Non destructive evaluation quality of oil palm fresh fruit bunch (FFB) (*Elaeis guineensis* Jack) based on optical properties using artificial neural network (ANN)

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Abstract. Oil palm (*Elaeis guineensis* Jacq) is one of the oil-producing plants with high productivity. The quality of palm fresh fruit bunches (FFB) is affected by harvesting activities. Generally, the method of harvesting oil palm by visual observation (maturity fraction) and harvest rotation systems. This study evaluated the quality of oil palm FFB non-destructively based on optical properties. Oil palm Fresh Fruit Bunches harvested in 5 ripeness ranges (110-130 DAA, 131-150 DAA, 151-170 DAA, 171-190 DAA, and 191-200 DAA). The oil palm FFB image recorded using a mobile camera with a minimum resolution of 25 megapixels, and then the image was processed using a digital image processing program. Furthermore, the quality parameters of oil palm FFB tested, and data were analyzed using SPSS Statistics 20.0 with the Artificial Neural Network (ANN) method. The model’s $R^2$ upon calibration was 0.6934. While upon validation $R^2$ value was 0.7211. The model was considered appropriate since $R^2$ value both in calibration and validation were high.

1. Introduction

Oil palm (*Elaeis guineensis* Jack) is one of the oil-producing crops with the highest productivity level (Pahan, 2006). Palm oil production over the last ten years has continued to increase. In 2018 Indonesia had a palm oil plantation area of 851,513,000 ha with palm oil production of 26,576.40 tonnes [1]. Especially for West Sumatra province, the plantation commodity with the largest planted area in 2018 is oil palm with a planted area of 385,237.46 hectares [2].

One of the fields of research that needs to be put forward to increase palm oil production is harvest. The quality of palm fresh fruit bunches (FFB) is affected by harvesting activities. When harvested at the right time, the FFB will produce good quality oil. To get good oil quality, we need a way to replace the harvest determination process based on visual observations (maturity fraction) [3]. The weakness of visual inspection is that it requires a very experienced operator but still carries a significant risk of error. These errors include environmental factors such as weather, wild animals that do not support this process.

Another method of harvesting oil palms is using harvest rotation. Harvest rotation is required between the last harvest and the next harvest at the same place [4]. The problem with this harvest rotation is that when the harvest is done too early, it will result in many fruits that cannot be harvested. Meanwhile, when the rotation is done too slowly, it results in high losses such as fruit passing ripe, rotten fruit, and the number of loose fruit, which are not quoted [5].
One way to consistently observe the quality of an object is by observing the physical properties or appearance of the product. Physical properties can be observed using optical devices such as cameras. One of the factors that affect the quality of FFB is the level of maturity. One of the quality parameters that is influenced by the level of maturity is the oil content. If the level of maturity of palm FFB is high, the oil content of palm FFB will also be higher and will decrease with age or overripe. This is because when it is overripe, the cell walls will crack and also break so that the oil easily gets out of the cells, and the fat sacs are torn [6]. However, in the field, the determination of the maturity level of palm FFB is still done traditionally and proven by the quality of the oil in the laboratory [7]. This causes crop errors and requires an expensive, long time, and extensive resources.

For this reason, research that focuses on the evaluation of oil palm FFB is needed to accelerate this stage. Both destructive and non-destructive methods can be used to evaluate the quality of oil palm FFB. A non-destructive evaluation has advantages; among others, there is no required chemical, faster evaluation time, and can be done without damaging the sample of the material being tested [8].

In addition to the advantages in terms of resource and time requirements, non-destructive evaluation has also been successfully used to evaluate various food products or various fruit products [7] has conducted research on nondestructive evaluation of palm fruit bunches based on machine-vision based optical properties. This study uses tools with high complexity so that the damage to the tools in the field is greater, especially in the laser probe mechanism and other moving components. Meanwhile, in other studies, a simple camera can be used to determine maturity. Smartphone cameras have been used in determining the maturity level of tomatoes with the highest accuracy, namely 80.21% [9]; His research on the classification in determining the maturity level of Sunpride banana fruit using the Asus Zenfone 5 smartphone camera with the highest level of similarity obtained, namely 100% for the very ripe class [10]; and the use of a smartphone camera to determine the ripeness index of strawberries with the highest identification accuracy obtained at 94% [11]. Therefore, the camera can be used to determine the maturity level of the oil palm FFB.

Based on this description, non-destructive evaluation methods based on optical properties can be applied to oil palm FFB. Optical properties are the response of materials (in this case palm FFB) to exposure to electromagnetic waves, especially for the visible light range. Therefore, this study will examine the correlation of the optical properties of FFB with the maturity level of oil palm FFB and obtain a predictive model.

2. Material and Methods

In this study, the selected oil palm plants are already in production and are at least seven years old. The location of the plantation is in Sijunjung Regency (0° 41'44.6" S 100° 58'54.7" E Longitude). The sample used in this study was TBS oil palm varieties Tenera with five maturity levels, namely 110-130 DAA, 131-150 DAA, 151-170 DAA, 171-190 DAA, and 191-200 DAA [7]. The level of maturity of the study sample was determined based on the cross-sectional shape of the fruit [12-13]. In this study, 70% of the sample was used for calibration data, and 30% of the sample was used for data validation.

Furthermore, the oil palm FFB image is recorded using a mobile camera with a camera resolution of at least 25 megapixels. The recording of TBS images was carried out during the day with a minimum light of 303 lux and a maximum of 1537 lux [7]. Meanwhile, the distance from the camera to the TBS object is at least 3 meters and a maximum of 12 meters [7]. If at the time of taking the distance data from the camera to the remote TBS object, optical magnification is used so that the TBS object fills the view of the sensor. To maintain stability in capturing oil palm FFB images, a tripod is used. When taking the image, the camera's position is adjusted so that the FFB surface to be recorded is not obstructed by fronds or other plant parts. At the time of recording the palm FFB image, light measurements were made using a light meter and measuring the distance from the object to the camera using the distance meter.

After recording the image, the FFB is harvested. Each bunch was taken to the laboratory for analyzing the oil content. Upon arrival, the sample was boiled immediately to inactivate the lipases. The test was conducted within 24 h after the bunch had been harvested. Fruitlets were detached from the bunch and chopped to separate fruit's mesocarp. Mesocarp was weighed using an analytical balance (Sartorius, BP
Samples were then dried to remove physical water from the mesocarp. The oil in the mesocarp was extracted using a soxhlet extractor (Figure 1), with hexane as a chemical solvent. The remaining fiber and the oil solution in the thimble were dried to remove the dissolved hexane and then cooled in the desiccator. It was then weighed in the analytical balance, and the result was recorded for mesocarp oil content calculation. This gravimetric procedure was defined by IOPRI [14] in accordance with standards established by the National Standardization of Indonesia SNI-01.2891.1991 [15]. The Mesocarp oil ($Oilm$) can be calculated as:

$$\%\ Oilm = \frac{W_1 - W_2}{W_3} \times 100$$ ................................................................. (1)

Where $W_1$ is thimble and residue weight (g); $W_2$ is empty timble weight (g); and $W_3$ is mesocarp sample weight (g).

The CPO recovery from the sample FFB was calculated using equation:

$$\%\ Oil_{content\ (OC)} = \frac{\sum M_f \cdot M_m \cdot Oilm}{M_{FFB}} \%$$ ................................................................. (2)

Where $M_{FFB}$ is weight of FFB (jg); $M_f$ is fruitlets weight (kg); $M_m$ percentage of mesocarp weight from fruitlets (%); and $Oilm$ is percentage of mesocarp oil (%).

The data obtained were correlated with data from FFB image processing. Image processing of oil palm FFB is carried out using an image processing program. The value obtained from the program is the RGB value which is then processed into its derivatives using Ms. Excel. The derivative of the RGB value is the result of oil palm FFB image processing which is the second optical characteristic of recorded palm FFB. The derivative of this RGB value is obtained from the ratio of RGB values such as $R/G$, $R/B$, and other functions that can be generated from these RGB values [7].

After that, a prediction model was build using an artificial neural network (ANN). In this study, the values of $R$, $G$, $B$, and their derivatives are used as input in the data processing. The derivative value is the result of processing from oil palm FFB images, which are secondary optical characteristics of recorded palm FFB. The output is generated by multiplying the input weight with an abstract number used as a multiplier or known as the hidden layer. The output of this ANN data processing is the value of oil content.

3. Results and Discussion

In this study, FFB samples were used with five levels of maturity. A change in color marks the level of maturity of the FFB. Oil palm fruit is usually categorized as entering the mature phase when it is approximately six months after pollination. The ripening process of oil palm bunches can be seen from the color change in the fruit. Unripe oil palm fruit is green due to chlorophyll; then, the fruit will turn red or orange due to the influence of beta-carotene dye. Color change in FFB affects optical properties
Differences in optical properties can be observed using optical devices, one of which is a mobile camera. The recorded image is then processed using image processing software. Visualization of the results of FFB image processing can be seen in Table 1.

| DAA     | Initial Image | Digitize | Segmentation |
|---------|---------------|----------|-------------|
| 110-130 | ![Image](110-130.png) | ![Image](110-130_digitize.png) | ![Image](110-130_segmentation.png) |
| 131-150 | ![Image](131-150.png) | ![Image](131-150_digitize.png) | ![Image](131-150_segmentation.png) |
| 151-170 | ![Image](151-170.png) | ![Image](151-170_digitize.png) | ![Image](151-170_segmentation.png) |
| 171-190 | ![Image](171-190.png) | ![Image](171-190_digitize.png) | ![Image](171-190_segmentation.png) |
| 191-200 | ![Image](191-200.png) | ![Image](191-200_digitize.png) | ![Image](191-200_segmentation.png) |

The value obtained from the program is in the form of an RGB value, which is then processed into its derivatives using Ms. Excel. The derivative of the RGB value is the result of processing the palm FFB image, which is the second optical characteristic of the recorded palm FFB. The derivative of this RGB value is obtained from the ratio of RGB values such as R / G, R / B, and other functions that can be generated from these RGB values [7].

One of the essential characteristics of fruits is their color, both external and internal, which in many cases, determines the degree of ripeness and quality. Color means specific reflections of light influenced
by the pigments present on the surface of an object. Color is the brain's interpretation of a mixture of three primary colors, namely, red (R), green (G), and blue (B) are combined in specific compositions [16]. The recorded FFB image at five ripeness levels was then tested for oil content in the laboratory.

The level of maturity at harvest becomes a critical factor in harvest management because it is related to the value of the quality parameters produced. In oil palm fruit, the fruit ripening process is closely related to the oil content. The oil content will increase in quality until it reaches the peak of optimum maturity. After passing the optimum limit, it will cause degradation, causing the oil content to decrease due to the fruit's decay. The measurement results can be seen in Figure 2.

![Figure 2. Oil Content Value according to FFB Ripeness](image)

The minimum oil content is founded in FFB with a maturity level of 110-130 HSP, with a value of 11.50%. The quality of oil palm fruit at a young age has low quality; this can be seen from the low palm oil [7]. The optimum oil content value is founded in FFB with a maturity level of 171-190 HSP, namely 24.44%; then, at the 191-200 HSP maturity level, the oil content value is reduced by a value of 23.44%. The oil content increases according to the ripeness of the fruit [13].

Once past the peak of optimal ripeness, the oil content will decrease. Palm oil begins to form after 100 days after anthesis and stops after 180 days or after the fruit is saturated. Based on the oil content, it can be concluded that the maturity level of 171-190 HSP is the optimal harvesting age because it has the highest oil content. If the oil does not form again in the fruit, what happens is the breakdown of triglycerides into free fatty acids and glycerol. Oil formation ends when the loose fruitlets of the FFB [17].

From the test results, it is known that the level of maturity influences the FFB oil content. The level of maturity can be observed based on optical characteristics. Therefore, it is necessary to develop a model using ANN and step ways PCA to see the effect of optical factors and their derivatives in predicting the quality parameters of oil palm FFB. A calibration model was constructed with 70% of the sample. The remaining 30% of the sample will be used for model testing (validation).

Model development uses input variables in the form of R, G, B, and their derivatives consisting of 26 factors. In the initial stage, all variables are entered into ANN processing. Furthermore, input variables that have a low contribution to the predicted value will be eliminated. This stage will be carried out continuously until a high predictive value is obtained. The development of this model using pretreatment, namely normalized. Normalized is chosen because it can minimize the noise that occurs. The network architecture in the calibration model is shown in Figure 3, and the parameter estimate of the developed model for FFB OC prediction using MLP analysis is given in Table 2.
Figure 3. MLP Network Diagram of FFB OC Model
Table 2. Parameter Estimates of FFB OC Model Obtained by JST-MLP Method

| Predictor | Predicted | Hidden Layer 1 | Output Layer |
|-----------|-----------|----------------|--------------|
| (Bias)    | .796      | -1.067         | .510         | .837         | -.528        |
| R         | 1.486     | .659           | 1.002        | -.618        | .138         |
| G         | 1.501     | .700           | .173         | -.030        | -.445        |
| B         | 1.526     | .648           | -.769        | -.316        | .415         |
| AverageEVIGreen | 1.326   | -.267          | -1.333       | -.122        | .482         |
| @_r       | -.549     | .378           | 2.084        | .576         | .112         |
| @_b       | 1.332     | -.127          | -1.785       | -.638        | .013         |
| AverageVA | .050      | -1.473         | .940         | -.688        | .094         |
| R2GB      | -.541     | -.105          | .153         | -.066        | -.467        |
| B2RG      | -.735     | .582           | -.133        | -.268        | -.390        |
| GR        | -.553     | .236           | .216         | .120         | -.105        |
| BR        | -1.186    | 1.214          | .389         | -.671        | -.341        |
| BG        | -1.190    | .491           | .154         | -.463        | .387         |
| @1RG      | .357      | -.520          | -.402        | .582         | .309         |
| @1RB      | -.058     | -.071          | -.172        | -.103        | .262         |
| @1BR      | .843      | -.083          | -.693        | .993         | .268         |
| @1BG      | 1.241     | -1.270         | -.411        | .846         | .306         |
| (Bias)    |           |                |              |              |              |
| H(1:1)    |           |                |              |              |              |
| H(1:2)    |           |                |              |              |              |
| H(1:3)    |           |                |              |              |              |
| H(1:4)    |           |                |              |              |              |
| H(1:5)    |           |                |              |              |              |

The OC model prediction showed acceptable performance both on calibration and validation (Figure 4). The model’s R² upon calibration was 0.6934. While upon validation R² value was 0.7211. The model was considered appropriate since R² value both in calibration and validation were high.

Figure 4. (a) Calibration and (b) Validation Results for Oil Palm FFB Oil Content (OC) Prediction del JST-MLP Method
4. Conclusion
In this study, the quality parameters of FFB were identified based on optical properties at five levels of fruit maturity. Optical characteristics are observed using a mobile camera and evaluated based on the recorded image. The level of maturity influences the optical properties of the image. The level of ripeness causes changes in oil content. The model is developed from the optical properties of recorded FFB images, where these optical properties are used as input variables. The models successfully predict with $R^2$ upon calibration was 0.6934. While upon validation, the $R^2$ value was 0.7211.

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