Non destructive method for maturity index determination of *Garcinia mangostana* L using image processing technology

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Abstract
Postharvest maturity index for mangosteen (*Garcinia mangostana* L) is very important for picking and grading during postharvest processing. Skin color change is the primary maturity index for mangosteen. However determination using human eyes needed many skilled labours and was inconsistent therefore new method in image processing technology using SVM (Support Vector Machine) was employed in this study. Chemical analysis of mangosteen was performed and used as a reference of SVM method. The chemical analysis of mangosteen showed that anthocyanin content increased from 126.20 ppm at stage 1 to 213.98 ppm at stage 6. Reducing sugar content increased from 3.17% at stage 1 to 7.92% at stage 6. The same pattern was found for total soluble solid, an increase from 3.86% at stage 1 to 7.81% at stage 6. Whereas for total acid content and hardness the pattern was the opposite. Total acid content was decreased from 1.78% at stage 1 to 1.06% at stage 6 and the fruit hardness of mangosteen was also declined, showing the number from 4.30 N at stage 1 to 0.69 N at stage 6. For SVM method, image aquisition was conducted for mangosteen images from stage 1 to stage 6, followed by color feature extraction for each stages. The result was trained and tested using SVM and resulted accuracy level of 83.3%.

Introduction
Mangosteen (*Garcinia mangostana* L.) is a climacteric fruit with white flesh, juicy and sweet taste. The skin of mangosteen fruit (pericarp) is dark purple and rich with secondary metabolites of active compounds including anthocyanins, oligomers proanthocyanins and xantone (Fu et al., 2007; Jie, et al., 2007). Mangosteen is very popular in Indonesia and it is one of major horticultural export products. The export of mangosteen significantly increased however there is only approx. 11,79% are eligible to be exported due to the low quality of the fruit. The high post-harvest loss is caused by the difficulty of mangosteen maturity detection that results in declining quality of fruit (Palapol, et al., 2009).
Mangosteen is usually picked when the colour is pink to red across the skin. If it is picked too early the fruit will not be ripe perfectly and it degrades the quality (Tongdee and Suwanagul, 1989; Paull and Ketsa, 2004; Palapol, et al., 2009). The low quality of mangosteen makes the fruit is declined for export purposes and that is a loss for the farmer since the price of mangosteen overseas is about 5-8 higher than the local marketplace (Suyanti and Setyadjit, 2007).

The purplish red color skin in mangosteen is caused by the anthocyanin pigments. Anthocyanin is a pigment found in mangosteen when the fruit is ripe. The identification of mangosteen colour can be measured visually or with destructive analysis using HPLC, Spectrophotometer, GC/MS and other chemical analyzes. Measurement done by human eyes is usually subjective and inconsistent and the measurement can differ from one person to another. Meanwhile destructive method requires the fruit to be destroyed and through stages

of complex analysis that take a long time to finish. Therefore it is important to develop a non destructive method in determining the ripeness of the fruit. Mechanical analysis of non destructive ends for ripeness by color using a "neural network" (NN) and fuzzy already widely tested (Riyadi, et.al., 2007a; Riyadi, et.al., 2007b). Recently a new technique has been developed that is "support vector machine" (SVM) which has a higher degree of accuracy. Testing SVM on mangoes showed very good results with a 95% accuracy rate (Nandi et al., 2014).

Material and methods

Mangosteen

Mangosteen was obtained from a fruit plantation in Purworejo, Central Java, Indonesia. The fruit was immediately brought to the Post Harvest Laboratory, Faculty of Agriculture Universitas Muhammadiyah Yogyakarta, Indonesia (UMY) and stored at room temperature. Mangosteen was classified based on the maturity level visually and divided into six criteria of maturity (Standard ASEAN STAN 10; 2008):

Stage 0: yellowish white or yellowish white with 5-50% scattered pink spots
Stage 1: light greenish yellow with 5-50% scattered pink spots
Stage 2: light greenish yellow with 51-100% scattered pink spots
Stage 3: spots not as distinct as in stage 2
Stage 4: red to reddish purple
Stage 5: dark purple
Stage 6: purple black

Method of Destructive Fruit Maturity

Detection of maturity with destructive methods was performed to obtain the reference data of mangosteen maturity.

Extraction of anthocyanin - Methods of extraction and isolation of anthocyanins were modified from Lestario et al. (2011). Mangosteen peel was cut into small pieces then macerated with methanol containing 1% HCl in 1: 4 (w/v) overnight at 5°C. The filtrate was filtered with Whatman no. 1, and partitioned with a separating funnel with the addition of diethyl ether to separate the components of non-anthocyanin (Ozela, et al., 2007). To add polarity in order to separate solvent well, it was added distilled water (filtrate volume ratio: diethyl ether: distilled water = 1: 2: 1).

Total Content of Anthocyanin - Method from Giusti and Wrolstad (1996) was used to determine the total anthocyanin content in the skin of mangosteen. Anthocyanin extract was dissolved in KCl-HCl buffer (1M, pH 1) and NaOAc buffer (1M, pH 4.5) with a ratio of extract against buffer was 1: 5 (v/v). Each solution was measured its absorbance at 520 nm and 700 nm after incubation for 15 min at RT and the results was incorporated into the formula $A = [(A_{510}\text{-}A_{700})_{pH1} - (A_{510}\text{-}A_{700})_{pH4,5}]$ and calculation was incorporated into the law of Lambert-Beer that $A = \varepsilon.L.C$.

Analysis of Reducing Sugar - Reducing sugar analysis was done used Nelson-Somogyi method. Mangosteen flesh was destroyed and filtered. Sample of 1 mL was added with distilled water up to 10 mL and taken 1 mL to be added with 9 mL of distilled water. Diluted samples was taken 1 mL and mixed with Nelson mixture (Nelson mixture of A and B 25: 1 (v /v)) then heated at 100°C for 20 min. The sample was cooled at RT. Sample was added with 1 mL of arsenomolybdat and 7 mL of distilled water and then shaken. The sample was measured its absorption at 510 nm.

Analysis of Total Soluble Solid (TSS) - TSS analysis was done by destroying the flesh of mangosteen then sealed with a refractometer (Atago, Tokyo, Japan) and calibrated with distilled water.

Analysis Tertitrasi acid (TA) - It was conducted by making a filtrate flesh of mangosteen (5 mL) and titrated with 0.1 M NaOH.
Fruit Hardness Test - Fruit hardness test was done with a hand held penetrometer.

Non destructive methods in detection of fruit maturity by image processing technology
The development of non destructive methods to mangosteen in this study was conducted in three main phases: 1) data collection, 2) determining the maturity index of the mangosteen with a destructive method, 3) the manufacturing method of non-destructive method SVM and 4) validation of the results, such as shown in Fig. 1.

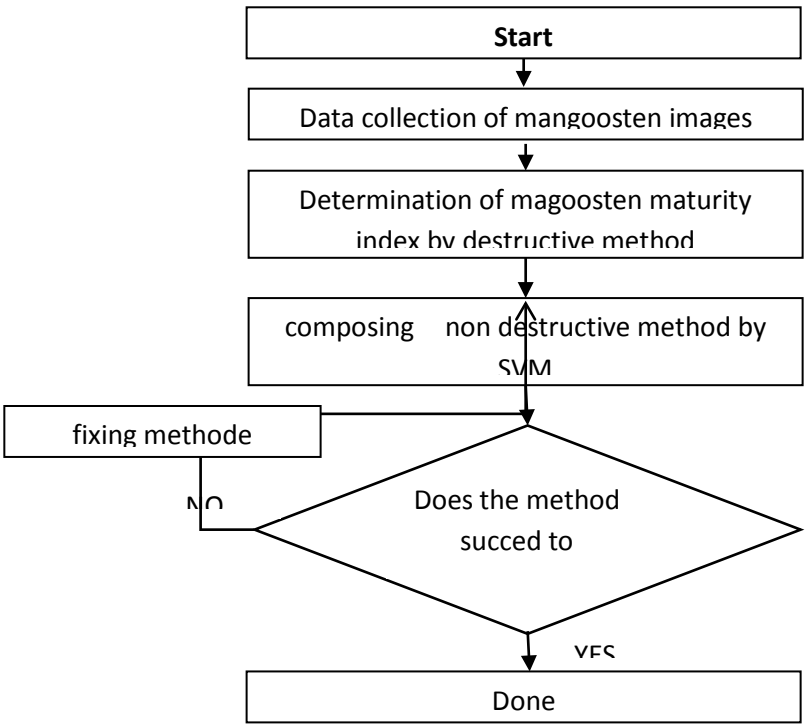

Figure 1: Development of non-destructive method for mangosteen maturity index

The description of each phases of the development of non dektruktif methods for mangosteen maturity as follows:

1. Data collection of Mangosteen - At this stage, mangosteen was photographed to obtain image data of mangosteen maturity from stage 1 to stage 6. The fruit was photograph using digital camera with 24 mp CMOS sensor in a light box of 60x40x50 cm to create even lighting.
2. Establishing image processing technology method- The process of SVM method began with the extraction of RGB (red, green blue) color features of mangosteen image. RGB features were summed and averaged for each colour and 6 values were processed in the SVM method.
3. Results validation - Validation of the results was done to determine whether the determination of maturity index with SVM method gave accurate results as the destructive method. The data reference was the concentration of anthocyanin content and supporting data including sugar, TSS, TA and fruit hardness test.

Result and discussion

Destructive method in fruit maturity detection

Ripening process of mangosteen from stage 1 to 6 showed an increase in anthocyanin content from 126.20 ppm at stage 1 to 213.98 ppm at stage 6 (Fig. 2). The increase of anthocyanin was reflected in the change of its skin color from stage 1 to stage 6 as shown in Fig. 3. The skin color changes correlated with ethylene production and it was shown by our data on other chemical compound changes we will be discussed later. Studies showed that the development of skin color in outer pericarp of mangosteen was correlated with the increase of cyanidin-3-sophoroside and the cyanidin-3-glucosides during ripening process (Palopol et.al., 2009). Reducing sugar increased from 3.17% at stage 1 to 7.92% at stage 6 during ripening process as shown in Fig. 4, and this indicated glycolysis process where polysaccharides converted into glucose. This finding was supported by the increase of total soluble solids from from 3.86% at stage 1 to 7.81% at stage 6 and the decrease of total acid content from 1.78% at stage 1 to 1.06% at stage 6 as shown in Fig. 4. These phenomenon was affected by the increase in ethylene production during ripening process of mangosteen as suggested by Palopol et.al. (2009). Fig. 5 showed the decrease of hardness from 4.30 N at stage 1 to 0.69 N at stage 6 indicated degradation of pectin in the cell wall, and this also found in other fruit like oranges (Prabasari et.al., 2011).

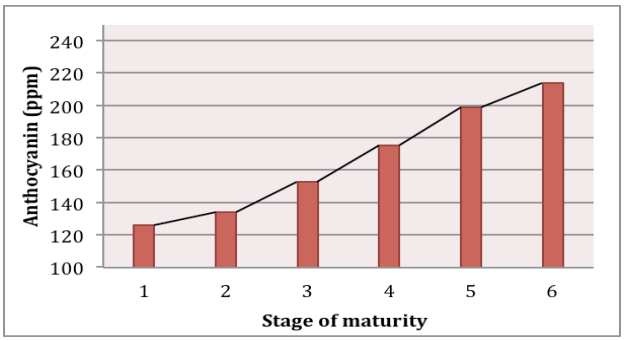

Figure 2. The increase of anthocyanin content during ripening of mangosteen

Stage 1

Stage 2

Stage 3

Stage 4 Stage 5 Stage 6

Figure 3. Maturity stages of mangosteen during ripening. The skin color changed from yellow green in stage 1 to deep purple in stage 6

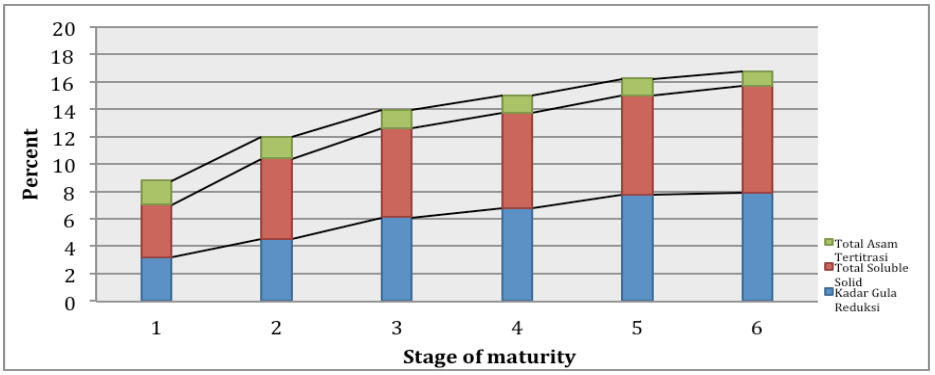

Figure 4. The increase of reducing sugar, total soluble solid and total acid during ripening of mangosteen

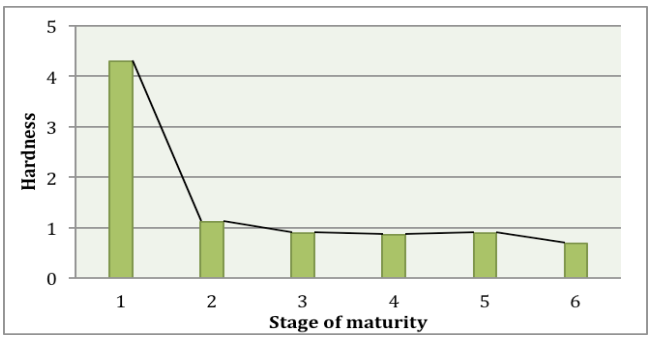

Figure 5. The decrease of hardness during ripening of mangosteen

Non destructive methods in fruit maturity detection

The sum of R and G was quite far between stage 1, 2 and 3. When the values were put into scatter plot the pattern indicated obvious group between stage 1, 2 and 3 as shown in Fig. 6 and 7. However in stage 4, 5 and 6 the pattern of scatter plot between stages was slightly overlapped. Meanwhile scatter plot from sum of B did not show distinguish groups particularly between stages 4, 5 and 6 as shown in Fig. 8. All together the result of sum of R, G and B was in line with the result of visual detection (data not shown) that differentiation between stages 1, 2, and 3 was easier than differentiation between stages 4, 5 and 6.

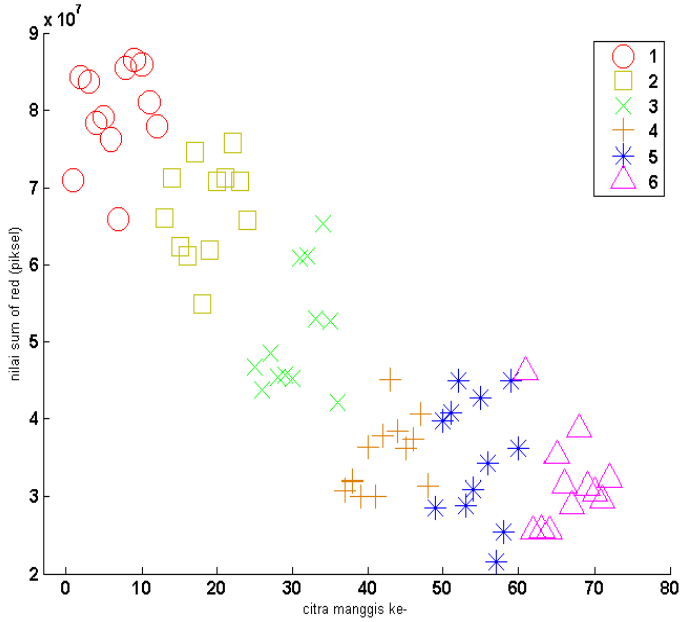

Figure 6. Scatter plot from sum of R (red)

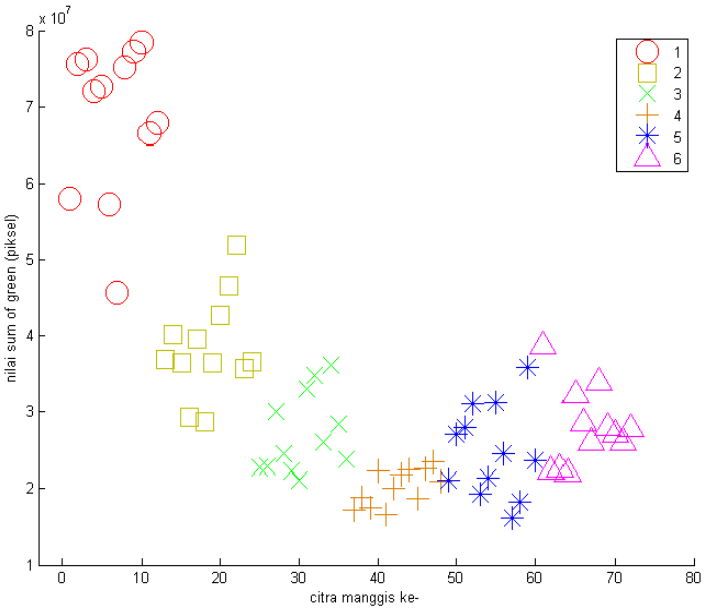

Figure 7. Scatter plot from sum of G (green)

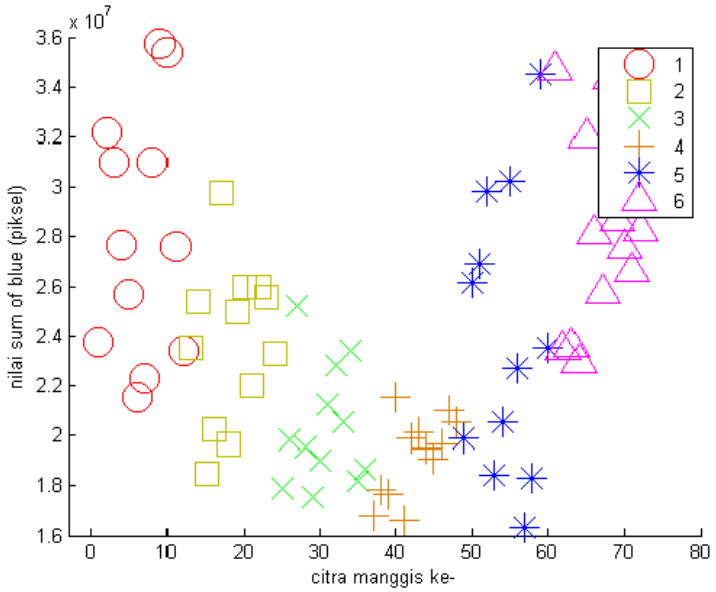

Figure 8. Scatter plot from sum of B (blue)

Values of mean from R, G and B were put into scatter plot and the result was shown in Fig. 9, 10 and 11. The pattern resulted were similar with the pattern from sum of R, G and B. Obvious grouping can be detected clearly between stages although slightly overlapped grouping was found in stage 4, 5 and 6. The scatter plot from the sum and mean of R, G and B when counted together indicated characteristics of grouping of R, G and B and showed that it was possible to be used as a non destructive methods to diffrentiate stages of mangosteen.

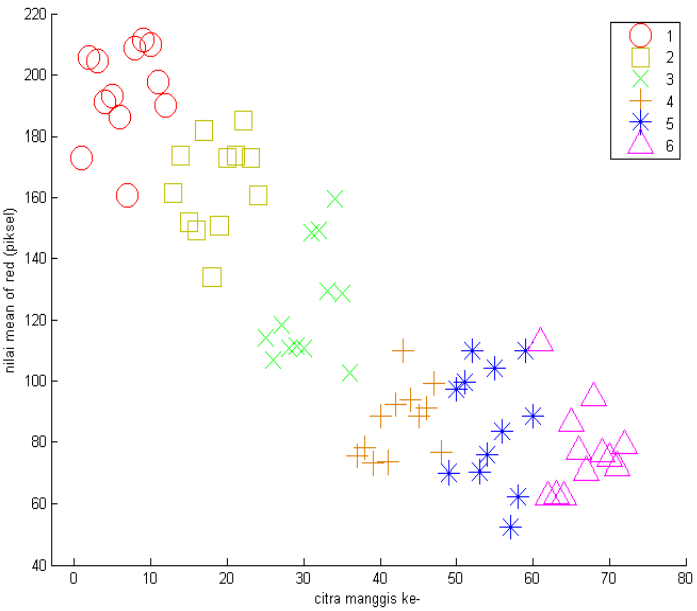

Figure 9. Scatter plot from mean of R (red)

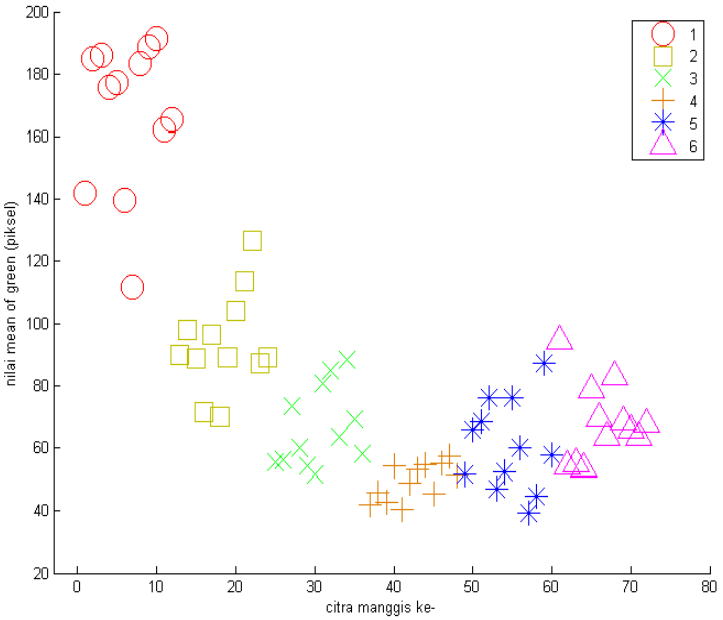

Figure 10. Scatter plot from mean of G (green)

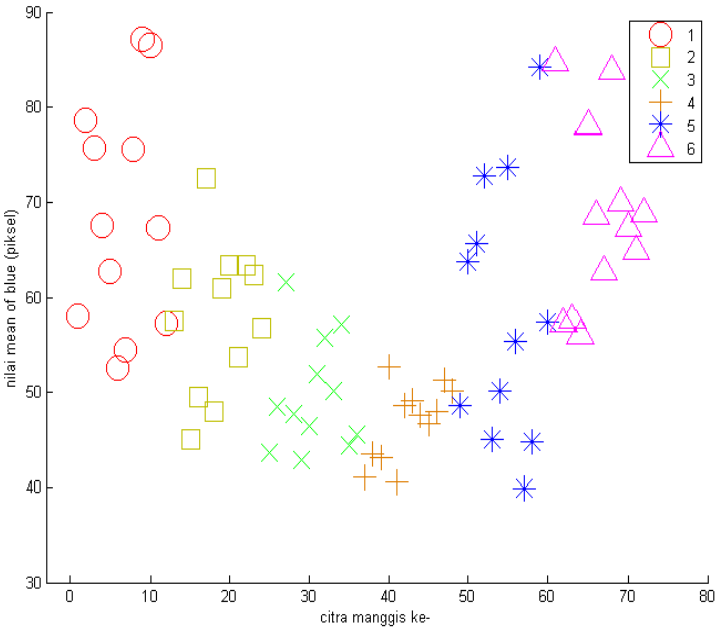

Figure 11. Scatter plot from mean of B (blue)

Two characteristics resulted from sum and mean of R, G and B were used as input for training and testing of SVM as shown in Table 1. In stage 1 and 2, the accuracy were 100% whereas in other stages were between 50 and 85%. In summary, the mean of accuracy in detecting mangosteen maturity was 83.3%.

Table 1. Result of training and testing of SVM to detect mangosteen maturity

Stage	Sum of image testing	Sum of images classified correctly	Accuracy of classification (%)	Note
1	8	8	100.0	-
2	8	8	100.0	-
3	8	7	87.5	1 image classified as stage 4
4	8	4	50.0	1 image classified as stage 3 meanwhile 3 images classified as stage 5
5	8	5	62.5	3 images detected as stage 4 whereas 2 images detected as stage 6
6	8	8	87.5	-
Mean of accuraccy in stage detection			83.3	

Conclusion

In conclusion, destructive methods showed characteristics of chemical compound changes during senescence and when the same samples were used to examine non destructive methods using image processing technology it showed the accuracy in detecting mangosteen maturity with the level 0f 83.3%.

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