Quality assessment of chilies (Capsicum annuum L.) by using a smartphone camera

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Abstract. This study aims to determine the image parameters that can the chili quality and arrange the best Artificial Neural Networks (ANN) architecture in order to classify the quality into several groups. The image was taken and analyzed by means of image processing and ANN. Samples of chilies were divided into 2 groups, 75% for training data and 25% for network testing. The sample was placed in a black box and the image was captured using smartphone camera for both sides. The sample image was converted to binary to get the color value. Value color of image processing results using Matlab were used as input parameters for color group identification of ANN. Subsequently, color used as variable for classification using ‘if then’ logic. The results showed that the color elements of the image that could be the quality identity of chili were red, green, a*, and intensity. The ANN input layer that consisted of 4 input cells, 9 hidden layer cells, and 1 output layer cell could classify chilies into 4 color groups i.e green, tinge of red, red and dark red with an accuracy of 90.43%.

Keywords: chili, image, smartphone camera, quality.

1. Introduction
People evaluates a product based on visual perception and predicts the taste of the product before trying it as a way of making a decision whether the product will be consumed or not [1]. Schutz and Wahl suggest that color and appearance are attributes of great concern in fruit, vegetables and cakes [2]. Color is the first quality attribute of food that is evaluated by consumers; therefore, color is an important component of food quality that has correlation with market acceptance. Objective quality control is needed for the rate and measurement of food color to increase product profits [3].

Chili is a popular plant with a combination of color, taste, and nutritional content. Fresh chili is an agro product that has high vitamin C content and a good source of pro-vitamin A [4]. The quality and quantity of chili greatly influence consumers’ acceptance and its selling prices. The characteristics of chili that are often used as indicators are physical appearance, such as color, shape, hardness, and the absence of defects. The quality standard for fresh red chili is SNI 4480: 2016. In order to maintain the chili’s selling price, it is necessary to sort and grade it. Usually, sorting is done by farmers and grading is done by traders. Sorting is done to select healthy, normal, and good-shaped chili. The sorting delay will increase the rotting. In general, grading is done manually through eye observations. This method has several weaknesses; among other things, it results in inconsistent quality due to the limitations of human visual ability, fatigue, and the existence of differences in perceptions of the quality of each observer [5].

Chili image analysis is one of the non-destructive tests that can be applied to sort and grade. By taking images of the chili and analyzing them with certain methods, we can produce information on the quality and content of the product consistently. In recent years, there has been a growing interest among researchers to develop image processing applications by using a smartphone’s camera [6].
smartphones equipped with a camera and supporting software has a great potential to be used as a measuring tool for the quality of chili in a non-destructive manner, and it can also be used in real time. This real-time quality information will provide quick feedback for all stakeholders in making decisions to safeguard and enhance this strategic commodity. Therefore, this research was conducted to develop a non-destructive quality test application in the form of physical quality testing of chili that was in real time, accurate, consistent, and easy to implement.

2. Materials and Method

2.1. Sample Collection
A total of 190 of fresh chilis (c.v. Helix) were hand-harvested from coastal area of Bugel Village, Kulon Progo Regency, one of the highest producing areas for chili in Yogyakarta Special Province, Indonesia. Sampling was done in the afternoon between 3.00 pm and 4.00 pm when the harvesting activities by farmers was taking place. The samples were chilis in the various growing stages with color variations of green, red tinge, red, and dark red. Samples were brought into a laboratory for measurements. Sample measurements were conducted on physical properties i.e. length, diameter, and weight.

2.2. Measurement of Physical Properties
Quality assessment through image processing aimed to determine the color of the chilis. The length measurements were conducted by means of a bar, and the color measurements were carried out with chromameters (Minolta CR 400). The color of the chilis were measured at 3 (three) points evenly on the chilis. This stage aims to get some features from the sample that can be combined into the identity of each sample as an input in the image processing.

2.3 Image Acquisition
Each sample was put into the black box, and its image captured with a smartphone camera (13 megapixel, aperture f/2.2). A smartphone camera (13 megapixel, aperture f/2.2) chosen was a low cost device. The box was equipped with a USB LED lamp as a light source. The box was designed to make the image acquisition process possible with the same lighting, the same distance between objects with the camera, and the same camera type. The height was 12 cm with the length and width of the box were adjusted to the sample size which were 16 cm and 18 cm respectively (figure 1). The image was taken from two sides of sample.

![Figure 1](image.png)

Figure 1. The schema of the image acquisition device.

A. Black box made of plastic fibre.
B. Light source of portable USB LED light strip (Sun Light: 5500-6000K, Rated voltage: DC 5V, dimension: 16 cm x 1.5 cm x 0.7 cm).
C. Powerbank as a power source for LED lights.
D. Smartphone with camera (13 megapixel, aperture f/2.2).

2.4. Image Processing
Image data from a smartphone camera was transferred to a computer for image processing which included image segmentation and feature extraction. Segmentation is a process to segregate chilli
samples from the background. Feature extraction is the extracting features or information in the form of numerical data of objects in the image that would be recognized or distinguished from other objects namely redness, greenness, blueness, entropy, contrast, homogeneity, energy, and correlation. The numerical data of the extracted features were then used as parameters or input values to distinguish between objects with each other at the stage of identification or classification in ANN. The image processing was conducted by using MATLAB software.

2.5. Arrangement of Artificial Neural Network Architecture
Artificial neural networks were arranged using MATLAB R2013a which was carried out in several stages of determination as follow.

a. the number of neurons in the input layer and output layer
b. the training function
c. the number of neurons in the hidden layer
d. the type of activation function at each layer
e. maximum error (MSE)
f. maximum iteration (Epoch)
g. learning rate (lr)
h. constant momentum (mc)

2.6. Artificial Neural Network Training
The training phase was carried out with MATLAB software. The parameters obtained from image processing were used as input for the training program. Data from the image processing stage was trained to get an output in the form of sample classifications.

2.7. Validation
Validation was conducted to test the accuracy of ANN against the training provided. The formula used was the following:

\[ \text{Accuracy (\%)} = \frac{A}{B} \times 100\% \]  \hspace{1cm} (1)

where

A: the amount of data predicted results are the same as the target.
B: the amount of data

3. Results and Discussion
Sample of chilies used in the study are presented in table 1. Chilli used as sample had a variety of colors and lengths with a fairly wide range. The colors of the chili will change along with its level of maturity, from green to red as shown in the \( L^* \) value in table 1. Low values indicate green chilies and high values indicate the chili has a red color.

Table 1. Characteristics of samples (n=178)

| Quality Parameter | Range   | Mean  | Std Dev |
|------------------|---------|-------|---------|
| Length (cm)      | 7.7 – 17.4 | 10.87 | 1.70    |
| \( L^* \)        | 23.55 – 44.02 | 34.77 | 4.06    |
| \( a^* \)        | 13.77 – 44.57 | 23.21 | 21.52   |
| \( b^* \)        | 5.01 – 36.68  | 21.01 | 6.23    |

3.1 Image Processing Program
Read the original image. The original image (figure 2) was obtained through image acquisition using a 13 megapixel Xiaomi smartphone’s camera, \( f / 2.2 \), taken with ISO 200 setting, and 1/60 shutterspeed in the box. Image acquisition produced an RGB color image format and extension .jpg. The image from
the smartphone was then transferred to the computer for further processing with MATLAB. The image was then read via MATLAB using the command:

\[ I = \text{imread('nama file');} \]

### 3.2 Converting an RGB Image To A Grayscale Image

Image conversion to grayscale aimed to simplify the image model. Each pixel of a grayscale image has shades of gray, from 0 (black) to 255 (white). Grayscale image is very suitable for processing image files (figure 3). The command in MATLAB used for conversion from RGB to grayscale was the following.

\[ I = \text{rgb2gray (I);} \]

### 3.3 Uniformity of Lighting

The uniformity of lighting aimed to eliminate gradations and get a uniform black background (figure 4). The image obtained was then increased in its contrast through the following command:

\[ \text{gray=imadjust(I2);} \]

### 3.4 Conversion To Binary Image

The process of converting images to binary was done by using the following command:

\[ \text{thresh = graythresh (gray);} \]
\[ \text{imbw = im2bw (gray, 0.2);} \]

`im2bw` is a command to convert images from grayscale into binary form with a certain threshold. Threshold was determined by using the `graythresh` command. To get the maximum threshold results can be done by adjusting the threshold level. In this image, a threshold level of 0.2 was used.

### 3.5 Eliminating small objects.

Binary conversion images often have small objects that can interfere with the detection process and can affect the final image. Therefore, it is necessary to remove these small objects. The following command was used for this purpose.

\[ \text{bw = bwareaopen (imbw, 300);} \]

`bwareaopen` functions to eliminate objects smaller than certain pixels. For this image, 300 was determined. The result of this stage is shown in figure 5 below:
3.6 Reversion of the Original Color of the Image

The image that had been separated from the background was then returned to the original color (RGB) as shown in Figure 6.

![Figure 6. Final image](image)

3.7 RGB Feature Extraction

Image features were used as input parameters in artificial neural networks. The feature used in this image was the RGB color feature. RGB feature extraction was done by the following commands:

```matlab
red=RGBawal(:,:,1);
green=RGBawal(:,:,2);
blue=RGBawal(:,:,3);

meanRed=red(red>0);
meanRed=mean(meanRed(:));
meanGreen=green(green>0);
meanGreen=mean(meanGreen(:));
meanBlue=blue(blue>0);
meanBlue=mean(meanBlue(:));
meanRed
meanGreen
meanBlue
```

3.8 Determination of Artificial Neural Network Parameters (ANN)

To determine the parameters used as input ANN, the R-square value calculation was performed using the SPSS 16 application. The parameters chosen were parameters that have an R-square value of more than 0.2 according to the correlation coefficient and interpretation table.
The R-square value would show how much influence the independent variable (color level) has on the dependent variable (RGB, HSV, Lab, and texture parameters). While the value of P value or significance < 0.05 indicates that the decision taken has a probability of error below 5%, meaning that the decision is justified. A summary of the calculated R-square values is shown in Table 2. Based on Table 2, it can be noticed that there were 4 parameters with R-square values of more than 0.399 (moderate correlation) with p < 0.05 namely intensity, red, a* and green parameters.

| No | Parameter | R-square | Sig  |
|----|-----------|----------|------|
| 1  | Green     | 0.769    | 0.000|
| 2  | a*        | 0.684    | 0.000|
| 3  | Red       | 0.602    | 0.000|
| 4  | Intensity | 0.486    | 0.000|
| 5  | Correlation | 0.197    | 0.000|
| 6  | Energy    | 0.177    | 0.000|
| 7  | L         | 0.148    | 0.000|
| 8  | Saturation | 0.121    | 0.000|
| 9  | Contrast  | 0.108    | 0.000|
| 10 | b         | 0.105    | 0.000|
| 11 | Blue      | 0.083    | 0.000|
| 12 | Homogenity | 0.034    | 0.028|
| 13 | Entropy   | 0.033    | 0.029|

3.9 Development of Artificial Neural Network
Development of network architecture was carried out by using MATLAB R2013a software and neural network toolbox. This research used the parameters Red and mean Green, mean a*, and the value of intensity as input and color level as output.

Followings are the features of the feedforward backpropagation ANN architecture model utilized:

- Learning rate = 0.1
- Momentum constant = 0.2
- Desired performance value (mse) = 0.001
- Number of hidden layer neurons = 9
- Input activation function = logsig
- Hidden layer activation function = tansig
- Output layer activation function = logsig
- Maximum iteration = 3000

This artificial neural network design consisted of three layers, namely the input layer, hidden layer, and output layer. The input layer consisted of four cells, i1 to i4 consisting of red, green, a* and intensity values. The hidden layer consisted of 9 cells namely h1 to h18; and the output layer consists of 1 layer, o4, each of which is a group of colors ranging from green, red tinge, red, and dark red.

3.10 Validation of Artificial Neural Networks
The validation was done to test whether the network had been able to classify chili samples correctly. This required a group of test data with a known target (color group). This test data was taken from 47 chili samples that had been prepared for testing. The chili sample used as test data was not the same as the sample used for network training. The test data was then simulated with the same algorithm as the learning process, but weights and biases were not obtained randomly but rather by using stored weights and biases generated from the previous learning process. The results of the chili quality classification
by the network were then compared with known target data. Subsequently, it would be known if the network was either able or unable to classify inputs correctly. The test results showed the accuracy of 90.43%.

4. Conclusion
The color elements of the image that become the identity for the chili quality classification were red, green, a*, and intensity. The network architecture system was formed with 3 layers. The input layer consisted of 4 input nerve cells, the hidden layer consisted of 9 nerve cells activated, and the output layer consisted of 1 nerve cell in the form of a color group. Graphic User Interface (GUI) program which was designed based on ANN architecture was able to classify red chili color groups with an accuracy level of 90.43%.

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