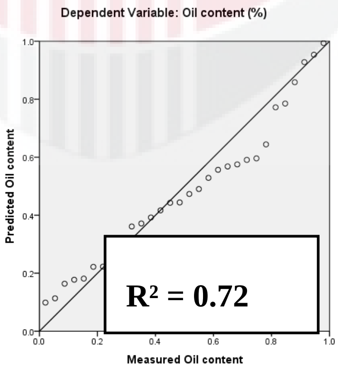
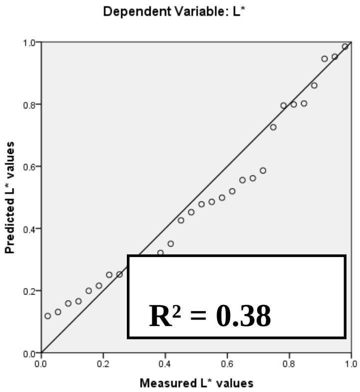
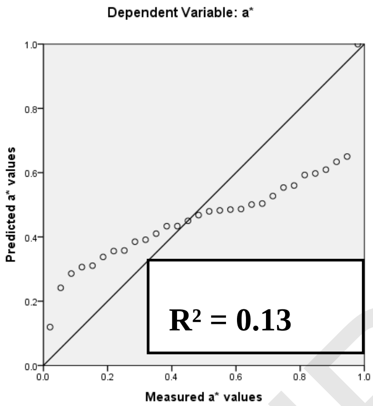


(e)

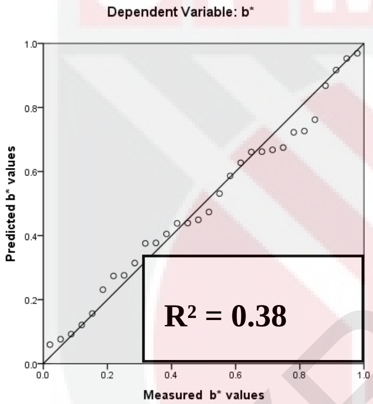
Figure 10 : L* (a), a* (b), b* (c), firmness (d) and oil content (e) BSI 658nm



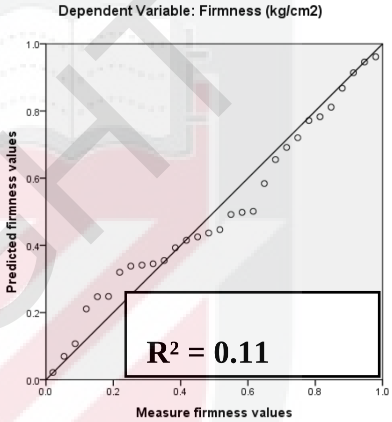
(a)



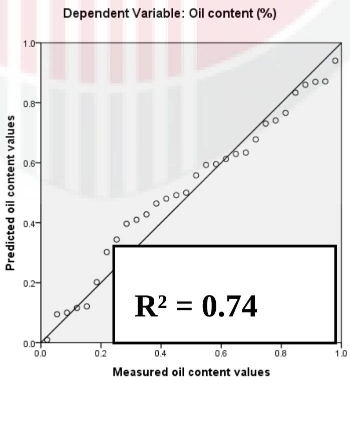
(b)



(c)



(d)



(e)

Figure 11 : L* (a), a* (b), b* (c), firmness (d) and oil content (e) BSI 780nm

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, the potential of BSI in determining quality properties of oil palm FFB was investigated. The results on this work had successfully prove the potential BSI system to detection of maturity level oil palm. Predicted color (L*, a*, b*,), firmness and oil content resulted to the highest R^2 with all of them above 0.6 at different maturity level. Therefore, this study has demonstrated the capability of BSI as a useful, rapid, and non-invasive optical technique for the color evaluation and firmness of the quality of oil palm during grading and sorting the different maturity level. Furthermore, BSI system has high potential to correlate between standard methods with a rapid evaluation for predicting oil palm quality maturity.

5.2 Recommendations

The recommendation for further research is follows:

1. Oil extraction should extract in same day to avoid the loses at oil palm.
2. The laser should place correctly at oil palm to avoid error at measurement.

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APPENDICES

Table 5: Data backscattering imaging (658nm)

MATURITY	SAMPLE	AREA	MAJOR LENGTH	MINOR LENGTH	MEAN INTENSITY	MAX INTENSITY	MIN INTENSITY	PERIMETER
RIPE	1	22014	171.702	162.6478667	95.28186667	255	22	542.985333
RIPE	2	15250.33	147.5318333	130.8478667	100.6995333	255	22.33333333	453.132333
RIPE	3	16458.67	152.8290667	136.5311667	93.57286667	255	22	463.634667
RIPE	4	18945.33	168.8327333	142.3258667	97.83213333	255	21.66666667	499.307333
RIPE	5	28266	198.5259667	181.7805667	95.79163333	255	20.33333333	610.260667
RIPE	6	16460	151.7894667	136.8175667	95.47653333	255	19.66666667	464.753667
RIPE	7	10313.33	115.6332333	101.5142	103.0303	255	18.66666667	352.473
RIPE	8	14709.67	144.2212667	129.3808667	97.03693333	255	20.33333333	442.114667
RIPE	9	17885	160.9262	142.0046	96.231	255	19.66666667	492.005667
RIPE	10	20540	157.8821	150.8761333	95.04316667	255	18.66666667	496.167667
UNRIPE	1	3500	68.5224	62.1572	102.7234667	235.6666667	16.66666667	204.792
UNRIPE	2	1956.333	54.27293333	45.75083333	112.5365	221.6666667	16.66666667	154.702333
UNRIPE	3	6282.333	95.4855	80.11266667	108.6716667	254.6666667	14.33333333	281.330333
UNRIPE	4	5859.667	93.4083	80.8317	105.0900333	255	17.66666667	277.572
UNRIPE	5	5381	86.6524	78.24663333	109.4563333	255	18.66666667	262.809333
UNRIPE	6	8055.333	106.8203333	93.48933333	107.5456	255	17	321.964333
UNRIPE	7	8142	109.0505	94.265	102.9307	255	16	321.799333
UNRIPE	8	5858.333	92.88576667	80.46393333	103.8385	253.333333	19.33333333	276.654
UNRIPE	9	8002.667	107.4781	94.1316	104.1151333	255	20	321.500333
UNRIPE	10	9091	108.9267667	99.55906667	105.4039667	255	17.66666667	332.097667
OVER RIPE	1	22611.33	177.4821	161.1307	92.7096	255	15.66666667	551.602667
OVER RIPE	2	29290	202.5866333	184.8427667	93.99876667	255	14	626.984667

OVER RIPE	3	10569	129.769	101.4429	98.84856667	255	17.33333333	369.527667
OVER RIPE	4	10882	123.9927	110.9419333	98.01806667	255	17	380.795333
OVER RIPE	5	14093.67	139.0237333	125.4486667	96.32053333	255	18.33333333	426.450667
OVER RIPE	6	11636.67	127.5289333	111.4175	98.58116667	255	16.33333333	397.477
OVER RIPE	7	15874	143.0079667	133.2911667	98.71883333	255	14	446.875
OVER RIPE	8	21591.33	173.2116333	158.1949667	96.25283333	255	13.33333333	536.565333
OVER RIPE	9	24698	183.6234333	172.1845333	89.13816667	255	14	584.900667
OVER RIPE	10	15185.33	144.0288	125.1639667	86.9772	255	14.33333333	446.592333

Table 6: Data backscattering imaging (780nm)

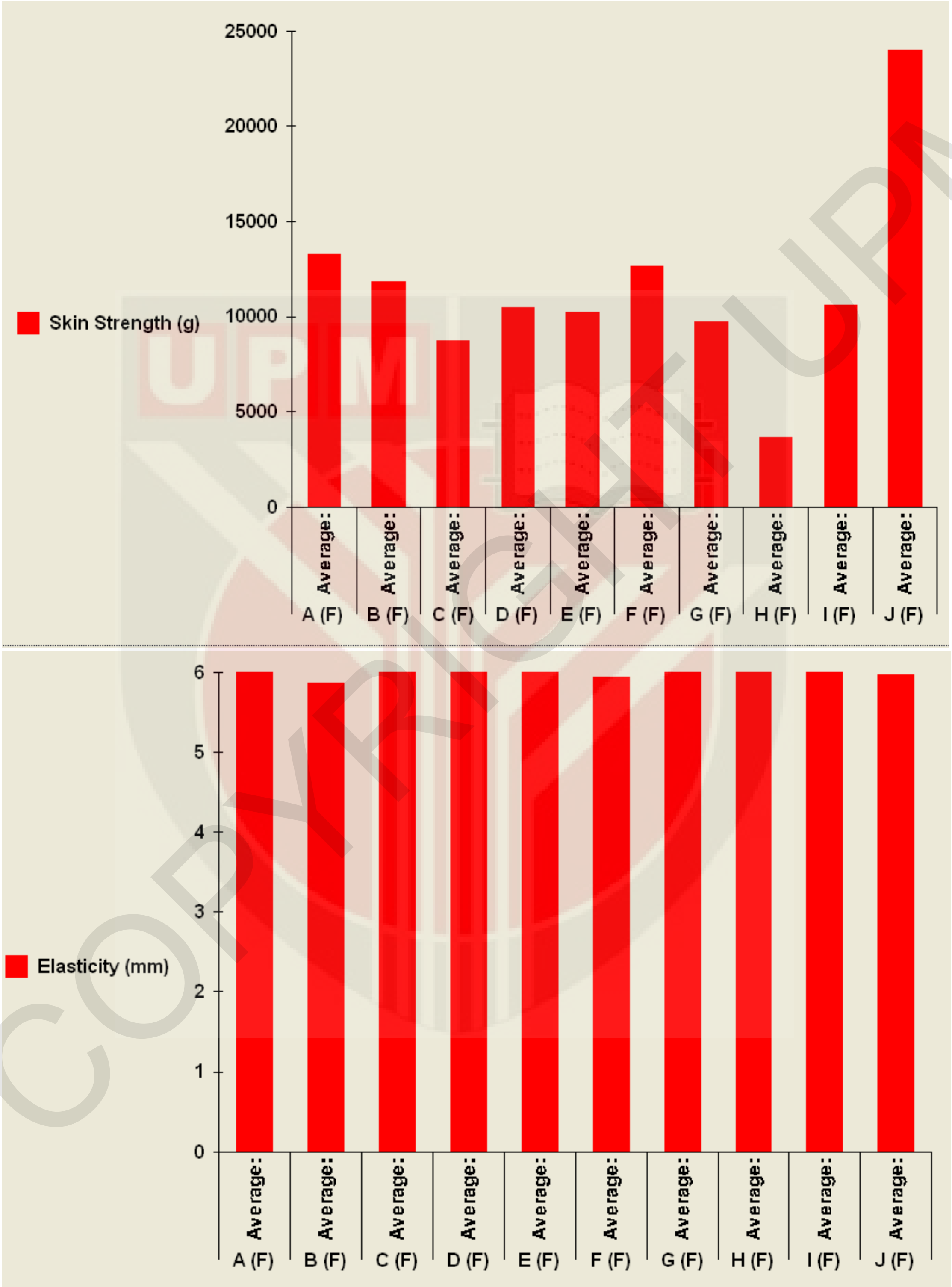
MATURITY	SAMPLE	AREA	MAJOR LENGTH	MINOR LENGTH	MEAN INTENSITY	MAX INTENSITY	MIN INTENSITY	PERIMETER
RIPE	1	7099.333	133.7184	69.46837	50.2987	115.3333	18.33333	355.510333
RIPE	2	8320.667	118.1287	91.16187	64.32907	176.3333	19.66667	345.51
RIPE	3	6709	117.5199	73.22093	60.371	165	18.66667	319.923667
RIPE	4	8283.667	117.7388	90.7186	62.882	171.6667	21.66667	338.449667
RIPE	5	8149.667	132.6648	79.37947	54.12763	123.6667	18.66667	362.853
RIPE	6	6632	128.5733	68.68977	53.1235	136.3333	17	345.218333
RIPE	7	3283.333	75.9581	54.64397	51.03877	113.6667	19	221.277333
RIPE	8	6697	112.8312	76.98957	56.85683	142.3333	18.66667	326.342333
RIPE	9	6954.333	115.5181	76.73113	53.5308	132	17.33333	324.815333
RIPE	10	6335	110.387	69.73023	55.3707	125.3333	18	315.538667
UNRIPE	1	10215.67	155.0533	87.11773	75.49907	198.3333	17.66667	412.570667
UNRIPE	2	8321.667	138.8938	77.44893	72.67277	203.3333	20	362.014
UNRIPE	3	9301.333	141.4404	84.70383	74.9512	199.3333	20	378.455667
UNRIPE	4	8916.333	143.4765	79.6805	81.16323	200.6667	18.66667	364.505667
UNRIPE	5	8066.667	130.6351	79.1266	72.4386	193.3333	19.66667	344.567
UNRIPE	6	9195.333	145.2659	81.67227	75.65167	199.6667	19.66667	377.385667
UNRIPE	7	8273	132.908	80.35713	70.42397	188.3333	18.33333	359.903
UNRIPE	8	7951.667	126.7856	80.54537	75.5416	202.3333	19.66667	344.005333
UNRIPE	9	9417	147.8409	82.0225	75.9477	198	19.66667	381.145667
UNRIPE	10	9613.667	155.2606	79.2325	81.8439	201.6667	17.66667	388.164333
OVER RIPE	1	5102	95.0322	69.5037	61.5948	151.6667	18.33333	277.159667
OVER RIPE	2	5132.333	107.7745	62.96473	58.79407	172	18	292.848333
OVER RIPE	3	6516	120.3455	69.56967	74.89953	177.3333	17.33333	313.361

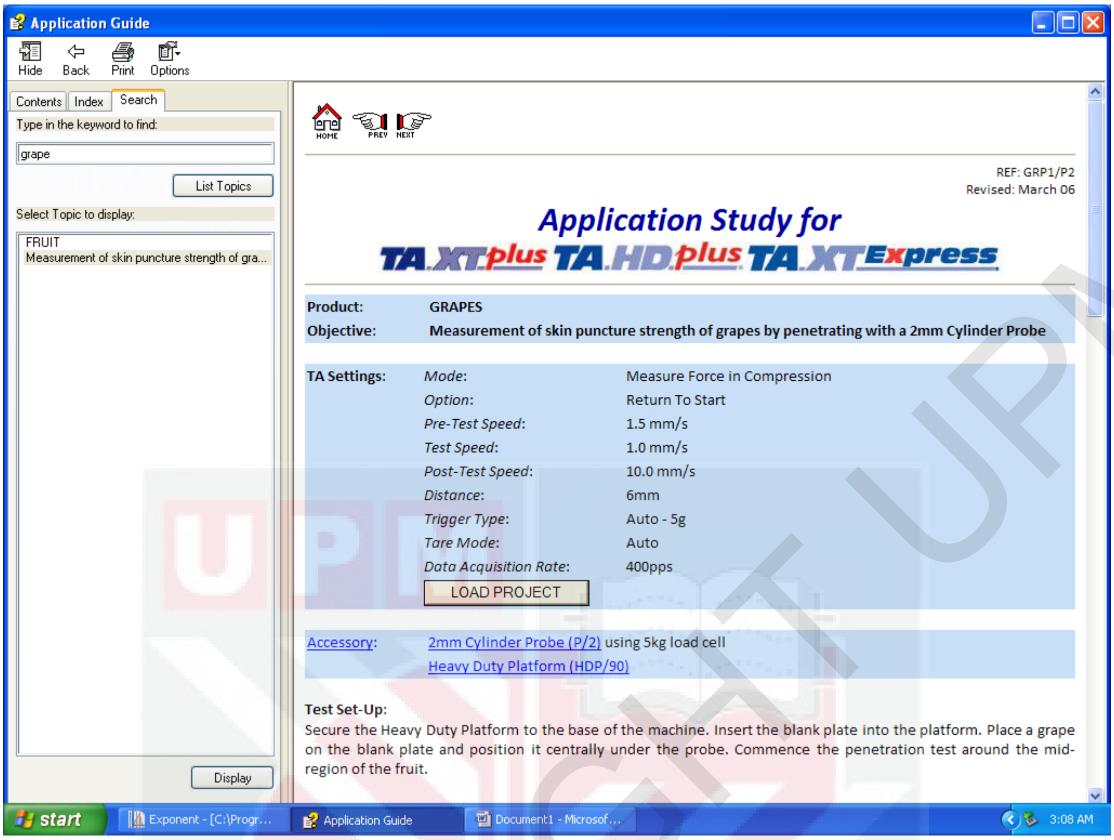
OVER RIPE	4	5416.667	100.0581	68.52583	71.25467	203.3333	18	275.324333
OVER RIPE	5	5462.333	97.5726	72.62893	67.88037	197.3333	20.66667	278.834333
OVER RIPE	6	5222.667	103.3672	66.2349	67.33047	198.3333	17.33333	302.935667
OVER RIPE	7	6565	116.7232	72.61477	68.18633	197	17.66667	313.247667
OVER RIPE	8	6470.667	111.2462	72.9732	69.05337	187.3333	18.33333	317.135
OVER RIPE	9	5301.667	94.65923	71.8253	72.69373	202.3333	21.33333	273.869333
OVER RIPE	10	6176.667	112.0279	72.81007	83.05963	207.6667	18.33333	315.627333

Table 7: Standard method data

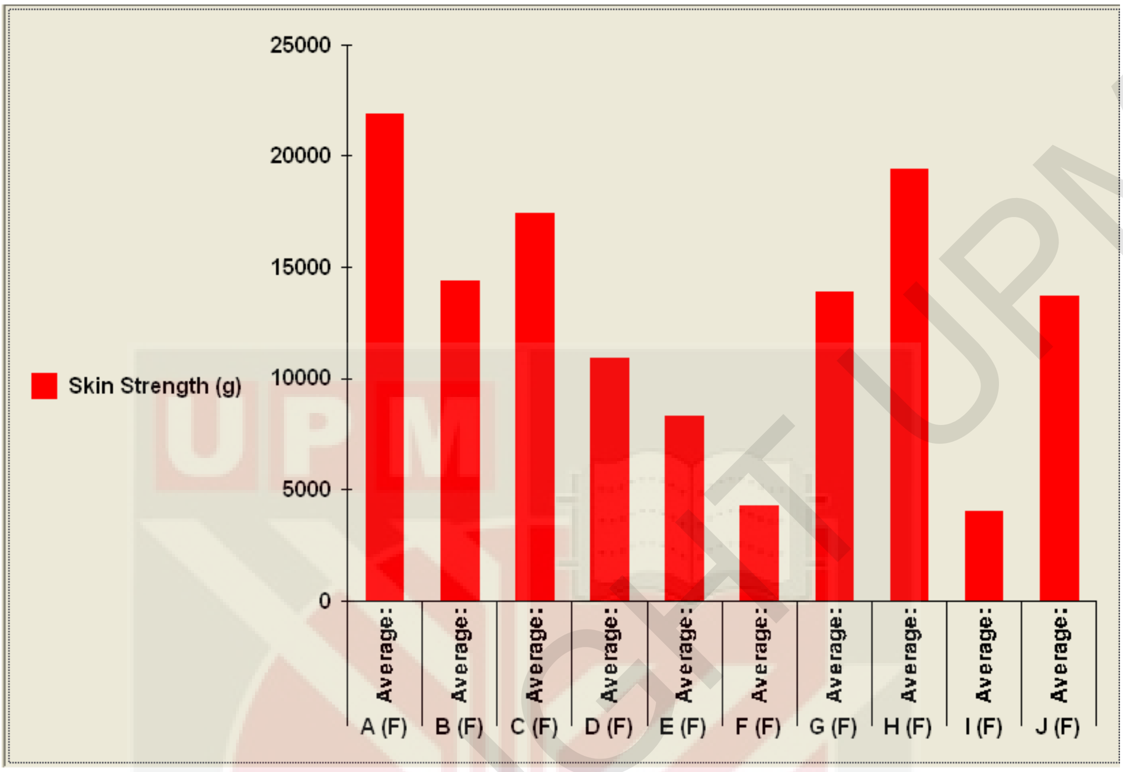
Maturity level	Firmness (kg/cm^2)	Oil content (%)	L*	a*	b*
RIPE	24450.73667	26.59	44.51	32.00667	31.99667
	17396.39333	18.49	50.81333	30.85667	42.02667
	17359.24667	23.4	36.55333	27.18667	17.42
	9304.186667	21.22	45.45	34.35667	40.51667
	12598.25333	23.37	56.86333	37.51	55.28667
	1726.306667	29.3	35.06	28.62	21.19
	14466.70333	31.83	42.69	43.67333	46.32667
	20699.55333	25.88	40.91667	23.24	13.41
	4944.506667	23.04	47.89333	35.75	38.92
	13482.83667	22.87	43.35667	30.50667	23.86333
UNRIPE	13285.76	8.5	32.2	15.23333	15.3
	11821.71	0.53	26.06333	3.763333	-1.24333
	8760.01	5	29.42333	9.556667	5.363333
	10498.6	16.65	31.79	12.46667	7.57
	10216.21	6.81	30.56	12.38	4.686667
	12657.44	12.35	32.56667	19.3	22.29667
	9707.26	13.32	37.7	20.1	16.55333
	3658.42	9.06	31.91667	18.61333	13.31333
	10600.74	10.29	42.65667	27.19667	25.35667
	24025.37	11.41	51.37	30.66667	44.33667
OVER-RIPE	12509.73	23.22	41.76333	37.41333	37.87
	9107.58	27.54	47.56333	37.46	44.27
	14222.05	15.34	44.84333	37.13667	41.47
	5897.04	22.73	39.67333	35.28	30.73
	11097.44	30.19	41.92667	37.03333	34.61667
	15979.41	36.05	29.97	20.96	12.47333
	15010.66	21.43	34.8	28.26667	23.92667
	15579.72	21.63	41.79	292.6333	27.82333
	7686.15	25.56	42.31667	38.93	41.07
	4640.27	28.56	37.36	22.59	16.32333

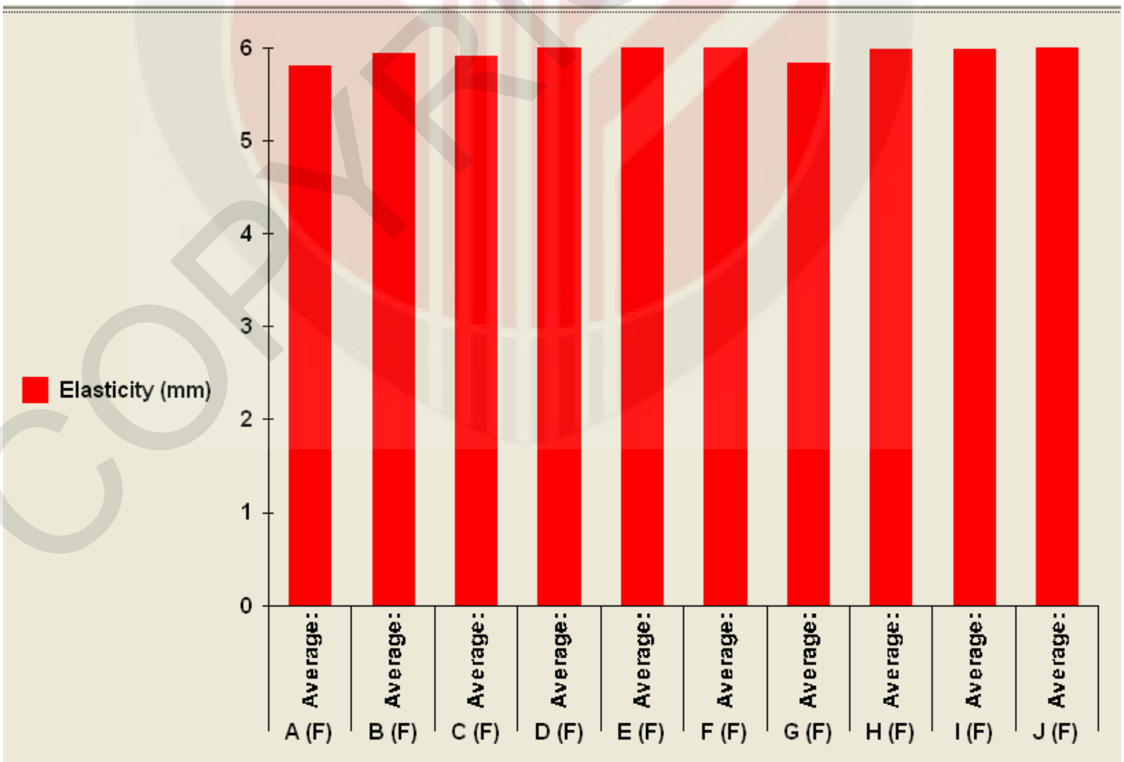
Texture analyzer (Unripe)



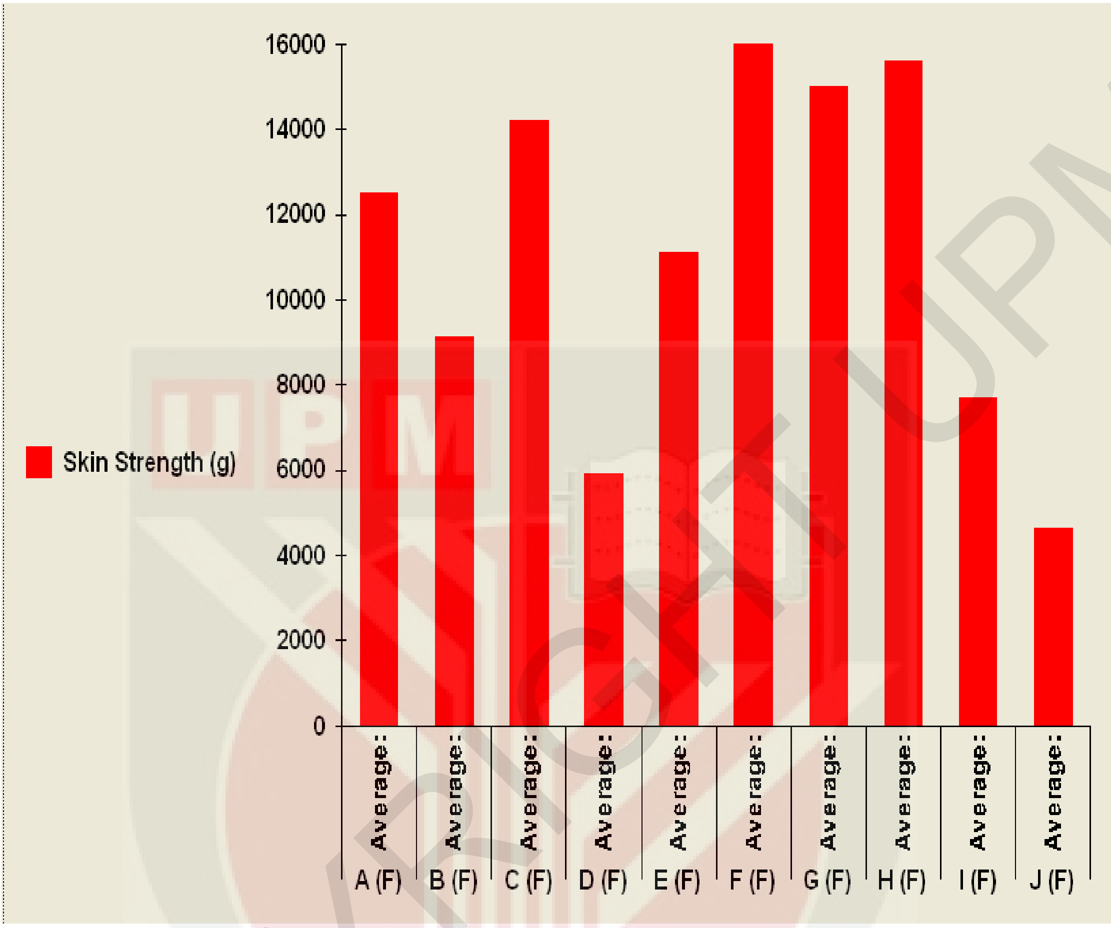

Application Guide
Hide
Back
Print
Options
Contents
Index
Search
Type in the keyword to find:
grape
List Topics
Select Topic to display:
FRUIT
Measurement of skin puncture strength of gra...
Display
HOME
PREV
NEXT
REF: GRP1/P2
Revised: March 06
Application Study for
TA.XTplus TA.HDplus TA.XTExpress
Product: GRAPES
Objective: Measurement of skin puncture strength of grapes by penetrating with a 2mm Cylinder Probe
TA Settings:
Mode: Measure Force in Compression
Option: Return To Start
Pre-Test Speed: 1.5 mm/s
Test Speed: 1.0 mm/s
Post-Test Speed: 10.0 mm/s
Distance: 6mm
Trigger Type: Auto - 5g
Tare Mode: Auto
Data Acquisition Rate: 400pps
LOAD PROJECT
Accessory: 2mm Cylinder Probe (P/2) using 5kg load cell
Heavy Duty Platform (HDP/90)
Test Set-Up:
Secure the Heavy Duty Platform to the base of the machine. Insert the blank plate into the platform. Place a grape on the blank plate and position it centrally under the probe. Commence the penetration test around the mid-region of the fruit.
start
Exponent - [C:\Progr...
Application Guide
Document1 - Microsof...
3:08 AM

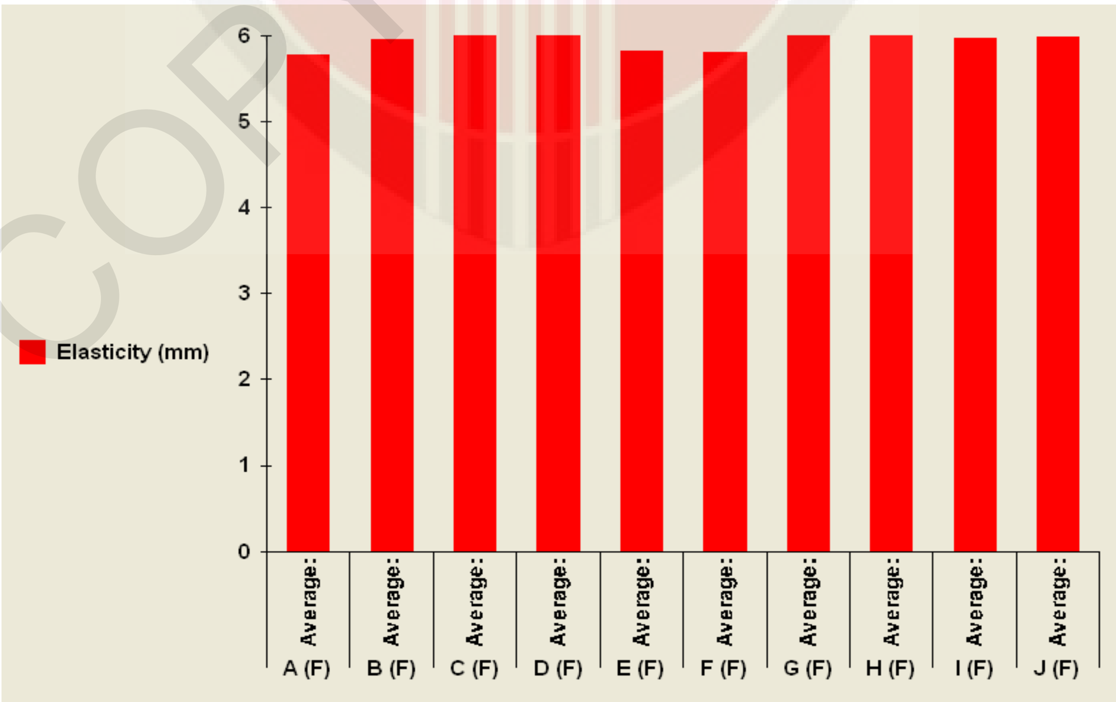
Texture analyzer (Ripe)





Texture analyzer (Over ripe)





Type of laser diode (658nm and 780nm)

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