Prediction of tomatoes maturity using TCS3200 color sensor

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Abstract. Vitamin C (ascorbic acid) increased as the maturity advances from green to fully ripe stage and ascorbic acid showed continuously increasing patterns throughout ripening until the red stage. Vitamin C analysis with an invasive method at a laboratory, will cause damage to the sample, require a long time, and can not be used in further measurements. Digital image processing techniques as noninvasive method can predict the maturity of tomatoes and vitamin C non-destructively. The purpose of this study was to design a digital image system to predict tomatoes maturity automatically, simply and practically. RGB digital image and vitamin C content are used as a database system to predict maturity on tomatoes. The performance test used 30 pieces of unripe, medium and ripe tomatoes. The result shows each maturity phase of the tomato has a different RGB value. The Green value decreases with an increasing level of tomato maturity. Red values tend to be the same because tomatoes have a red index from the beginning of their ripeness. From the database of RGB and vitamin C, the equipment shows that unripe level of maturity with RGB values below 10 have vitamin C content about 29.5, medium level of maturity with RGB value between 11-23 have vitamin C content about 33.4, and ripe level with RGB values above 23 have vitamin C content approximately 36.9. The result of the performance test shows that it can detect tomatoes maturity by obtaining a success rate of 93%.

1. Introduction
Tomato is one of the most popular and extensively consumed vegetable crop worldwide. There is evidence that regular tomato consumption decreases the incidence of chronic degenerative diseases such as certain types of cancer and cardiovascular diseases [1-4]. The beneficial effects of tomato consumption are generally attributed to carotenoids, which can reduce the risk of certain types of cancer, arteriosclerosis and cataract formation [4]. Two main carotenoids are present in tomato: lycopene, which is the major carotenoid compound (180–90%) giving the red color to the fruit, and β-carotene, which is 7–10% of the total carotenoid content. Carotenoids are also responsible for the characteristic color of tomatoes, in that lycopene is mainly responsible for red color [5-6]. Tomatoes represent by far the main source of lycopene, ascorbic acid, vitamin E and phenolic compounds, particularly flavonoids [7]. One medium sized tomato provides 40% of the Recommendation Daily Allowance (RDA) of vitamin C (Ascorbic acid), 20% of the RDA of vitamin A, substantial amount of potassium, dietary fibre, calcium and lesser amount of iron, magnesium, thiamine, riboflavin and niacin, yet contain only about 35 calories [8]. The ascorbic acid content of the tomato hybrids varied between 11.50-21.75 mg/100g. It increased as the maturity advances from green to fully ripe stage [9] and ascorbic acid showed continuously increasing patterns throughout ripening until the red stage [10].
Tomatoes need to be harvested on time. If it is held too soon or too late, the quality of tomatoes would not be optimum. Therefore post-harvest handling plays an important role in maintaining the quality of tomatoes. In the ripening process, the color changes gradually from light green to yellow. When they reach optimal ripe, their color turns into bright red. Young tomatoes taste bitter and do not smell good because they still contain mucus-shaped Lycopersicon[11]. The unpleasant aroma will disappear automatically when they enter the maturation phase. It also feels to be a rather sour sweetness that is characteristic of tomato delights. The distribution of tomatoes in various regions makes the importance of classifying tomatoes based on their maturity level [12]. Tomatoes that will be marketed with long-distance, should be picked when the fruit is still greenish-yellow or 70% maturity, while tomatoes are marketed locally, harvesting is done when the fruit is reddish yellow or 80% ripe [13].

| Table 1. Classification of Tomato Maturity Stage [14] |
|------------------------------------------------------|
| **Color level** | **Classification** | **Description** |
|------------------------------------------------------|
| Mature green | All green color and mature |
| Breaker | Start to change color (pink, red or yellowish green) but not more than 10% |
| Turning | More than 10% but not more than 30% pink, red or orange |
| Pink | More than 30% but no more than 60% pink or red |
| Light-red | More than 60% but no more than 90% red |
| Red | More than 90% is red, the expected level of maturity |

The maturity level of tomatoes and vitamin C content can be determined by the changes in the color of the skin surface. Vitamin C with invasives method at a laboratory, will cause damage to the sample, require a long time, and can not be used in further measurements [15]. Meanwhile human can predicting the maturity of tomatoes by color change, but it produces a different color of observations. Therefore, it needs noninvasive method and equipment that able to predict the maturity level of tomatoes as well as vitamin C content.

The changes in the tomato maturity level can be analysed with the help of image processing. This study was conducted by observing and analysing an object without contact with the object being
observed [16]. Digital image processing techniques as noninvasive method can predict the maturity of tomatoes and can automatically predict the content of vitamin C non-destructive or they do not damage the fruit.

The purpose of this study was to design a digital image system to predict tomatoes maturity automatically with the TCS3200 color sensor as a camera on image processing. Image color capture was only one pixel and then it programmed into a frequency converter combining configurable silicon photodiodes and current into the frequency converter on a monolithic CMOS integrated circuit. The output was a square wave (50% duty cycle) with a frequency directly proportional to the intensity of light (irradiance). TCS3200 the light converter reads 8x8 diode arrays. Sixteen photodiodes had blue filters, 16 photodiodes had green filters, 16 photodiodes had red filters and 16 photodiodes without filters [17].

2. Materials and Method

2.1. Materials
Tomatoes from servo varieties were used in this research, with 30 pieces of unripe, medium and ripe tomatoes for the analysis of vitamin C and performance test of tomatoes maturity prediction equipment.

2.2. Method

2.2.1. Hardware design
The body frame of tomatoes maturity prediction used 2mm-DOP acrylic type, with characteristics of not easily broken, light, and easily carved drilled, smoothed or painted. Acrylic is cut based on the size and the design of the tool. The 16x2 LCD was used as the output value of the TCS3200 color sensor reading. The output produced was information from the results of reading the tool in the form of a tomato maturity level. Sensor-based color sensor TCS3200 was used to measure the color of RGB (Red, Green, Blue) from an object. This sensor module has the facility to record up to 25 color data that will be stored in the EEPROM. The sensor module was equipped with the UART TTL and I2C interfaces. The distance between the color sensor TCS3200 and object was 3 cm. Arduino Uno, which has been transferred to an RGB color reading program using the Arduino IDE software application, was connected with the TCS3200 color sensor. A power supply of the device used a power bank with 7800 mAh capacity resulting in an output of 5 V to power the appliance. The design of a tomato maturity prediction equipment can be seen in Figure 1.

![Figure 1](image1.png)

Figure 1. Front and side view of hardware design (in cm unit)

2.2.2. Electronic system design
The electronic system sequence consisted of several components, namely Arduino Uno, 16x2 LCD, TCS3200 color sensor and Powerbank as tool power supply. All components were arranged following the pin/port to be used. The TCS 3200 color sensor was able to read the RGB value of the object by reflecting the LED light on the object and the object reflected the light to the photodiode installed on the color sensor. Data received from the TCS 3200 color sensor was processed by Arduino Uno. The result was displayed on a 16x2 LCD which contains information from the results of reading the tool on the object. The electronic system circuit can be seen in Figure 2.
2.2.3. Equipment testing
Equipment testing was carried out to determine the performance of the TCS3200 color sensor [22] and analysed changes in the color of tomatoes. Color sensor testing was carried out by comparing RGB values that are read by the sensor with RGB values using the Photoshop application on the same object. The object used was paper red, green, blue and white. The results of this test were connected by using a graph to obtain the value of R².

Color analysis was carried out by collecting a database of vitamin C from the maturity level of tomatoes, i.e.: 30 pieces of unripe level, 30 pieces of medium level, and 30 pieces of a ripe level. The grouping of maturity values was displayed on the 16x2 LCD in the tool with the classification in Table 2.

![Figure 2. Electronic system circuit](image)

**Table 2. Tomato maturity index**

| Color of tomatoes | Classification |
|------------------|---------------|
| Mature level 1,2,3 | unripe        |
| Mature level 4,5  | medium        |
| Mature level 6    | ripe          |

Then, the classification of vitamin C content was analysed using the iodine titration method. The classification was functioned to determine the range of RGB color values on the color of tomato skin according to the vitamin C content, and to identify vitamin C according to the phase of maturity.

3. Results and Discussion
Figure 3 shows the vitamin C prediction equipment. The framework is made of acrylic material thickness 2mm in black and a 6cm diameter PVC pipe as a handle. Equipment design has weighed 350 g. On the outside, there is a Sensor TCS3200, LCD 16x2, power button and USB port as a charger.

The program code in electronic circuits serves to direct the performance of arranged electronic circuits. The application used to perform the programming process is **Arduino software IDE** with the **Arduino** programming language. The final coding tool enters the value according to the database obtained, which is based on a comparison of the value of GM. If the RG value is ≤ 10 then the tool will show that tomatoes are still unripe and the vitamin C content about 29.5. If the RG≥23 tool will show that tomatoes are ripe with a vitamin C content about 36.9. Apart from these two values, the range of GM values between 11-22 tomatoes is classified as medium with a vitamin C content about 33.4.
3.1. **TCS3200 color sensor testing**

A color sensor test is performed on papers as calibration with four basic colors of this treatment as well as a sensor working indicator. Five repetitions are carried out and the average RGB value was obtained. Reading R on red paper, G from green paper and B from blue paper using Sensor TCS3200 compared with the value obtained from image capture through Canon Scanner. The image that has been obtained is processed using *Photoshop CC* 2016 as comparison. Table 3 shows that the difference in the RGB value of the sensor TCS3200 with *photoshop* reading. It can be concluded that light affecting the result and the capturing sensor by TCS3200 sensor only one pixel, so *photoshop* reading more reliable [19].

| Paper color | Photoshop reading (RGB) | Sensor reading (RGB) |
|-------------|-------------------------|---------------------|
|             | R   | G   | B   | R   | G   | B   |
| Red         | 212 | 209 |     | 199 |     |     |
| Green       | 197 |     |     | 216 | 223 | 231 |
| Blue        |     |     |     |     |     | 221 |
| White       | 226 | 223 | 231 | 223 | 214 | 226 |

3.2. **Tomato color change analysis**

Analysis of tomato discoloration serves to see how tomatoes color change based on their level of maturity by the initial code of RGB reading. The sample is 115 pieces with different levels of maturity. Four repetitions are performed on different sides and averaged.

**Figure 3.** Vitamin C prediction equipment

**Table 3.** Results of RGB reading by *photoshop* reading and sensors TCS3200

**Figure 4.** Red value on every maturity level

**Figure 5.** Green value on every maturity level
Figure 4 shows that maturity advances from red color increasing patterns throughout ripening until the red stage. The green color in raw fruits changes gradually into deep red when they come to fully ripe. The color of tomatoes is highly correlated with lycopene content [20], and when the fruit develops from the green stage mature to the red stage, the concentration of lycopene increases significantly [21]. Tomatoes with maturity level > 70% red skin have higher levels of lycopene and carotene so that the red color of tomatoes tends to be evenly distributed. The results of the distribution of Red values on each maturity in this study are almost the same as the results of Bhandari and Lee research [22], this is due to the spread of the value of the red color index intensity on tomatoes at each age level already exists. It is seen that the maturity level of 1.2 and 3, red intensity are below other maturity levels.

Figure 5 shows that unripe tomatoes have a high of green color intensity, while ripe tomatoes have a low of green intensity. Discoloration occurs due to the synthesis of certain pigments, such as carotenoids (the most influential factor) and flavonoids, in addition to the occurrence of chlorophyll changes. Discoloration in fruits is caused by pigments which are generally divided into 4 groups, i.e. chlorophyll, anthocyanin, flavonoids, and carotenoids. Chlorophyll changes make the color of fruits which are originally green will eventually turn into red. Thus, the intensity of the green color obtained decreases along with the increasing levels of maturity on tomatoes [23].

![Figure 6. Blue value on every maturity level](image)

Figure 6 shows that the maturity level of 1, 2 & 3 has a higher blue color index compared to other maturities, although the differences are not quite high. Instead, tomatoes with maturity 6 have a smaller blue color index. Referring to the previous study of Tor and Savage [24], the red and green index can be used as a parameter to determine the maturity level of tomatoes because it shows significant differences in three groups of unripe, medium and ripe tomatoes. Otherwise, the blue index cannot be used as a parameter to determine the fruit maturity level tomatoes because they cannot produce a real difference for the distribution of blue values. The average RGB value obtained is as follows:

| Table 4. RGB average value based on maturity level |
|-----------------------------------------------|
| Maturity level | Information | R | G | B |
|----------------|-------------|---|---|---|
| 1, 2 & 3       | Unripe      | 195 | 189 | 197 |
| 4, 5           | Medium      | 199 | 179 | 194 |
| 6              | Ripe/mature | 199 | 171 | 193 |

Figure 7 shows that vitamin C content in tomatoes increases along with the level of increasing maturity but it decreases again when the tomatoes have been overripe [25]. The enhancement of vitamin C content usually occurs with the length of storage time but if the substrate formation of vitamin C is no longer available then the content of vitamin C decrease [26]. Vitamin C in horticultural products is synthesised from hexose, where the hexose content increase during storage as well as the content of vitamin C [24].
3.3. Performance of tomatoes maturity prediction

The performance of the equipment on 30 samples with different levels of maturity (10 unripe, 10 medium, and 10 ripe) was shown in Table 5. From 30 samples tested there were 2 samples with inappropriate recitation, the ripe samples are detected medium. This error is caused by the peel of mature tomatoes tend to be shinier, so when the photodiode emits light it will bounce and affect the reading of the RGB value of the equipment. The percentage success of tomatoes maturity prediction is about 93%, it is indicated excellent result because only 2 data from 30 samples not suitable.

| Sample | R    | G    | B    | Fruit   | Weight | Vit C | Classification |
|--------|------|------|------|---------|--------|-------|----------------|
| 1      | 186  | 189  | 207  | Unripe  | 29.5   | 29.5  | Suitable       |
| 2      | 206  | 208  | 211  | Unripe  | 29.5   | 29.5  | Suitable       |
| 3      | 197  | 194  | 201  | Unripe  | 29.5   | 29.5  | Suitable       |
| 4      | 205  | 203  | 211  | Unripe  | 29.5   | 29.5  | Suitable       |
| 5      | 184  | 183  | 204  | Unripe  | 29.5   | 29.5  | Suitable       |
| 6      | 209  | 205  | 213  | Unripe  | 29.5   | 29.5  | Suitable       |
| 7      | 183  | 192  | 205  | Unripe  | 29.5   | 29.5  | Suitable       |
| 8      | 207  | 208  | 218  | Unripe  | 29.5   | 29.5  | Suitable       |
| 9      | 208  | 204  | 218  | Unripe  | 29.5   | 29.5  | Suitable       |
| 10     | 208  | 205  | 218  | Unripe  | 29.5   | 29.5  | Suitable       |
| 11     | 214  | 197  | 210  | Medium  | 33.4   | 33.4  | Suitable       |
| 12     | 215  | 198  | 217  | Medium  | 33.4   | 33.4  | Suitable       |
| 13     | 216  | 202  | 218  | Medium  | 33.4   | 33.4  | Suitable       |
| 14     | 215  | 199  | 211  | Medium  | 33.4   | 33.4  | Suitable       |
| 15     | 217  | 199  | 212  | Medium  | 33.4   | 33.4  | Suitable       |
| 16     | 214  | 201  | 212  | Medium  | 33.4   | 33.4  | Suitable       |
| 17     | 216  | 198  | 212  | Medium  | 33.4   | 33.4  | Suitable       |
| 18     | 215  | 199  | 212  | Medium  | 33.4   | 33.4  | Suitable       |
| 19     | 214  | 202  | 213  | Medium  | 33.4   | 33.4  | Suitable       |
| 20     | 217  | 201  | 214  | Medium  | 33.4   | 33.4  | Suitable       |
| 21     | 208  | 179  | 200  | Ripe    | 36.9   | 36.9  | Suitable       |
| 22     | 206  | 180  | 199  | Ripe    | 36.9   | 36.9  | Suitable       |
| 23     | 206  | 181  | 202  | Ripe    | 36.9   | 36.9  | Suitable       |
| 24     | 208  | 189  | 202  | Ripe    | 36.9   | 36.9  | Not Suitable   |
| 25     | 208  | 183  | 202  | Ripe    | 36.9   | 36.9  | Suitable       |
| Fruit Samples | Value Weight | Sample classification | Results |
|---------------|--------------|-----------------------|---------|
| 26            | 207 182 202  | Ripe                  | Suitable |
| 27            | 206 185 202  | Ripe                  | Not Suitable |
| 28            | 206 183 201  | Ripe                  | Suitable |
| 29            | 205 182 202  | Ripe                  | Suitable |
| 30            | 207 182 201  | Ripe                  | Suitable |

4. Conclusions

Each phase of tomato maturity has different RGB values. Green values decrease along with the increasing maturity level of tomatoes. Red values tend to be the same because tomatoes have a red index from the beginning of maturity. The results of the tool performance test show that the tool can detect vitamin C content based on the database by obtaining a success rate of tool readings of 93%.

References
[1] Heber, D 2000 Colorful cancer prevention: a-carotene, lycopene and lung cancer Am. J. Clin. Nutr. 72 4 901–902.
[2] Bazzano L A, Serdula M K, Liu S 2003 Dietary intake of fruits and vegetables and risk of cardiovascular disease Current Atherosclerosis Rep. 5 6 492–499.
[3] Faller A L K, Fialho E 2009 The antioxidant capacity and polyphenol content of organic and conventional retail vegetables after domestic cooking Food Res. Int. 42 1 210–215.
[4] Nguyen M L, Schwartz S J 1999 Lycopene: Chemical and biological properties Food Technol. 53 38–45.
[5] Story E N, Kopec R E, Schwartz S J, Harris G K 2010 An update on the health effects of tomato lycopene An. Rev. Food Sci. Technol. 1 1 189–210.
[6] Holden J M, Eldridge A L, Beecher G R 1999 Carotenoid content of U.S. foods: an update of the database J. Food Comp. Anal. 12 3 169–196.
[7] Raffo A, Leonardi C, Fogliano V, Ambrosino P 2002 Nutritional value of cherry tomatoes (Lycopersicon esculentum cv. Naomi F1) harvested at different ripening stages J. Agric. Food Chem. 50 6550–6556.
[8] Ogaraku A O, Alanana J A, Omananyi P O 2010. Decay of tomato (Lycopersicum ssculentum Mill) and vitamin C content of infected fruits in Keffi, Nasarawa State PAT 6 2 91-98.
[9] Singh A K, Pan R S, Bhavana P, Srivastava A, Seth T 2017 Quality ang nutritional composition in tomato fruit at different stages of maturity Veg. Sci. 44 2 49-52.
[10] Bhandari S R, Lee J G 2016 Ripening-dependent changes in antioxidants, color attributes, and antioxidant activity of seven tomato (Solanum lycopersicum L.) cultivars J. Anal. Meth. Chem. 2016 1-13
[11] George B, Kaur C, Khurdiya D S, Kapoor H C 2004 Antioxidants in tomato (Lycopersicon esculentum) as a function of genotype Food Chem. 84 45–51.
[12] Riska S Y, Subekti P 2016 Classification of tomato maturity level based on color features using Multi-Sv Jurnal Ilmiah Informatika 1 1 39-41. [In Indonesian]
[13] Sholeha S F 2015 Study of the physical and chemical properties of tomatoes (Lycopersium esculentum Mill) using image processing Universitas Negeri Jember. [In Indonesian]
[14] Batu A 2003 Determination of acceptable firmness and colour values of tomatoes J Food Eng. 61 3 471-475.
[15] Kuo-Yi H 2007 Application of artificial neural network for detecting Phalaenopsis seedling diseases using color and texture features Comp. Elec. Agric. 57 1 3-11.
[16] Suhardi I I P 2016 Study of tomato maturity using image processing and fuzzy logic integrated with PI raspberries Institut Pertanian Bogor Bogor [In Indonesian]

[17] TAOS 2009 TCS3200 TCS3210 Programmable color light-to-frequency converter The Lumenology Company Texas

[18] Al Mamun M A, Ali, M H, Ferdous M S 2017 Design, construction and performance test of a color detective device International Conference on Mechanical, Industrial and Materials Engineering 28-30 December 2017 RT-142.

[19] Shen L J, Hassan I 2015 Design and development of colour sorting robot J. Eng. Sci. Technol. 71-81.

[20] Cox S E, Stushnoff C, Sampson D A 2003 Relationship of fruit color and light exposure to lycopene content and antioxidant properties of tomato Can. J. Plant Sci. 913-919.

[21] Nunes M C N 2008 Color atlas postharvest quality of fruits and vegetables: solanaceous and other fruit vegetables J Wiley & Sons Ltd USA.

[22] Novita M, Hasmarita E 2015 Content of lycopene and carotenoids of tomatoes (Lycopersium pyriforme) at various levels of maturity: the effect of coating with chitosan and storage Jurnal Teknologi dan Industri Pertanian 2 1 35-39. [In Indonesian]

[23] Bhandari S R, Lee J G 2016 Ripening-dependent changes in antioxidants, color attributes, and antioxidant activity seven tomato (Solanum lycopersicum L.) cultivars Journal of Analytical Methods in Chemistry 2016 1 1-13.

[24] Rizali Y 2007 Development of image processing algorithms to determine the maturity level of fresh tomatoes Fakultas Teknologi Pertanian Institut Pertanian Bogor Bogor. [In Indonesian]

[25] Windasari A, Yuliati Y, Umniyatie S 2016 Effect of KMnO4 dose variations on the quality of tomatoes (Lycopersico lycopersicum L.) servo varieties after harvest Jurnal Biologi 5 7 39-46. [In Indonesian]

[26] Valsikova-Frey M V, Komar P, Rehus M 2017 The effect of varieties and degree of ripeness to vitamin C content in tomato fruits Acta Horticulturae et Regiotecturae 2 44-48.