Physical quality determination of fresh strawberry (*Fragaria x ananassa* var. Osogrande) fruit in tropical environment using image processing approach

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**Abstract.** Strawberry (*Fragaria x ananassa* var. Osogrande) fruit has a high economic value and healthy for human. However, there was a problem with strawberries quality for supply chain and can be deteriorated easily during the transportation process, especially in tropical environment. Image processing is one of the methods considered to be applied for rapid detecting using non-destructive method. Objective of this research was to compare the determination of physical quality of strawberry fruit between conventional method and image processing method. Determination of the image processing method was using webcam 8 mp with 100% maturity level of strawberry fruit, then after acquisition of the sample of strawberry the data was analysed using Matlab software. Observations of the physical quality parameters observed including color and texture of skin, diameter, length, volume and the surface area of strawberries. Performance of image processing have relatively good, with high accuracy for several physical quality of strawberry fruit such as: length (96,50%), diameter (93,70%), Area (93,88%), volume (96,42%), texture (83,8%) redness (a*) (76,74%) and yellowness (b*) (66,89%) with not significant difference with conventional method measurements, however lightness (L*) color parameter significant difference between image processing and conventional measurements.

1. Introduction

Strawberry fruit (*Fragaria x ananassa*) is the unique fruit with high nutritious content which could be consumed in freshly due to their sensitivity to fungal attack and excessive textures softening caused by the natural ripening process, and it can be processed in many other forms such as juice, concentrate jam, and jelly and dried rehydrated with yoghurt and bakery products [1, 2]. Strawberry fruit was different change on physical quality and chemical during storage at 4°C, 10°C, dan 27°C after harvest [3], and local strawberry fruits from Ciwidey, Garut, West Java Indonesia was recommended to store strawberry fruits in lower temperature conditions, around 10°C, to maintain their quality [4]. Changes of quality during postharvest caused by several metabolism process such transpiration, photosynthesis, respiration and also environmental effects.

Conventional quality inspection trough laboratory analytics and sensory analytics were time consuming, need the high technology instrument to get high validity result and need special human resources [5, 6]. Fruit quality inspection and detection using automatic and real time measurement was
interesting to know and elaborate, especially physical quality as external quality parameters such as color, texture or hardness and shape [7]. Inspection quality using digital image processing can be measure continuously, real-time with good documentation system [8]. Digital image processing technology will continue to develop to be an objective instrument using non-destructive testing technology and will be detection several physical quality parameters of fruit such as color, texture of the skin of fruit, size and also maturity of fruit [9]. Image processing approach as a non-destructive method for determination and prediction the quality of fruit was an important approach to make easier and faster using high-technology adoption with relatively low cost and budgeting, also to anticipate change in technology disruption of industry 4.0. Objective of this research was to compare the determination of physical quality of strawberry fruit between conventional method and image processing method.

2. Material and Methods

2.1. Plant Material

Greenhouse technology for strawberry fruit production using hydroponics system was used for sample of strawberry fruit, it was located in Dusun Jetis, Argomulyo, Cangkringan Sleman, DIY with latitude 7°39”58” and longitude 110°27”42”. Strawberry fruit (Fragaria x ananassa var. Osogrande) using 100% maturity level with fully covered red color on strawberry fruit based on Rahman et.al [10]. Then, sample was determined and analyzed in Departement of Agroindustrial Technology Faculty of Agricultural Technology Universitas Gadjah Mada, Yogyakarta, Indonesia

2.2. Direct and conventional physical quality determination of strawberry fruit

Physical quality determination was directly measured using conventional determination, and measurement size of strawberry length (fruit measured from the end of the blossom to the top of the shoulder) and diameter (fruit diameter was measured at the widest point of the fruit shoulder) were determined using a digital caliper (150MMX6, Krisbow, Indonesia); surface area of strawberry fruit was measured using analytical balance with gravimetric regression analysis [11], and volume of strawberry was measured using water displacement methods using cylinder glass; fruit texture of skin strawberry was determined using a texture analyzer (FHT-200 Extech, Taiwan) and color of strawberry fruit was measured using a chromameter (Minolta, CR-400, Japan) and expressed on L*-a*-b* value.

2.3. Image processing determination on physical quality of strawberry fruit

Image capture of strawberry sample was used a webcam (C922 Pro Stream, Logitech, Switzerland) for maximal resolution from the highest on 1080p/30 fps (1920x1080 pixel) to 720p/60 fps (1280x720 pixel) with autofocus. Strawberry sample was put into Box Machine Vision that was developed by Lestari [12], and image was captured 4 times then image will be processed for several steps from capturing sample image in Red Green Blue (RGB image) value, then convert into YCbCr image (that meaning of Y is luminance or light intensity, Cb and Cr were the blue-difference and red difference from chroma components), and next step were convert YCbCr image to binary image using thresholding and segmentation image method. Then, result of binary images were convert back into RGB image again. Furthermore, feature extraction method were applied for measuring some physical quality of strawberry on length and diameter, surface area, texture and color (L*, a* and b*), and it will be processed using Graphical User Interface (GUI) that was developed based on Lestari [12] and some feature extraction modification for physical quality measurement of strawberry fruit using MATLAB software (Mathworks, Inc, USA). However, only volume of the strawberry calculated based on equation from Hidaka e.al [13] that inserted in the computer script programming on GUI.

2.4. Statistical analyses

The data obtained from the experiment results were tabulated and calculated using Microsoft Excel 2010 (Microsoft Corporation, USA). Comparison between the measurement using image processing
and conventional value of physical quality of strawberry were calculated with the dividing the result from image processing value with conventional value. Statistical analysis for data with normal distribution was used one way anova and non-parametric data was used Kruskal Wallis test, to compare average data resulted from the measurement using image processing and conventional and it can be utilized using SPSS version 23.0 (SPSS Incorporation). Furthermore, accuracy of texture analyses were compared the using scatter plot and correlation coefficient value (r value) will be found from the image processing and conventional measurement correlation, and highest r value will be chosen.

3. Results and Discussion
3.1 Graphical User Interface (GUI) for Image processing on Physical Quality of Strawberry
Figure 1 show GUI of image processing that was resulted and will be used for determination on physical quality of strawberry fruit. This figure show step of capturing image from the camera in the box machine vision to the last featuring image that was determined using script programming in the MATLAB. YCbCr image was used in the step for segmentation and threshold because more effective on threshold for color changing and YCbCr technique was used based on the luminance (Luma Y) is the brightness that occurs using black and white gray shades which combination of chroma (Cb and Cr) is the color information in a signal mainly concentrated in YCbCr either than in red and blue signal [14]. Gray scale image were extracted their feature using Gray Level Co-occurrence Matrix (GLCM) method for measuring texture value (homogeneity, contrast, correlation, entropy, dan energy). Then, binary image will be extracted their feature for measuring length, diameter, surface area and volume. Binary image was used for segmentation to change again in the last RGB image without background and other objects to reduce bias for calculated of featuring image parameter in RGB image and L*a*b*.

3.2. Comparison on Physical Quality Strawberry Determinations
Measurements physical quality of strawberry fruit was important in modern fruit industry and it can be detected for conventional using manually or some conventional tools, but nowadays traditional manual
expertise for quality inspection is no longer adequate and automatic technologies for detecting the quality of strawberries are being sought [15].

Table 1 was shown result of comparison measurement between image processing and conventional method with accuracy of diameter was 96.49% and length was 93.70% and were not significantly difference on p<0.05 using statistical analysis. Physical quality change on size (diameter and length) also can be detected accurately using image processing that be shown as size decreasing of strawberry fruit from day first to third day. This result was similar with another researcher for automatic grading for strawberry size detection error is not more than 5% [9]. Physical quality strawberry such as size (diameter and length) will affected the manner of presentation strawberry then affect the consumers’ purchase decision [15].

Table 1. Comparison measurements between image processing and conventional for length and diameter of strawberry fruit. Data is average from 4 fruits with standard deviation on each day.

| Day | Image processing | Conventional | Accuration (%) |
|-----|------------------|---------------|----------------|
|     | Diameter* (cm)   | Length** (cm) | Diameter* (cm)| Length** (cm)| Diameter (cm)| Length (cm) |
| 1   | 2.23 ± 0.26      | 2.91 ± 0.25   | 2.14 ± 0.24   | 2.71 ± 0.19 | 96.25 ± 1.48 | 92.78 ± 2.84 |
| 2   | 1.92 ± 0.32      | 2.44 ± 0.27   | 1.91 ± 0.22   | 2.48 ± 0.11 | 96.28 ± 2.90 | 93.85 ± 3.29 |
| 3   | 1.55 ± 0.21      | 2.17 ± 0.19   | 1.60 ± 0.18   | 2.27 ± 0.09 | 96.96 ± 1.74 | 94.49 ± 3.60 |
|     | Accuration of average |             |               |               | 96.49 ± 2.04 | 93.70 ± 3.25 |

*normality data one way anova with p< 0.05; ** non parametric data Kruskal-Wallis test with p< 0.05

Table 2 and 3 show the comparison measurement of surface area and volume using image processing and conventional of strawberry fruit with accuracy 92.5% and 96.4%, respectively and were not significantly difference on p<0.05 using statistical analysis. Table 2 was also show the change of surface area of strawberry measurement between image processing and conventional measurement that indicated natural quality deterioration of post-harvest strawberry. Image processing on this research was used monocular scheme is a machine vision system consisting of a single camera with relatively high accurate for the physical detection of strawberry fruit [16].

Table 2. Comparison measurements between image processing and conventional for surface area of strawberry fruit. Data is average from 4 fruits with standard deviation on each day.

| Day | Image processing | Conventional | Accuration (%) |
|-----|------------------|---------------|----------------|
| 1   | 6.83 ± 1.51      | 7.11 ± 1.45   | 95.83 ± 4.72   |
| 2   | 5.12 ± 1.46      | 5.56 ± 0.99   | 88.42 ± 4.90   |
| 3   | 3.74 ± 0.90      | 3.95 ± 0.75   | 93.24 ± 4.44   |
|     | Accuration of average |             | 92.50 ± 5.31   |

Data was used normality and homogen, using one way anova with p< 0.05

Table 3. Comparison measurements between image processing and conventional for volume of strawberry fruit. Data was non parametric and used Kruskal-Wallis test with p< 0.05

| Sample | Image processing | Conventional | Accuration (%) |
|--------|------------------|---------------|----------------|
| 1      | 5.12             | 5             | 97.76          |
| 2      | 5.13             | 5             | 97.44          |
| 3      | 4.87             | 5             | 97.40          |
| 4      | 5.88             | 5.5           | 93.08          |
|       | Accuration of average |         | 96.42 ± 1.44   |
Table 4 was show color of L*, a* and b* of strawberry fruit that measure using image processing and conventional method with accuration of 74.05%, 76.74%, 66.89%, respectively and were not not significantly difference on p<0.05 using statistical analysis for redness (a*) and yellowness (b*), but significantly difference for lightness (L*). Although, color change of the strawberry fruit could be also detected using image processing during over-ripe processed of strawberry during three day measurements, and it can be supposed of GLCM method of image processing was good detector, although were still low accuration compare with another researcher with 88% [9, 15]. Lightness value of image processing was affected by single camera can only provide 2D information with light change influences the imaging results [16].

| Day | Image Processing | Conventional | Accuration (%) |
|-----|------------------|--------------|----------------|
|     | L*   | a*   | b*   | L*   | a*   | b*   | L*   |
| 1   | 45.21| 35.83| 17.37| 33.77| 30.92| 16.14| 64.67|
|     | ± 3.42| ± 2.15| ± 1.81| ± 4.84| ± 3.14| ± 4.69| ± 16.53| ± 8.19| ± 15.50|
| 2   | 38.85| 18.85| 8.36 | 30.99| 23.62| 9.98 | 74.12|
|     | ± 3.19| ± 2.54| ± 2.12| ± 2.22| ± 2.79| ± 2.08| ± 14.30| ± 1.89| ± 15.66|
| 3   | 32.64| 13.19| 5.27 | 28.06| 19.60| 9.91| 83.37|
|     | ± 2.34| ± 2.42| ± 0.69| ± 1.26| ± 1.25| ± 1.12| ± 11.68| ± 8.67| ± 12.64|

Data was non-parametric and used Kruskal-Wallis test with p< 0.05.

Table 5. Comparison measurements between image processing and conventional for texture of strawberry fruit. r value mean coefficient correlation. a,b,c,d,e = coefficient correlation between image processing (homogenity, energy, contrast, entropy and correlation) with conventional measurement, respectively. Data was non-parametric and used Kruskal-Wallis test with p< 0.05.

| Sample | Image processing | Conventional |
|--------|------------------|--------------|
|        | Homogeneity | Energy | Contrast | Entropy | Correlation |         |
| 1      | 0.96      | 0.63   | 0.12    | 2.22    | 0.97       | 1.72     |
| 2      | 0.95      | 0.50   | 0.16    | 2.95    | 0.95       | 0.77     |
| 3      | 0.97      | 0.64   | 0.11    | 2.24    | 0.98       | 1.45     |
| 4      | 0.94      | 0.46   | 0.18    | 3.30    | 0.96       | 0.93     |
| r value| 0.838a    | 0.833b | 0.761c  | 0.792d  | 0.675e     |          |

Table 5 show texture of strawberry fruit with image processing and conventional measurement, and highest r value between these measurements was homogeneity, and this indicated that texture measurement using image processing of homogeneity was not significant difference statistically with conventional method. High accuracy of texture for image processing can be supposed by using GLCM [15, 16]. Furthermore, non-destructive technology such as image processing which can sort strawberry fruit based on the physical quality such as appearance, texture, and nutritional quality such as taste, flavor would assure fruit quality and consistency, will increase consumer confidence and satisfaction, then enhance the competitiveness and profitability of the fruit industry in the future. This image processing research was important and will be enhance with higher accuracy, faster and easier for competitive fruit industry in the era of 4.0 industrial revolution.
4. Conclusion
Comparison of Image processing determination on several physical quality of strawberry fruit have high accuracy and similarity with not significance different with conventional method for Diameter (93.70%), Length (96.50%), Area (93.88%), Volume (96.42%), color of redness (a*) (76.74%) and yellowness (b*) (66.89%) and texture (83.8%), however only color of lightness (L*) (74.05%) was significantly different with conventional method.

5. References
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