Analysis of cassava chip image characterization during drying process

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Abstract. Monitoring method during food processing is an indispensable activity in the industry of food processing. A digital image processing technique is one of the methods to process images into information in the form of product physical condition. This study aimed to monitor the changes in cassava chips image characteristics through the images along the drying process. The image characteristic i.e covered color, texture, and area. The images were captured by using Webcam type Logitech C525 8.0 megapixel autofocus per minute. Then, the result of these images was processed to get color data of R, G, B, H, S, I, L, a*, b* and the texture i.e. energy, homogeneity, contrast, entropy, and to identify chips size was processed by the number of pixels of the image. While the data about the mass changes along the drying process were taken per minute from a digital scale. The results of this study showed that the length of drying made the value of R, G, B, H and I decreased, but the value of S contrastively increased. The area or the number of image pixels declined dramatically in 1 hour of drying, later (after one hour of drying) the decline was almost zero.

1. Introduction
Cassava (Manihot esculenta Crantz) is the third most important source of calories after rice and maize in tropical regions. In Africa, Asia, and Latin America, millions of people depend on cassava. Cassava can be preserved in the form of chips to make it more durable in storage and to facilitate selling as well as transporting. Chips are made in irregular slices of various sizes, but the size should not exceed 5 cm to enable them to be stored in silos. Cassava chips are widely produced in Thailand, Malaysia, Indonesia, and parts of Africa [1].

The process of cassava into chips is through a drying process. During the drying process, the cassava characteristics such as its moisture content, its colour, its texture, and its size change. The process is terminated by considering the expected quality based on the physiochemical characteristics. Digital image processing technique or machine vision is one of the techniques to be used for monitoring the characteristics of product directly along the processing.

Recently, the digital image technique has been widely used to evaluate the quality of agricultural and food products because it is fast, reliable and easy. Whereas manual judgment has some subjective weaknesses such as inconsistency and subjectivity. [2] used image processing technique to evaluate the quality of food using a camera, ultrasound, magnetic resonance imaging, computed tomography, and electric tomography for image acquisition. Color is one of the important components in the quality of the product. [3] conducted research on the grade of tomatoes and Kepok bananas based on the skin colour; [4] on the classification of avocados [5] [6] [7] used digital images to predict fruit weight based
on the number of pixel images on mangosteens, the identification of free fatty acids in the palm fruits, total carotene of palm fruit [8], [9] found the color change on tomatoes due to the damage in the transportation process. Evaluation on food products was carried out by [10] who evaluated snak pellet characteristics. Grain foods [11].

The meaning of texture into process images is completely different from agricultural or food products. Image textures can be defined as set of spatial various types of images, such as the spectrum of visible and infrared spectra [12]. These features provide a summary of information that is defined from the map of intensity image which is related to visual characteristics (texture roughness, regularity, presence of special directions, etc.). Texture analysis has been used to analyze the surface of agricultural products.

Some researchers have studied the physical characteristics of foods such as color appearance, brownish area and oily areas on the surface, image textures etc. by using image analysis techniques, such as [13] for chips, [14] studied for French fries, [15] for Cabbage, oranges, apples, grapefruit and tomato seeds, [16] for beef, [17] for apples, [18] for fries, [19] and [20] for potato chips; [21] for pizza, [22] for beef, [23] for the avocado, [24] for meat, [25] For hazelnut. However, there is no recorded data on the analysis of snack-light images of pellets. Therefore, the aims of this study are: (i) to evaluate the intensity potential of L*a*b*, (ii) image texture information i.e energy, contrast and entropy to identify the quality of cassava chip.

2. Material and methods

2.1. Equipment and materials

The material used in this research was white cassava. While the tools used were a shelf-type dryer that was equipped with some Machine vision tools. Logitech C525 8.0 megapixel auto focus webcam was used to capture image.

![Figure 1. Dryer with machine vision.](image)

2.2. Research procedure

The Cassavas for the sample was purchased from a seller in Malang, Indonesia. Before the cassavas were used in this study, they were washed thoroughly in running water to remove the dirt, then they were chopped into the form of chips with a thickness of 1 mm. After the process of chopping, the cassava
chips were soaked for 10 minutes and dried in open water to make their moisture content balance. The initial moisture content was measured using an oven set at 105 °C for 24 hours. The tray dryer used in this research was set at 70 °C. It was equipped with a camera to record the physical changes of cassava chips every one minute. The dryer was equipped with a scale above to measure the weight changes. The changes of numbers on the scale were recorded in accordance with the time of chips' recording. The drying process went on until the moisture content reached 10% wet base.

2.2.1. Moisture content analysis
a. Balancing the sample mass (m₁)
b. Comparing the final mass of sample (m₂)
c. Calculate the moisture content using the following formula:

\[
\text{Moisture content (\%)} = \frac{m_1 - m_2}{m_1} \times 100\%
\]

2.2.2. Image analysis. The image of cassava chips was taken by a webcam put in the drying chamber. The webcam was placed 15 cm above the object to record the changes in moisture content per one minute. The image record was in Bitmap format (.bmp) with the resolution, which is 316 x 236 pixels. The actual image of the chip was separated from the background, processed and segmented in the same procedure. Removing the background outside the selection permits clear visualization of the selected object [26].

2.2.3. Image color analysis. The intensity of color was measured by using RGB (Red, Green, Blue), color models. RGB color components were directly obtained from the color image readings. The RGB color model can be transformed to the HSI colour model based on the following formula [27]:

\[
I = \frac{(R + G + B)}{3}
\]

\[
\cos H = \frac{2R-G-B}{\sqrt{(R-G)^2 + (R-B)(G-B)}}
\]

\[
S = 1 - \left[3 \times \min(R, G, B) / (R + G + B)\right]
\]

In converting RGB color model to L*a*b*, firstly RGB was converted to XYZ, then XYZ was converted to L*a*b*. Here is the conversion equation from XYZ index value to L*a*b*:

\[
\text{var}_X = X / 95.047
\]

\[
\text{var}_Y = Y / 100.000
\]

\[
\text{var}_Z = Z / 108.883
\]

\[
\text{CIEL} = (116 \times \text{var}_Y) - 16
\]

\[
\text{CIEa} = 500 (\text{var}_x \times \text{var}_y)
\]

\[
\text{CIEb} = 200 (\text{var}_Y \times \text{var}_Z)
\]

2.2.4. Image texture analysis. The measurement of texture in this study used four features introduced by [12], namely: Energy, Contrast, and Entropy. The Measurement was made on a window having the same size as the window used to measure color intensity. The energy was calculated based on the following formula:
Energy = $\sum \sum p^2 (i, j)$ \hspace{1cm} (11)

The contrast was calculated based on the following formula.

Contrast = $\sum_{n=0}^{N_g} n^2 \left\{ \sum_{i=1}^{N_g} \sum_{j=1}^{N_g} p (i, j) \right\}; |i - j| = n \hspace{1cm} (12)$

Entropy was calculated based on the following formula:

$\text{Entropy} = - \sum \sum p(i, j) \log p(i, j) \hspace{1cm} (13)$

where:
- $i$ and $j$: the gray nature of adjacent 2 pixel resolution
- $p(i, j)$: the relative frequency of the matrix of adjacent 2 pixel resolution
- $n$: absolute differences $i$ and $j$
- $N_g$: number of different gray characteristics on the image calculation

2.2.5. The number of image pixels analysis. The number of image pixels analysis aimed to detect the area of the cassava chip. Firstly, it was done by converting the color image into the binary image to distinguish between object and background through thresholding process with certain values. The object was in white, while the background was black. Then the process of labeling was done to find the object with the largest area, the center of the object was then determined, the calculation of the area was done by counting the number of white pixels (objects). The area was shown by the number of pixels belonging to the mangosteen fruit. The calculation used the following formula [28]:

\[ A = \sum \sum O(x, y) \hspace{1cm} (14) \]

where:
- $A$: the area of the object
- $O$: point of object in binary image
- $x$ and $y$: locations in an array or image field

3. Results and discussion

3.1. The effect of the length of drying on the decrease of moisture content

The data on the decrease of moisture content in the drying process were taken from the beginning of drying until reached 10%.

![Figure 2. Moisture content during the process of drying.](image-url)
Figure 2 shows the decline of moisture content was relatively fast in the first 60 minutes because the free water contained in the chips was high at the beginning of drying. On minutes 60th-140th, the declining of the moisture content was slower because the vaporized from the chips was physically bound water. After that, the decline of moisture content was relatively small because the water vaporized was water that was physically and chemically bound. Sanni et al. 2016 [29] explain dried cassava flour with a temperature of 140 °C, the airflow of 0.03 m³/s, it took 50 minutes to reach 10% moisture content. Wankhade et al., 2013 [30] reported that the moisture content of okra slices decreased until minute 60th using a temperature of 90 ° C sharply. While on the drying of guava slices using a microwave, the moisture content decreased very rapidly during the early stages of drying due to the rapid release of water vapor from the surface of the product [31].

3.2. The effect of the length of drying on the changes in colour

The data of colour was captured by using an online video camera during the drying process, but the recorded data were taken per minute.

![Figure 3. The values of R, G and B along drying.](image)

The changes of color values R, G, B along drying procession cassava chips had the same trend. After minutes 26th, there was a sharp changes in the color value. Later, the changes was stable relatively (figure 3). This change was related to the decrease of the chips moisture content (see Figure 4). Figure 4 (A) represents the chips colour before minutes 26th, while image 4B shows chips colour after minutes 26th. The same trend was also stated by [32], on the drying of two varieties of bananas, the changes of colour was closely related to changes in moisture content during drying.

![Figure 4. The changes of chip characteristics during drying.](image)
Figure 5. The values of L, a*, and b* during drying.

Figure 5 showed that significant decrease in L value after minutes 30th. The L value was a whiteness or brightness indicator. The longer the drying, the chip's brightness decreased, and the L value was stable after minute 47th. Study conducted by Abdullah et al. [33] showed that the tortillas chips darkenned after being processed and dried. This brightness value might also be influenced by the amount of moisture content in the chip. At the beginning, the chip had a higher moisture content, the brightness was also higher. It was visually seen in figure 6. Initially the chips looked brighter than after they were dried for 1 and 2 hours. A research on the the brightness of L* banana using laser backscattering drying was conducted by Romano et al. [34]. The result showed that L* brightness became the most sensitive parameter to describe the rate of color change among treatment on banana drying. Behroozi et al.[35] stated that the decrease of L* value related to the length of grape drying. The L* value decreased from 35 ± 1 to about 16 ± 1.5.

Figure 6. The changes of chip brightness level (a) 0 hour, (b) 1 hour, and (c) 2 hours.

The increase of value of a* was related to the length of chip drying time. The result showed that the length of drying made the colour of the chips moved towards redness. While the value of b* during
drying was same relatively, it means the colour of the chip is not yellow or blue color because the value of + a* (positive) from 0 to +80 for red color and the -a* (negative) value from 0 to -80 for green, the value of + b* (positive) from 0 to +70 for the yellow color and the -b* (negative) value from 0 to -70 for blue [31]. According to Suyatma [36], the value of L a* b* carrots after drying looked different. Chroma components a* and b* between fresh carrots and drying process carrots was different. It showed the degradation of carrot color pigments during drying, especially carotenoids. There was difference of chroma (ΔC*) on fresh and dried carrots. Nahimana et al. [37] and Doymaz et al. [38] reported a L* value of approximately 18 ± 1.5 for dry grapes at different temperatures. The values of b* decreased from 7.4 to 2. The colour changes might occur due to enzymatic or non-enzymatic reactions during the drying process. The best L value on nectarine drying was 69.91 while the a* and b* were 11.39 and 30.64 [39]. While the dry lemon slices value ranges were 39.92-43.39, 4.68-5.96, and 12.58-16.12 for each L, a*, and b* [40].

![Figure 7. The values of hue, saturation and intensity during drying.](image)

The HSI model is a closest system to the work of human eye. H describes the pure color, S describes how the degree of pure color softened, and I combines color information from H and S [41]. While [42] explained that the quantitative saturation was a representative distance of the object point to the white color. So, the more saturated the colour (closer to white point) the higher the saturation. The value of I decreased along with the length of drying since the I value corresponded to the RGB value. According to Ahmad [27], the value of the intensity of an image was the sum of the RGB value divided by three. A research conducted by [43] on tomato slices showed that the value of Hue decreased after the tomato slices was dried, the possibility of browning process is lower.

Figure 7 showed that the Hue value (H) and the saturation value (S) rose based on the length of the chips drying process. It means that the white color of chips faded from the initial color when the drying process is longer. The effect of heat that occurs on the chip makes the saturation value decrease in the 20th minute with a value of 0.054 and starts to stagnate at the 40th minute with a value of 0.086. Stagnant values occurred at 40 to 200 minutes because the basic color of the cassava chip was white and there was no significant change in color to darker. Saturation is usually a value from 0 to 1 (or 0 to 100%) and denotes the grayish value of the color where 0 indicates gray and 1 indicates a pure primary color.
3.3. The effect of the length of drying to the changes on image texture

The data on texture changes were processed from the images generated by video cameras were taken online along the drying process, but the recorded data were taken per minute. The values of energy, entropy, and contrast along drying are shown in Figure 8.

Energy measures presented the statistical feature for the texture with the threshold value for each image; the mean value presented the intensity of the image, and the high value means the image is bright if it is low means that the image is dark. The entropy gives indication about the number of grey level value in the image. It gives information about the randomness of the distribution of grey level pixel. When the entropy is high, the number of grey level is high. The energy is inversely proportional to the entropy it decreases as the number of grey level in the image increases. Images that have low contrast can occur due to lack of lighting, lack of dynamic field of the image sensor [44].

Energy, which measures the uniformity of the image texture. Energy is a type of feature that is used to see the level of texture uniformity. The higher the energy value, the higher the level. The energy parameter is opposite to entropy. Energy on the cassava chip decreased in the 40th minute. The energy value decreases because decrease in chip surface homogeneity. The Contrast feature shows variations in intensity between images, where the higher the contrast value, the more varying the intensity value in the image. The entropy feature is a feature that provides information about the coarse or fine texture. The higher the entropy value, the coarser the texture in the image. Figure 8 shown that the higher the drying temperature, the higher the entropy value of the cassava chip. Drying produces texture changes on the surface of the chip image.

3.4. The effect of the length of drying to the changes on the number of pixels

The data on the changes of pixel or area is data about the changes on cassava chips number of pixel due to the changes on chips volume along the drying process.
Figure 9. The number of pixels during drying.

At the first minute, number of cassava chip pixels before drying treatment was 44,000. During drying time, in the 10th minute, the number of pixels decreased to 41,000. This indicates the shrinkage of the area due to reduced water content. Until the 50th minute, it continued to decline by 27,000. However, minutes to 60-200 the number of pixels does not decrease. Therefore shrinkage occurs at 0-50 minutes.

The length of the drying process decreased the chips number of pixels. It was due to the shrinkage of the chips area. The number of pixels could predict the chips area during drying. A research conducted by [7] showed that the number of pixels could predict the diameter of the mangosteen fruit with \( R^2 \) of 0.9326 and it could predict the weight of the mangosteen fruit with \( R^2 \) of 0.9236.

4. Conclusions
Digital image could analyze the characteristics of cassava chips during drying process. The characteristics to be analyzed were: the colours of RGB, L a* b* and HSI; four image textures covering energy, entropy, and contrast. The characteristic of chips area changes during drying and moisture content change could also be analyzed using digital image.

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