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Application of Image Processing to Determine the Tomato Fruit's Ripeness

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Abstract: This study aims to apply image processing techniques in determining the level of fruit maturity based on color and the relationship of color changes with physical and chemical properties in Servo F1 varieties of tomatoes. This research has been conducted at the Laboratory of Agricultural Product Chemistry, Department of Agricultural Technology, Faculty of Agriculture, Sriwijaya University, Indralaya. This research was conducted from February 2019 until July 2019. This study used a descriptive method. The measured parameters are color, texture, moisture content, total sugar, and total acid. The results showed that the use of image processing methods can help the process of fruit sorting by looking at the relationship between the percentage of red color with the age of picking, the physical and chemical properties of the fruit. The percentage of tomato fruit red color on average ranged from 5.99% for picking age 25+1 days AFB (After the Flowers Bloom), 36.3% for picking age 29+1 days AFB, 67.41% for picking age 32+1 days AFB, and 76.85% for picking age 35+1 days AFB. The coefficient of determination of the relationship between the percentage of red color with the age of picking, texture, water content, total sugar, and total acid was 0.959, 0.908, 0.902, 0.835, and 0.750, respectively.
Keywords: Tomatoes, postharvest, sorting, image processing.

1. Introduction

Horticultural products are products with perishable properties so special treatment is needed at the harvest and post-harvest stages [1]. Product prices are determined by quality, not by quantity. Unlike the consumption of food plants, the human body requires the consumption of horticultural plants in small amounts but if not met will harm health. Horticultural products are a source of vitamins, minerals, and are not preferred as a source of protein and carbohydrates.

Tomatoes are one of the horticultural commodities which have the potential to be developed and cultivated as having quite high economic value. This can be seen by its superiority as one of the agricultural commodities which is very beneficial for the body. According to [2], the nutritional content in every 100 grams of fresh tomatoes is vitamin A 1500 (IU), vitamin B 60 (mg), vitamin C 40 (mg), protein 1 (g), carbohydrates 4.2 (g), fat 0.3 (g), phosphorus 5 (mg), and Ferrum 0.5 (mg). Tomato fruit as a vegetable commodity has a profound market prospect in terms of prices that are affordable by all levels of society, thus opening up greater opportunities for market absorption.

The good quality of tomato production is influenced by various factors, one of which is post-harvest handling. Postharvest is an activity after harvesting. One of the decisive post-harvest activities is sorting [3]. Sorting is the first treatment of freshly harvested tomatoes to sort tomatoes based on size, weight, shape, flavor, and color according to harvest age.

Manual sorting is usually used by farmers directly by looking at color as a standardization of fruit maturity [4]. Manual identification is less efficient because it has many shortcomings including the limitations of humans to work, requires a relatively long time, and a low level of sorting accuracy [5]. Therefore we need a non-destructive method for sorting effectively and efficiently without damaging the fruit. One of them is the image processing method that can be used to help fruit sorting which produces uniform results by prices, uses and types of markets suitable for tomatoes [6].

According to [7], image processing is a system where the process is carried out with input in the form of an image and the result is also in the form of an image. Image processing is done to improve image quality or image information presentation. Image as one of the multimedia components has an important role as visual information so that the image has characteristics that are not owned by text data. Visual observation is not done directly using the camera as an image processor but images are recorded and then processed using computer software so that they can be used to identify fruit maturity based on color images [8].

Based on these problems, the research was conducted by applying image processing to determine the degree of ripeness of tomato varieties *Servo F1*. This study aims to apply image processing techniques in determining the level of fruit maturity based on color, and the relationship of color to changes in physical and chemical properties in *Servo F1* varieties of tomatoes.

2. Method

The method used in this research is descriptive by presenting data in graphical form.

2.1. Procedure

The work procedure performed in this study consisted of image capture, image processing, color, and measurements of hardness, water content, total sugar content, and total acid content.

2.1.1. Image Capturing

According to [9] , the image capture procedure is as follows:

1. Tomatoes are cleaned.
2. The white paper is prepared to be used as a background.
3. Tomatoes are placed on white paper.
4. Tomatoes are photographed using a digital camera for their images to be captured and stored in storage memory in the form of a bitmap format.

2.1.2. Image processing

Image processing of tomatoes is done by a computer program that has been created using the Visual Basic programming language. According to [9], when the program is run, four buttons are used, namely: filter control (scan), image display control (load picture), refresh control button, and program control button (quit). The steps taken in image processing are as follows:

1. The stored tomato image data is then displayed by pressing the load picture control button in the dialog box. The image of the tomatoes displayed will be displayed on the graphic display module.
2. Filtering the image of tomatoes is done by pressing the scan button. Filtering of the image of tomatoes is done to find the value of the projected area and color area of the tomatoes.
3. After the filtering is complete, measurement data are recorded so that the projected area and color area values will be listed.
4. The RGB value is obtained by hovering the mouse over the part where you want to know the RGB value. RGB values are displayed on the red, green, and blue labels while the color of the mouse pointer is displayed on the color display box.
5. The quit button is pressed to end the program.

2.1.3. Color Measurement

According to [10], the color measurement procedure using a color reader is as follows:

1. The color reader is calibrated first using a standard white plate.
2. The optical head is affixed to the white plate so that the white part of the plate faces the light source.
3. Select the reading scale menu (L^*), (a^*), (b^*), then the button is pressed so that it reads a value (L^*), (a^*), (b^*).
4. The sample is then measured by attaching the optical head to the tomatoes, then pressing the START button.
5. The measurement results will read the values (L^*), (a^*), and (b^*) of the sample.

2.1.4. Hardness Measurement

According to [8], the measurement of the hardness of tomatoes using a texture analyzer is based on the level of resistance of the fruit to needle penetration from the texture analyzer. The procedure for measuring the hardness of tomatoes is as follows:

1. The needle-type probe is mounted on the texture analyzer.
2. The sample is placed just below the needle-type probe.
3. The texture analyzer speed is then set (trigger, distance, speed).
4. The probe will press the surface of the sample.
5. The peak load and final load numbers in units of gram force (GF) listed on the display are recorded.

2.1.5. Moisture Measurement

According to [11], the measurement of water content in tomatoes was carried out by the thermogravimetric method using an oven. The working principle used is to evaporate the moisture content in the material by heating, then weighing the material to a constant weight. The procedure for measuring water content (bb) is as follows:

1. The aluminum dish is dried in the oven for 30 minutes and cooled in a desiccator for 15 minutes then weighed using an analytical balance.
2. In the form of tomatoes, 2 grams are taken which are weighed using an analytical balance.
3. The material is then put into a cup that has known weight.
4. The material is heated in an oven at 105ºC for 6 hours.
5. The material is then cooled in a desiccator for 15 minutes.
6. The stage is repeated until the weight is constant with consecutive weighing differences of 0.2 mg (0.0002 g).

2.1.5. Total Sugar Measurement

Sugar is the main component of dissolved solids [12]. Measurement of sugar content on *Servo*

F1 tomatoes was carried out using a refractometer. According to [13], the measurement procedure to find out the sugar content is as follows:

1. Tomatoes are cut for meat, then crushed with mortar.
2. Tomatoes that have been crushed are taken as much as 5 g and placed in a beaker glass then the juice is taken as much as one drop of the sample.
3. Tomato juice is placed on a refractometer prism that has been calibrated with distilled water.
4. The ON button on the tool is pressed and the total sugar contained in the fruit will automatically appear.

2.1.6. Measurement of Total Acid

Measurement of total acid titration performed using acid-base. According to [8], the total acid measurement procedure is as follows:

1. Tomato flesh is crushed using a mortar and then weighed as much as 5 g and 100 ml of distilled water is added while stirring.
2. The material is put into a measuring flask for 100 ml dilution.
3. 25 ml of material is taken from the dilution process and put into Erlenmeyer then given a PP indicator of 1-3 drops.
4. Titration using 0.1 N NaOH solution until pink color appear.
5. Then the initial and final NaOH solution volumes are recorded.

2.2. Observation Parameters

2.2.1. Color Percentage

According to [14] color model is a coordinate system specification used to facilitate color specifications in the form of a standard. The best-known color model on computer equipment is RGB which consists of 3 colors namely, red, green, and blue. The color percentage will be obtained by the color reader using the CIE (Commission International de l'eclairage) system with *L**, *a**, *b**, coordinates, and the use of image processing. The *L** (Lightness) coordinate states the degree of brightness of the fruit, coordinates *a** represent the degree of the greenness of the fruit, and *b** represents the degree of yellowing of the fruit where each value is obtained automatically from the instrument. While the color obtained from the image processing program is produced from a comparison of the selected area and projection area through the filtering process [8]

2.2.2. Water content

According to [11], water content is measured using the thermogravimetric method. Water content is the percentage of the water content of a material that can be expressed based on wet weight or dry weight. Calculation of water content using the following formula:

$$\text{Moisture Content (bb)} = \frac{A-B}{A} x100\% \quad \text{.........(2.1)}$$

Information :
A = weight of material before drying (g)
B = weight of material after drying (g)

2.2.3. Fruit Hardness

According to [8], fruit hardness is the solid value of an ingredient. The hardness of this fruit can affect the level of fruit maturity. The measurement of fruit hardness is done by using a texture analyzer, which has a diameter of 1 mm and a cone height of 5 cm.

2.2.4. Total Sugar Levels

Measurement of overall sugar content is done using a refractometer. Measurements were made three times, then the values were averaged. The scale on the refractometer will automatically show the total value of dissolved solids expressed in °Brix .

2.2.5. Total Acid Levels

Measurement of total acid content was carried out using the acid-base titration method. Calculation of %acidity is calculated as acetic acid with the equation:

$$\%\text{Acidity} = \frac{V_{NaOH} x N_{NaOH} x BMxFP}{W} x100\% \quad \text{.....(2.2)}$$

Information :
V_{NaOH} = volume of NaOH solution used for titration(ml)
N_{NaOH} = normality of NaOH solution (mol/ml)
BM = molecular weight
FP = dilution factor
W = weight of material (mg)

2.3. Observation data

Data obtained from this study will be analyzed and is associated with parameters that have been done. Analysis of the data from this study are:

1. Analysis of the relationship between color and water content.
2. Analysis of the relationship between color and fruit hardness.
3. Analysis of the relationship between color and total sugar.
4. Analysis of the relationship between color and total acid.

3. Results and Discussion

3.1. Image Processing

Program image processing (image processing) is built using the programming language *Visual Basic* 6.0. According to [15], image processing is a process for observing and analyzing an object without damaging the observed object. The process and analysis involve visual perception with input data and output data obtained in the form of observed object images. In agriculture, this program is used for post-harvest processes, namely sorting.

This program can be used to calculate the area of projection, wide color content, and measure the intensity of red, green, and blue or RGB from tomatoes. According to [16], the RGB color model is a color model based on the concept of adding strong primary light namely red, green, and blue. This program consists of several control buttons including image display control (Load Picture), filter control (Filter), repetition control (Refresh), and control exit program (Quit). The appearance of the image processing program is presented in Figure 1.

Figure 1. Display image processing program.

Image display control functions to display images that have been stored in storage memory. Filter control functions to filter images. Repeat control functions to return the filtered image to its original shape. The exit control functions to exit the program. In this program, there is also a graphic display module that functions to display images and the percentage of colors red, green, and blue.

The development of color models is currently being done a lot, but the image processing process that is often used is the RGB color model. This is because computers generally use the RGB color model in presenting colors so that later the color processing value that will be generated is the RGB color model. The image of tomatoes is taken using a digital camera and stored in JPG format. For the image filtering process, the image format must be changed first to the BMP format. This is because the *image processing* program can only be read by changing the format of the image to the bitmap form. Results of filtration of tomatoes *Servo F1* on 4 maturity levels can be seen in Figures 6, 7, 8, and 9.

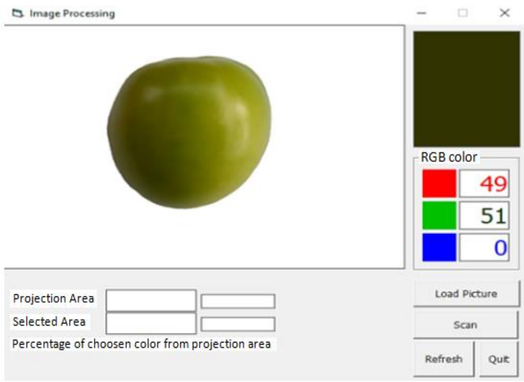

Figure 2. Display of old tomatoes at the picking age 25+1 days AFB.

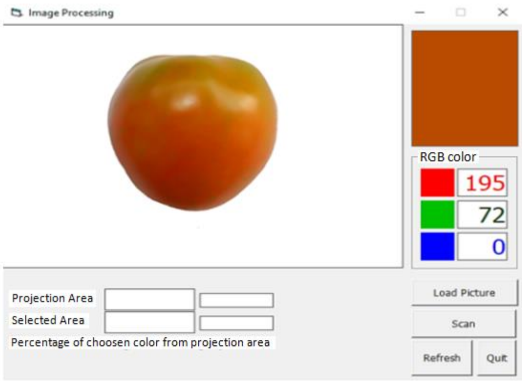

Figure 3. Display of medium-ripe tomatoes at the picking age 29+1 days AFB.

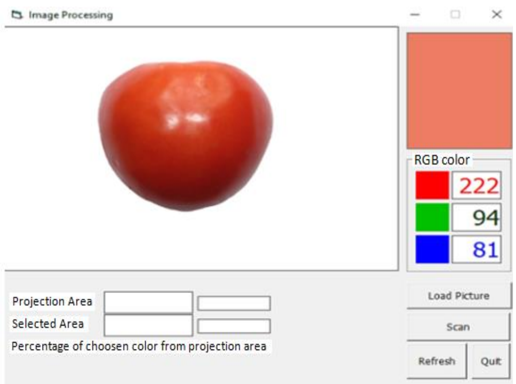

Figure 4. Display of ripe tomatoes at the picking age 32+1 days AFB.

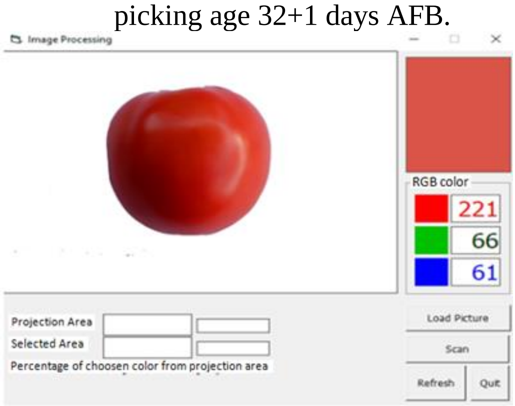

Figure 5. Display of over-ripened tomatoes at the picking age 35+1 days AFB.

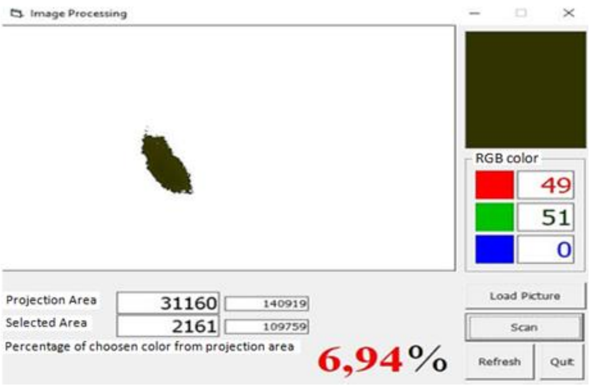

Figure 6. Display of old tomatoes at the picking age 25+1days AFB after filtering.

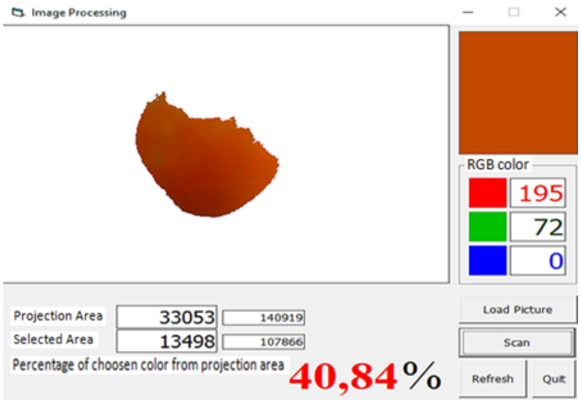

Figure 7. Display of medium-ripe tomatoes at the picking age 29+1 days AFB after filtering.

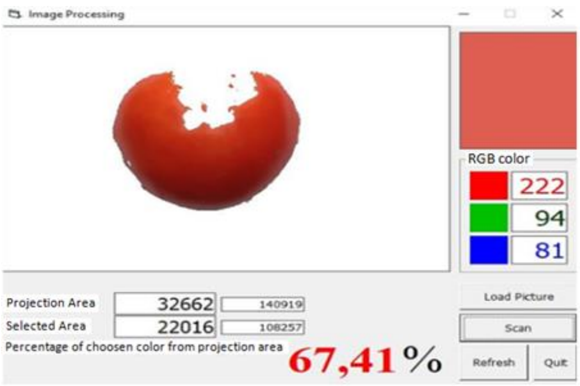

Figure 8. Display of ripe tomatoes at the picking age 32+1 days AFB after filtering.

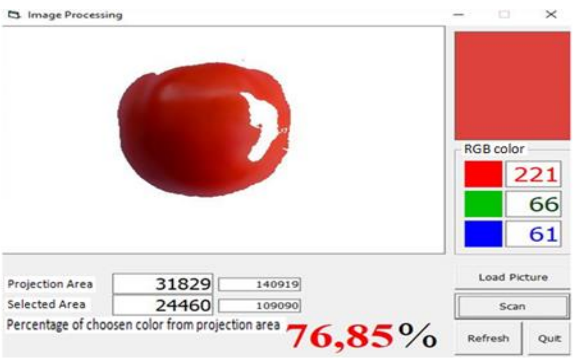

Figure 9. Display of over-ripened tomatoes at picking age 35+1 day AFB after filtering.

Visually, the level of tomato ripeness can be seen from the age of picking and the color of the skin of the fruit. Tomato fruit with a picking age of 25+1 day AFB is still fully green, tomato fruit at age 29+1 day AFB begins to turn reddish yellow, and fruit that has 32+1 day AFB picking a color is bright red while the tomato fruit whose age is picking is 35+1 day AFB red dull.

The average results of measurements made using *image processing* obtained a red percentage of 5.99% for the old category tomatoes at the picking age 25+1 days AFB, 40.15% for the category of medium-ripe tomatoes with picking age 29+1 days AFB, 66.34% for ripe tomatoes with 32+1 days AFB, and 75.67% for over-ripened tomatoes with 35+1 days AFB. The graph of the relationship between the percentage of red with the age of picking can be seen in Figure 10.

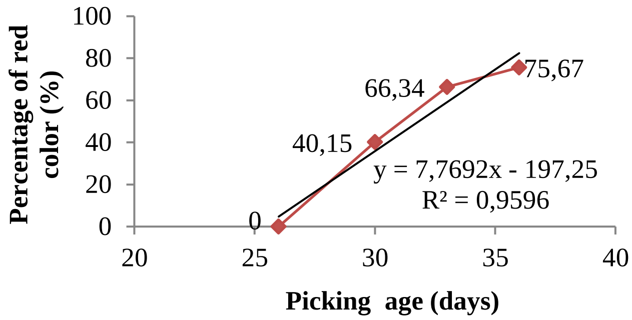

Figure 10. Relationship between picking age and red percentage

Figure 10 shows the coefficient of determination obtained from the linear relationship between the age of picking with the percentage of red color is equal to 0.968, which means that the age of picking tomatoes can be predicted from the value of the percentage of the red color. The percentage results also indicate that the bush in the longevity of picking and the percentage of red color on tomatoes will increase. The largest percentage of red color is found in tomatoes with the age of picking 35+1 day AFB which is equal to 75.67 % while the smallest percentage of red color is found in tomatoes with the age of picking 25+1 day AFB which is 5.99%.

Changes in fruit skin color are often an indicator of the ripeness process. The color change experienced by tomatoes is caused by a change in chlorophyll due to photosynthesis and respiration [17]. This change is catalyzed by the chlorophyllase enzyme. Changes in taste in fruit are caused by the formation of sugars, organic acids, and other volatile compounds derived from sucrose translocation from leaves.

3.2. Color

In the cooking phase, various physical and chemical changes are very clear, especially the color changes in the skin color. The ripening process in tomatoes is characterized by a change in color from light green to gradually yellow. When optimal ripe, the color of the tomatoes will turn bright red. Color is the first factor that humans see when choosing food so it can be said that color becomes a part of the most important sensory properties of food [18]. Color analysis of tom at *Servo F1* is done using *L**, *a**, and *b** coordinates.

*3.2.1. The value of L**

The value of *L** indicates the brightness based on white. The higher the brightness of the fruit peel measured, the value of *L** close to 100. Conversely, the darker the peel, the value of *L** approaches 0. The results of the measurement of the average color intensity of tomato lightness ranged from 45.70% to 50.47% with the coefficient of determination obtained from the graph of the relationship between the age of quotes and brightness that is equal to 0.641. The average value *L** of tomatoes can be seen in Figure 11.

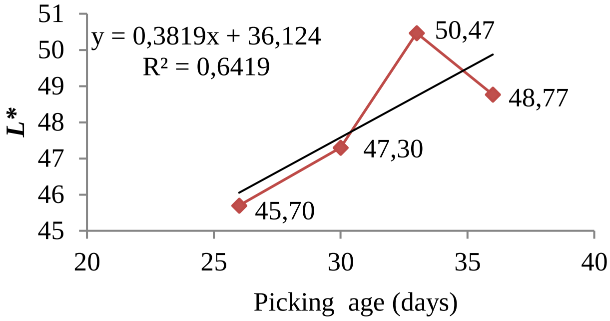

Figure 11. Relationship between picking age and *L** value.

Based on Figure 11 the brightness value for each picking age is 45.70 for picking age 25+1 days AFB, 47.30 for picking age 29+1 days AFB, 50.47 for picking age 32+1 day AFB, and 48.77 for picking age 35+1 day AFB. The highest *lightness* value lies in the age of picking 32+1 day AFB and the lowest brightness value is found in tomatoes with the age of picking 25+1 day AFB. The level of brightness of tomatoes has increased during the maturation process of the fruit, but in the category of maturity, the level of brightness has decreased namely at the age of picking 35+1 day AFB. According to [8] the value of *lightness* in sweet star fruit has decreased because the fruit is getting more mature which means the process of respiration is decreasing.

*3.2.1. The value of a **

The value of *a** indicates red or green coordinates, and the resulting value can change (-) or (+), where the value of +*a* is from 0 to 100 for red, and -*a* is from 0 to -80 for green. The results of measuring the intensity of *a** obtained a correlation of 0.688. The average measurement results of tomatoes ranged from -2.13 to 19.93. The average *a** value of tomatoes associated with picking age can be seen in Figure 12.

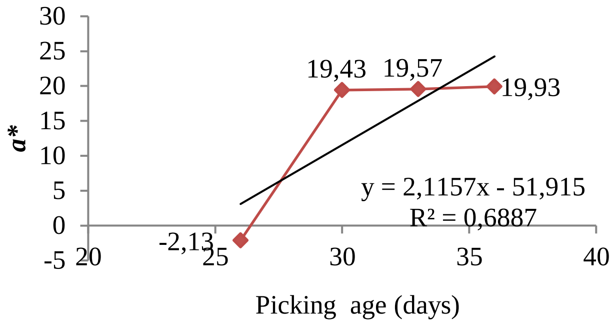

Figure 12. Relationship between the picking age and the value of *a**.

Based on the graph above it can be seen the value of *a** -2.13 which shows the tomato fruit with the age of picking 25+1 day AFB is closer to the green color coordinates, then the value of *a** continues to increase for tomatoes with the age of picking 29+1 day of AFB and 32+1 days AFB of 19.43 and 19.57 to reach the largest *a** value, namely tomatoes with picking age 35+1 days of AFB of 19.93. According to Apriani's study (2017), the value of *a** for sweet star fruit at the lowest picking age is closer to the greening coordinates and then continues to increase along with the picking age.

*3.2.2. The value of b**

The value of *b** is a value that indicates the yellowish and bluish degree of a sample. The value of+*b* **is** from 0 to 70 for yellow and -*b* is from 0 to -70 for blue. The results of the measurement of *b** in tomatoes ranged from 10.67 to 28.33 and a coefficient of determination value of 0.902 was obtained. The average *b** value of tomato fruit can be seen in Figure 13.

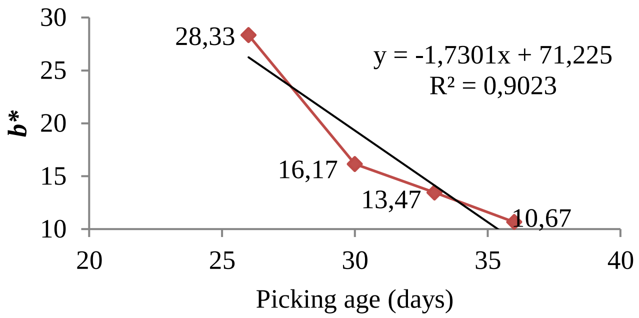

Figure 13. Relationship between picking age learned the value of *b**.

From Figure 13 we can see the relationship between the age of picking and the value of *b**, where the value of *b** has decreased. This is because the higher the age of picking, it affects the level of ripeness of the tomatoes so the skin color of the tomatoes tends toward red and dark. Where the largest *b** value obtained lies in the picking age 25+1 day AFB is 28.33, while 10.67 on the picking age35+1 day AFB, and on the age of picking 29+1 days AFB and32+1 days AFB amounting to 16.17 and 13.47.

2.3. Texture

Changes in tomatoes during ripening can be seen based on hardness or texture indicating a change in composition[19], the process of respiration results in the breakdown of carbohydrates into simpler compounds so that the fruit is soft. The decrease in the value of violence is caused by the preparation of cell walls due to the breakdown of insoluble protopectin into pectin which causes softening of the fruit.

Hardness values are conducive ta right with units of grams of force. The higher the value of hardness, the softer tomatoes. This is indicated by the depth of needle penetration in tomatoes. The results of the measurement of the texture of tomatoes with four levels of picking age ranged from 79.93 to 248.07 grams force (gf) and from the graph also obtained the coefficient of determination of the relationship between the age of picking with a hardness that is 0.862. The results of the average hardness testing on fruit tomatoes can be seen in Figure 10.

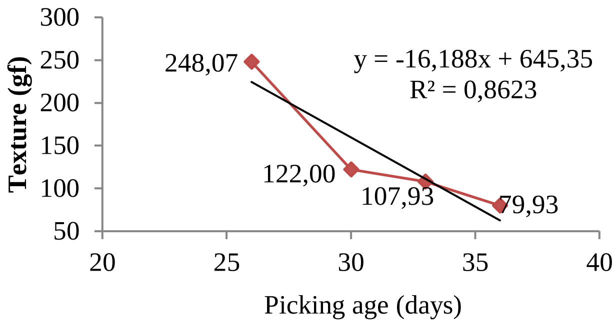

Figure 14. The relationship between picking age and texture

The decrease in hardness in fruit is an impact of the maturation process due to the process of degradation of pectin to protopectin which causes turgor cell wall pressure [20]. This is caused by the increased performance of enzymes in the cell wall, namely pectinmetilesterase, which functions to degrade cellulose and hemicellulose together with an increase in the rate of respiration towards the climax peak.

3.4. Water content

The average value of water content obtained from measurements ranged from 84.89% to 94.77%. The highest water content value of tomatoes is found at the age of picking 35 days AFB while the lowest water content is found at the age of picking 25+1 days AFB. The average analysis results of the water content of *Servo F1* tomatoes at the age of picking can be seen in Figure 11.

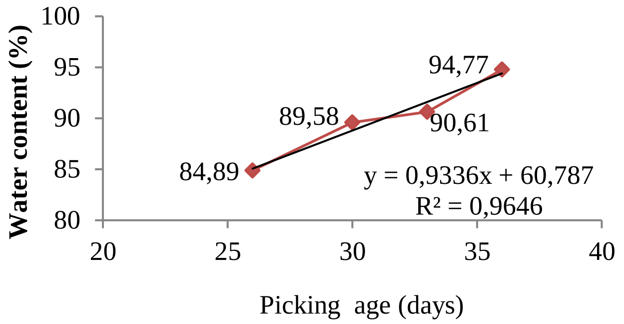

Figure 15. Relationship between picking age and water content

Figure 15 shows the value of the coefficient of determination obtained from the relationship between general picking with water content is 0.964. The coefficient of determination can indicate that the water content of tomatoes can be predicted from the age of fruit picking. The riper the tomatoes will get ripening picking age, and the water content of tomatoes will increase.

3.5. Total Sugar Levels

Maturation of the fruit will cause an increase in simple sugar levels to give a sweet taste. An increase in total sugar is caused by the accumulation of sugar as a result of starch degradation, whereas a decrease in total sugar occurs because a portion of sugar is used for the respiration process [21]. The average results of the analysis of sugar levels on the age of pickings can be seen in Figure 16.

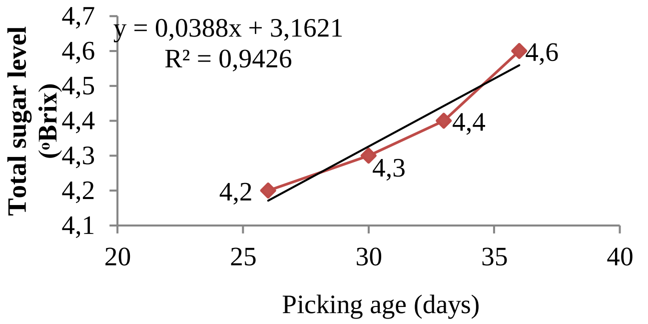

Figure 16. The relationship between picking age and total sugar levels.

Figure 16 shows that the average results of measuring total sugar ranged between 4,2 °Brix to 4,6 °Brix, where the chart has a value of the coefficient of determination of the relationship between age picking with a total sugar content of 0.942. Based on the graph, the value of total sugar increases with maturity. Total sugar levels have increased due to changes in polysaccharides consisting of pectin, starch, and hemicellulose into simple dissolved sugars [21].

3.6. Total Acid Levels

The total acid contained in the fruit will generally decrease during the monitoring process, so the older the picking age the lower the total acid content contained [8]. The average amount of acidity in tomatoes *Servo F1* ranges from 0.36 % to1.19%, where the chart obtained by the coefficient of determination of the relationship between age picking acid sometimes a total of 0.877.

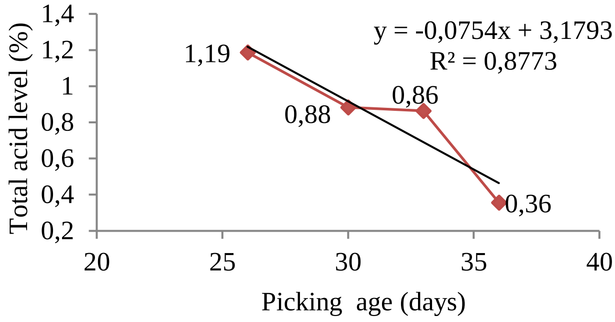

Figure 17. Relationship between picking age and total acid levels.

The maturation process will cause a decrease in organic acids and phenolic compounds to reduce the taste of acid and bitterness. The acid content will decrease with more fruit. This is because the acid is no longer formed and the acid is used as an energy source in the process of respiration. Acid levels will increase to a maximum, and after reaching the peak with more ripe fruit, the acidity will decrease [17].

3.7. *Relationship between Red Color and Color Intensity (L*, a*, b*)*

According to [17], fruit maturity can be characterized by a loss of green color because the chlorophyll content of ripe fruits will decrease. The green color of tomatoes is caused by the presence of chlorophyll which plays a role in the process of photosynthesis during ripening. The loss of green color in the fruit is caused by the enzymatic breakdown of chlorophyll little by little, caused by the activity of the enzyme chlorophyllase which will change chlorophyll to chlorophylloid so that the green color will fade and the appearance of carotenoid. The main pigment in tomatoes is carotene and lycopene ([21]. By the research of [22], during the ripening process of the conjoined citrus fruit, the synthesis of carotenoids was very rapid, this is because the substances caused during the breakdown of chlorophyll can be used for carotene synthesis.

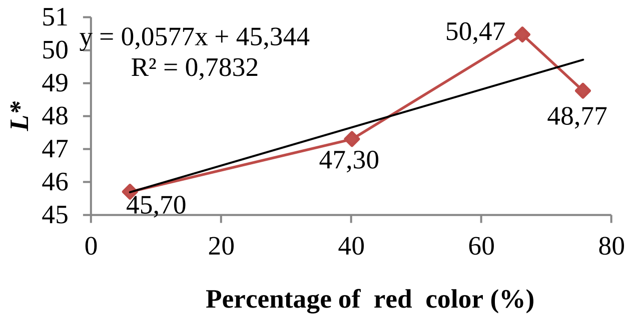

Figure 18. The relationship between the percentage of red with *L**.

Figure 18 shows the relationship between the percentage of red color and the color intensity *L**. The degree of brightness (*L**) in tomatoes tends to form the same pattern with their relationship to picking age. *L** values range from 0 to 100 where 0 for black and 100 for white. The smallest *L** brightness value obtained at the percentage of red color is 5.99%, which is equal to 45.70, the value continues to increase, but the largest percentage of red color is 75.67% brightness has decreased to 48.77 smaller than the percentage of red color 66.34% which is equal to 50.47. A decrease in the value of brightness is caused by the maturation of the fruit that has passed ripe, so the color of the fruit becomes darker.

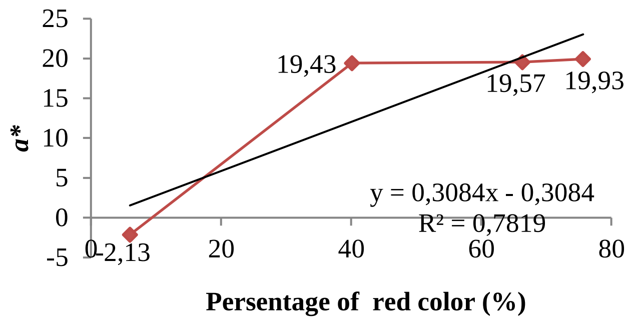

Figure 19. The relationship between the percentage of red with *a**.

Figure 19 shows the relationship between the percentage of red with the color intensity *a**. The degree of greenish color (-*a*) tomatoes are getting less and more positive as the percentage of the red color of the fruit increases. The more positive the value of *a** the green color of the tomatoes disappears and turns red. At the smallest percentage of red color is 5.99% the value of *a* is* -2.13 and at the largest percentage of red color is 75.67% the value of *a** is 19.93. The value of *a** increases indicating the change from green to red.

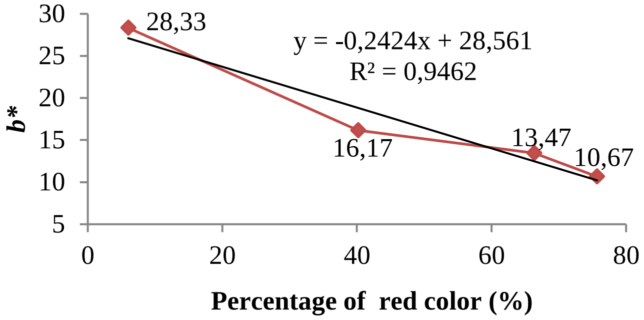

Figure 20. The relationship between the percentage of red with the value of *b**.

Figure 20 shows the relationship between the percentage of red color and the color intensity of *b**. The measurement results show that the percentage of red color is 5.99%, the degree of *b** obtained is 28.33, and begins to decrease in the percentage of red color is 40.15%; 66.43%; and 75.67%, with degrees *b** each obtained 16.17; 13.47; and 10.67. Decrease in value of *b** due to the content so that the green color of tomatoes will turn red.

3.8. Correlation between Red Percentage and Texture

The relationship between texture and percentage of the red color of tomato fruit can be seen in Figure 4.21. On the graph, it can be seen from the graph that the percentage of red color is 5.99 %, it has a hardness value of 248.07 gf, the percentage of red color is 40.15 %, the hardness is 122 gf, the percentage of red color is 66.34% is 107.93 gf, and the percentage of red color is 75.67% have a hardness of 79.93 gf. The results of tomato filtering showed that the harder the texture of the fruit, the smaller the percentage of red in the fruit. This shows that the hardness of fruit can be predicted by the percentage of red fruit.

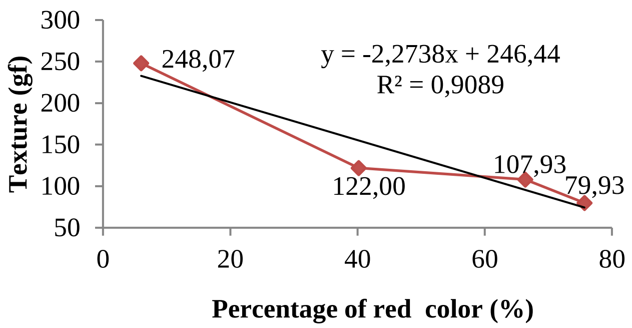

Figure 21. The relationship between the percentage of red color with texture

The hardness value of tomatoes decreases, this is because tomatoes are getting ripe. Changes in texture occur in tomatoes from hard to soft due to the process of wilting due to respiration and transpiration [21] . The process of respiration will result in the breakdown of carbohydrates into simpler compounds, which causes tissue rupture in the fruit so that the fruit becomes soft. Whereas in the process of transpiration there will be water evaporation which causes the fruit to wilt and constrict so that the fruit becomes soft. This can occur because some of the water in the fruit has evaporated so that the fruit's rigidity decreases.

3.9. Correlation between Red Percentage and Moisture Content

The mean measurement results of the relationship between the percentage of the red color of Servo F1 tomatoes and water content ranged from the percentage of the red color of fruit 5.99% with a moisture content of 84.89% to the percentage of the red color of 75.67% with a moisture content of 94.77%.

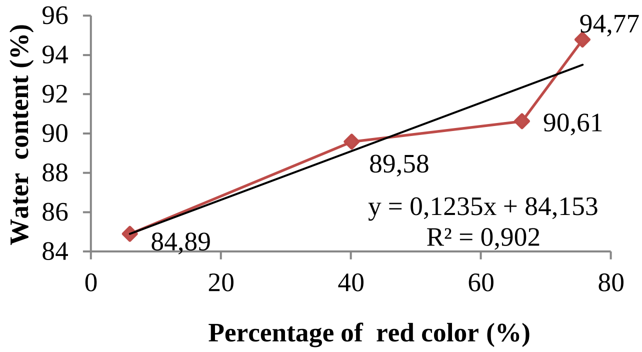

Figure 22. The relationship between the percentage of red color with water content

Figure 22 shows the increase in the percentage of red color with water content increasing in each picking age. The value of water content of *Servo F1* tomatoes is 84.89% in the percentage of red color 5.99 %, the moisture content of 89.58% in the percentage of red color is 40.15 %, the moisture content is 90.61% in the percentage of red color 66.34 %, and 94.77% moisture content in the percentage of red color 75.67 %. According to sweet starfruit, water content is increasing along with the loss of green color that turns yellow, which ranges from the percentage of yellow fruit 21.37% with a moisture content of 78.15% to the percentage of yellow color 73.26% with a moisture content of 80.72%.

3.10. *Correlation between Red Percentage and Total Sugar Levels*

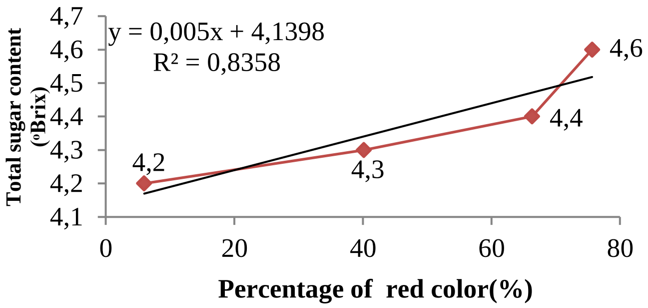

Figure 23. Relationship between the percentage of red color with total sugar content

Figure 23 shows the relationship between the percentage of red color with sugar content in tomatoes increases at each picking age. The percentage of the red color was 5.99% the total sugar value obtained was 4.1 °Brix, the percentage of the red color was 40.15% with a total sugar value of 4.3 °Brix, the percentage of the red color was 66.34% the total sugar value was 4.4 °Brix, and at the percentage of the red color, 75.67% of the total sugar value obtained was 4.6 °Brix.

3.11. Correlation between Red Percentage and Total Acid Content

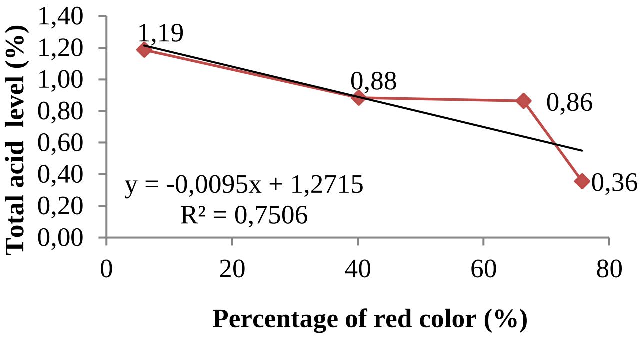

Figure 24. The relationship between the percentage of red color with total acid levels.

Figure 24 shows the relationship between the percentage of red color and acid levels decreasing with increasing picking age. The highest total acid value of 1.19 % in the percentage of the red color is 5.99 % and the total acid value of t is 0.36% in the percentage of the red color, 75.67 %. A decrease in acid content is inversely proportional to the increase in the percentage of red color in tomatoes.

4. Conclusion

The conclusions that can be drawn from this study are as follows:

1. The age of picking tomatoes has a linear relationship with the percentage of the red color with the resulting coefficient of determination of 0.959.
2. At each picking age the percentage of color *L** continues to increase and decreases at the age of picking 32+1 day AFB, from 50.47 to 48.77, while the color of *a** tomatoes increased from -2.13 to 19.93, the color of *b** tomatoes decreased from 28.33 to 10.67, texture decreased from 248.07 gf to 79.93 of water content increased from 84.89% to 94.77%, total sugar levels increased from 4.1 °Brix to 4.6 °Brix; total acid levels decreased from 1.19% to 0.36%.
3. The percentage of red color with texture, water content, total acid, and total sugar has a linear relationship with the rice coefficient determinant value of 0.930 each 0.900, 0.815, and 0.741.
4. It is suspected that there is a correlation between the hardness value, water content, total acid, and total sugar that can be predicted from the age of the picking and the percentage of tomato red color obtained from the *image processing* program.

5. Suggestion

For further research, lighting arrangements in the room should be done during the process of capturing images.

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