Study on Quality Parameters of Yellow Matoa Fruit (\textit{Pometia pinnata}) Using Digital Image Processing

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Abstract. At this time matoa fruits are sold without grading them first so high and low quality fruits are mixed. In addition to not having SNI, there is also no standard method for grading according to standardization of fresh horticultural products. Related to this issue, digital image processing can be used as an alternative method for grading. The purpose of this study were to study quality parameters and to develop quality evaluation method for yellow type matoa using digital image processing. Manual measurement using weight as quality parameter of 203 yellow matoa produced three categories of quality classes namely A, B and C. Image processing algorithm was then developed to replace the manual measurement by estimating the weight using projected area of fruits image and to measure skin color of the fruits. The overall accuracy of quality evaluation based on weight using developed algorithm was 73.89%. For quality evaluation based on visual parameter or skin color represented by red and blue color ratio (R/B), and hue and value (H/V) color ratio, it was found possible to classify the fruits into three quality classes namely class 1 (brown to yellow-brown), class 2 (yellow), and class 3 (yellow-green to green) with overall accuracy of 74.38%. Finally, using combination of those two parameters (i.e. area and skin color) nine new quality classes, namely A1, A2, A3, B1, B2, B3, C1, C2, and C3 classes were obtained with overall accuracy of 52.71%.

1. Introduction

Matoa (\textit{Pometia pinnata}) has been well known exotic fruits which is widely distributed in Asia Pacific including Papua, Indonesia \cite{1}. It has been designated as one of the important horticultural commodities in Indonesia \cite{2}. With its unique taste and texture, matoa fruit is quite popular and has good market potential outside Papua. Its marketing has spread from local markets, supermarkets, and even export markets. Matoa fruit also has the potential for further processing into syrup, juice and other processed products that are useful and become new economic opportunities for household and industrial scale.

At this time matoa fruit does not yet have a quality standard contained in Indonesia National Standard (SNI) or in other forms that can be used as a reference for standardization. Related to this issue, image processing can be used as an alternative method for quality evaluation prior to grading operation. Camera and image processing has been widely used for automatic fruit grading and classification \cite{3}, mainly due to its capability to evaluate the variety of produces non-destructively with high accuracy and speed so it is suitable for handling large quantities. Image processing is a visual technology with camera as the sensor, used to observe, process and analyze an object without dealing directly (non-contact) with the object, leaving the object without any harm.
Appearance of products, including fruits, is typically evaluated by some characteristics such as size, shape, form, color, freshness and absence of visual defects [4]. One of these characteristics, color is an important sensory attribute of product quality. Therefore, color is an important criteria for grading of any product, especially fresh fruits [5]. Many works have been reported the use of image processing for quality evaluation of various agricultural products such as coffee bean [6], melinjo (*Gnetum gnemon*) seed [7], and tea leaves [8]; application of image processing on mango grading machine [9]; and constructing a vision system to monitor harvested paddy grain quality in combine harvester operation [10]. In the field application, color image analysis of the melons fruits in combination with discriminant analysis could be used to distinguish between harvesting ages of 46, 53, 60, and 67 days after planting with an average accuracy of 86% [11]. The purpose of this study was to study quality parameters and to develop an alternative quality evaluation method of yellow matoa using digital image processing. The parameters are expected to be used for building the quality standard to be applied in matoa promotion and marketing in wider areas in Indonesia and export as well. The developed image processing evaluation method is expected to be used in automatic grading of the matoa fruits in the future to guarantee the quality of the fruits especially for export.

2. Material and Method
The study was conducted in August 2016 - January 2017 at the Laboratory of Food and Agricultural Product Processing Engineering, Department of Mechanical and Biosystems Engineering, Bogor Agricultural University. The material used was 203 yellow matoa fruits obtained from the local farmer in Papua. Physical quality parameters were measured as follows: weight (gram) using a digital scale (Metler PM-4800); length and diameter of fruit (cm) using calipers; hardness (kgf/cm²) using CR-30 model rheometer, carried out at three different points: top, middle and bottom of the fruits; total soluble solids (TSS, in % brix) using Atago PR-201 digital refractometer, carried out by slicing the fruit flesh, dropping the liquid on the refractometer and the average data were taken from three repetitions of measurement. Digital image of matoa fruits were captured using a set of machine vision system consisting of a color CCD camera (VED, OC-305 D), image frame grabber (PXC 200A), personal computer (PC) with Intel Pentium IV processor, and four 7 watts TL lamp as light source.

The obtained images were then processed using Matlab 2014 software. The algorithm include thresholding to eliminate unwanted background, noises cleaning and holes filling through a series of erosions and dilations to binary image, pixel counting to get projection area of the fruit, and color values picking and analysis from the fruit part, in RGB (red-green-blue) and HSV (hue-saturation-intensity) color models.

3. Result and Discussion
The results of this study will be explained in two sections which are physical parameters measurement to be used as reference values, and image processing to be used for prediction. Furthermore, the second sections will be divided into three sub-sections as to demonstrate the use of each size and color parameters individually, and combination of the two image processing parameters for the proposed new classes in quality.

3.1. Physical Quality Parameters of Yellow Matoa Fruit
Yellow-type matoa fruit typically has a light green skin color when it is unripe and turns into yellow to brown when it is ripe. Based on the color, the matoa fruit can be grouped into five color groups namely green, green-yellow, yellow, yellow-brown and brown. In terms of shape, the yellow type of matoa can be single or double fruit, either double fruit with the same or different size. Based on the form of harvest commonly traded on the market, the matoa fruit is divided into single fruits and fruit series. As a reference in compiling the standards for matoa fruit extraction, measurements of the physical quality parameters of the yellow matoa fruit were measured which included length, diameter, weight, total soluble solid, and hardness. The measurement results obtained can be seen in Table 1.
Table 1. Physical quality parameters of yellow matoa fruit

|                  | Length (cm) | Diameter (cm) | Weight (gr) | TSS (%brix) | Hardness (kgf/cm²) |
|------------------|-------------|---------------|-------------|-------------|--------------------|
| Means            | 3.6         | 2.9           | 10.3        | 21.9        | 2.8                |
| Maximum          | 8.3         | 8.3           | 20.8        | 31.2        | 6.9                |
| Minimum          | 1.9         | 1.2           | 6.8         | 9.8         | 0.2                |
| Standard Dev.    | 1.3         | 1.1           | 2.9         | 3.8         | 1.3                |

Because of shape of the fruit which is quite diverse, the weight are chosen among the parameters measured as a reference for grading, in addition to skin color. However, in this paper only weight of the fifth physical data measured directly from the object used for fruit classification, while the other four data were unused. Weight is very common to grade fruits based on its size, while length and diameter of the fruit were found to be less accurate to measure the size of the fruits. Meanwhile, TSS and hardness were assumed to be represented by skin color using image processing so they are not analyzed and discussed in this paper. Furthermore, considering the means, maximum, minimum and standard deviation value of the weight and practicality in grading operation, yellow matoa fruit can be grouped into three grades namely A, B and C with the criteria as shown in Table 2.

Table 2. Yellow matoa fruits grade based on weight

| Grade | Weight (gram) |
|-------|---------------|
| A     | >12.5         |
| B     | 9.5 - 12.5    |
| C     | < 9.5         |

3.2. Quality Parameters of Yellow Matoa Fruit by Image Processing

As discussed in the previous section, among measured parameters weight and skin color are considered to be used as main criteria for yellow matoa grading. More detail about the results of yellow matoa fruit grading using weight, skin color and combination of both parameters are discussed in the following sub-sections.

3.2.1. Fruit grading based on weight. In the previous section, it has been discussed that it is possible to classify yellow matoa fruit based on its weight into three grade: A, B, and C. Image processing algorithm was then developed to replace manual measurement of weight by estimating the weight using the projected area of the fruits in image. Measurements of area were made by converting color images into grayscale images and then to binary images at certain threshold values for distinguishing objects and backgrounds. The area was then determined by counting the number of white pixels of the segmented object. The counting pixels were actually the projection area which represents the size of the fruit in two-dimension. The number of pixels obtained from the area then were used as input to calculate the weight of the fruit using equation shown in Fig. 1 (weight = 0.0005 * area + 8.2741). The results of area counting from all images were then plotted again the weight of the fruits obtained from the direct measurement (weighing). Fig. 1 showed the relation between area and fruit weight, which is in linear relationship. It is shown that the fruit weight could be estimated using the developed linear mathematical model quite well with coefficient of determination 0.8499. Using this model, the criteria for matoa fruit grading based on area which is corresponding with the weight of the fruits was determined as shown in Table 3.
Figure 1. The linear relationship between the weight and the area of fruit in image.

Table 3. Correlation of fruit grade based on weight and projected area obtained using image processing

| Grade | Weight (gram) | Area (pixels) |
|-------|---------------|---------------|
| A     | > 12.5        | > 9318        |
| B     | 9.5 - 12.5    | 1584 - 9318   |
| C     | < 9.5         | < 1584        |

Table 4 showed confusion matrix showing the comparison between manual grading and the grading by image processing algorithm based on fruit weight using the mathematical model obtained from Figure 1. The overall accuracy is 73.89% with the highest accuracy of 88.62% for grade B and the lowest accuracy of 43.55% for grade C. This result indicated that the developed model could not estimate grade C (small size fruits) well enough. It is likely due to number the sample which were not well distributed among the fruits grade, or those which grouped into A and C classes were relatively small number as compared to B class.

Table 4. Comparison of fruit grading based on weight by manual and image processing algorithm

| Grade (Manual) | Grade (image processing algorithm) | Total | Accuracy (%) |
|---------------|-----------------------------------|-------|--------------|
|               | A       | B     | C       |          |
| A             | 14      | 4     | -       | 18       | 77.78 |
| B             | 1       | 109   | 13      | 123      | 88.62 |
| C             | -       | 35    | 27      | 62       | 43.55 |
| Total         | 15      | 148   | 40      | 203      |       |
| Recall (%)    | 93.33   | 73.65 | 67.50   |          |

3.2.2. Fruit grading based on skin color. The results of measurement of skin color visual quality parameter using image processing algorithm based on maximum, minimum, and average values shows that color parameter using each RGB and HSV color models directly and individually does not show high variation values so it is difficult to use skin color as a reference for matoa fruits grading with a
good result. However, visual color parameters based on red and blue ratio (R/B) and hue and value (H/V) ratio show fairly good variations that can be used as references for grading the fruits based on skin color (Fig. 2 and Fig. 3). However, it is quite difficult to distinguish all of the five classes based on the skin color (as done manually) due to high overlapping values among the different classes. Therefore it was decided to reduce the number of grades become three classes only, namely grade 1 (showing brown to yellow-brown skin colors), grade 2 (yellow), and grade 3 (green-yellow to green). The detail criteria used for classification the samples using color ratios from the two color models (RGB and HSV) were listed in Table 5.

![Figure 2](image1.png)

**Figure 2.** Distribution of R/B value for the skin color and selected threshold value.

![Figure 3](image2.png)

**Figure 3.** Distribution of H/V value for the skin color and selected threshold value.

**Table 5.** Criteria for fruit classification based on skin color

| Grade | Color ratio (R/B, H/V) | Skin color by               |
|-------|------------------------|-----------------------------|
| 1     | R/B < 2.0 & H/V < 0.25 | Yellow-brown to brown       |
| 2     | R/B > 2.0              | Yellow                      |
| 3     | R/B < 2.0 & H/V >0.25  | Green to green-yellow       |

Table 6 shows the comparison between manual grading and grading using image processing algorithm based on fruit weight. Image processing algorithm predicted the weight of the fruit by counting the number of pixels belongs to object, after a series of image processing algorithm applied to the image. Before reading the color values of the image, the background pixels were set zero so the pixels could be skipped. The overall accuracy is 74.38% with the highest accuracy of 79.13% for grade 1 and the lowest accuracy of 56.25% for grade B. Similar to previous case for grading based on weight,
the poor accuracy for grade 2 is likely due to distribution of the sample where grade 2 only contributes 7.9% of the total sample as a reference (manual grading based on skin color), while the grade 1 contributes 56.7% of the total sample and resulted in the highest accuracy in classification. It can be said here that not enough number of samples causing poor classification for grades 2 and 3, while grade 1 gave a relatively good result because it had enough samples.

**Table 6. Comparison of fruit grading based on skin color by manual and image processing algorithm**

| Grade (Manual) | Grade (image processing algorithm) | Total | Accuracy (%) |
|----------------|-----------------------------------|-------|--------------|
|                | 1       | 2   | 3       |
| 1              | 91      | 14  | 10      | 115       | 79.13 |
| 2              | 1       | 9   | 6       | 16        | 56.25 |
| 3              | 20      | 1   | 51      | 72        | 70.83 |
| Total          | 112     | 24  | 67      | 203       | 74.38 |

**Table 7. Comparison of fruit grading based on combination weight and color by manual and digital image processing**

| Grade (Manual) | Grade (Image processing) | Total | Accuracy (%) |
|----------------|-------------------------|-------|--------------|
|                | A1 | A2 | A3 | B1 | B2 | B3 | C1 | C2 | C3 |
| A1              | 5  | -  | -  | 1  | -  | -  | -  | -  | -  | 6  | 83.33 |
| A2              | -  | 3  | -  | 3  | -  | 1  | -  | -  | -  | 7  | 42.86 |
| A3              | 2  | -  | -  | 1  | -  | -  | 2  | -  | -  | 5  | 20.00 |
| B1              | -  | -  | -  | 44 | 10 | 7  | 4  | 2  | -  | 67 | 65.67 |
| B2              | -  | -  | -  | 1  | 3  | -  | 1  | -  | -  | 6  | 50.00 |
| B3              | -  | -  | 1  | 9  | -  | 34 | 3  | -  | 3  | 50 | 68.00 |
| C1              | -  | -  | -  | 28 | 2  | 1  | 9  | -  | 2  | 42 | 21.43 |
| C2              | -  | -  | -  | -  | -  | -  | -  | 1  | 2  | 3  | 33.33 |
| C3              | -  | -  | -  | 1  | -  | 3  | 5  | 1  | 7  | 17 | 41.18 |
| Total           | 7  | 3  | 5  | 84 | 16 | 48 | 21 | 5  | 14 | 203| 52.71 |

Recall (%) 71.43 100.00 20.00 52.38 18.75 70.83 42.86 20.00 50.00 52.71
In general the accuracy of the classification is still low and unacceptable for practical use. There were several reason for poor accuracy of the developed system. Image processing algorithm used to extract feature or information of the fruits should be improved. Also, number of sample should be increase and distribution of the fruits among quality classes also should be improved to provide broader range of data and also the generalization capability of the developed algorithm.

Figure 4. Examples of the grading results using combination of weight and color:
A1, A2, A3, B1, B2, B3, C1, C2, C3.

4. Conclusion
The quality parameter of yellow matoa fruits has been studied and then used as a reference to develop an alternative quality evaluation method using digital image processing. Among quality parameters studied weight and skin color of fruits was selected to classify the fruits into several classes. For quality evaluation based on weight, it was possible to classify the fruits into three classes namely A, B, and C. The developed quality evaluation based on image processing algorithm could classify the fruits based on weight with an overall accuracy of 73.89% compared to manual method. For quality evaluation based on visual parameter or skin color represented by red-blue color ratio (R/B) and hue-value color ratio (H/V), it was possible to classify the fruits into three quality classes namely class 1 (brown to yellow-brown), class 2 (yellow), and class 3 (yellow-green to green) colors with overall accuracy of 74.38%. Finally, using combination of those two parameter (i.e. area and skin color) nine new grades, namely A1, A2, A3, B1, B2, B3, C1, C2, and C3 classes were obtained with overall accuracy of 52.71%. There were several reasons for poor accuracy of the developed system. Beside image processing algorithm that should be improved to obtain more accurate feature or information of the fruits, the number and distribution of the fruits among quality classes and skin color also should be well prepared to get a balance samples number.

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