Accuracy in estimating visual quality parameters of mango fruits as moving object using image processing

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Abstract. Mango fruit grading in Indonesia is still done manually with low capacity and less accurate results. A conveyor mechanism with a camera as an evaluation tool can be used to increase the capacity and accuracy of grading. However, the image quality captured by the camera decreases with a moving object. The purpose of this study was to evaluate the accuracy of estimating mango quality parameters by image processing using images captured by a camera at different conveyor speeds. The results of the RGB color analysis of mango images captured from a moving conveyor at three different speeds were compared with the results of the same still images. The average error of the color analysis for low, medium, and high speeds were; red color index 3.56%, 4.76%, and 6.27%, green color index 2.39%, 3.66%, and 3.95%, while blue color was not considered due to its inferior compared to the red and green colors. For HSI color model, the results were; hue values 2.13%, 3.35%, and 3.56 %, saturation values 8.98%, 12.15% and 15.26%, intensity values 15.48%, 23.89% and 17.84%. Meanwhile, the estimated error rates for the projected area for low, medium, and high conveyor speeds were 2.34%, 2.83%, and 4.78 %.

1. Introduction
Mango is a tropical fruit that is rich in nutrients and vitamins, and popular in various parts of the world so that the demand for export quality mangoes is continuously increasing. Production of various fruits in Indonesia shows mango as the second-largest volume after bananas. Indonesia has set mango as one of the mainstay commodities for horticultural agribusiness development. One of the most popular mangoes on the international market is gedong gincu because of thick fruit flesh, a combination of fresh sweet-sour taste, fragrant aroma, size that is not too large, a lot of water content, and has an attractive color. Abundant production of mangoes certainly requires good management of postharvest handling and distribution to produce high-quality mangoes. Based on the variety, the weight size of the mango is classified into four, namely large, medium, small, and very small. Gedong mango is said to be large if it weighs more than 250 g, medium if it weighs 200-250 g, small if it weighs 150-199 g, and very small if less than the latter [1]. Sometimes the quality requirements are still added based on market demand (exporters or supermarkets). Mangoes for export have more quality requirements than for the domestic market. Several mango quality requirements for export are to have smooth skin surface (no spots, no holes, and no black color at the base of the fruit), free from injury (mechanical or microbiological injuries), free from postharvest diseases, and normal form [1]. The criteria for fruit to
export are still said to be smooth is the black stain on the surface of the skin is the dried sap stain (maximum 5% of the total surface of the rind). It also explained a number of additional quality requirements for exports, namely physiologically ripe, 30-50% yellow or red color depending on variety, evenness in ripeness level, and almost uniform in size and weight [2] [3].

The problem for export trading of mangoes from Indonesia is caused by high variation in the variety of mango fruits, maturity levels, and sizes as well so that the quality is not uniform. In order to compete in the export market, exporters must select high quality and relatively uniform mangoes to export. The good quality mangoes do not only depend on cultivation methods but also are determined by the applied postharvest handling activities, especially the sorting and grading processes. Large scale traders and industry activities require accurate and fast sorting and grading processes. The sorting and grading processes conducted manually produce high diversity, less consistent products, and relatively time-consuming. This is due to many factors that influence the activity such as human fatigue, diversity of human visual abilities, and different perceptions about the quality of the products. Therefore more robust and reliable methods are needed, and one of the possible methods is to use an automatic sorting and grading system with high accuracy and relatively fast. One visual system that can be used to develop the method is to utilize image processing technology to estimate the quality parameters of gedong mangoes based on their size and skin color.

Digital image processing is a process that aims to manipulate and analyze images with the help of computers. The process of analysis in image processing involves visual perception with input data and output data obtained in the form of images of the observed objects. Image processing techniques can include several aspects such as image sharpening, protrusion of certain features of an image, image compression, and correction of images that are unfocused or blurred [4]. The image input tool used is usually a CCD (charge-coupled device) or CMOS (complementary metal-oxide-semiconductor) camera, where the image sensor of this tool produces analog image output so that the digitization process is required by using the digitizing tool [5] or using a digital camera which can be directly connected to a computer. Image processing can be used for the analysis of shapes, colors, and dimensions of objects such as fruits. There are several color models commonly used in digital image processing, namely the RGB (red-green-blue) color model, the CMY (K) (cyan-magenta-yellow-black) color model, and the HSI (hue-saturation-intensity) color model. Color is the spectrum contained in a light, and the color is determined by the wavelength of the light reflected by the object and its intensity. Color information is needed as a description of an object in the process of analyzing an image. The process of identifying and extracting objects in an image can be simplified by including color information. The human eye also distinguishes objects from the colors and intensity of colors received [6].

Until now, the determination of the quality of the gedong mango is still done visually using naked eyes in the manual grading activity. There are some studies on the evaluation of the external quality of mangoes using optical means technology. HunterLab color values were used to predict the ripening process of mangoes [7]. Soluble solid content of mangoes for sweetness level can be predicted using color space values, also measured using HunterLab colorimeter combined with multiple linear regression, principal components regression, and partial least squares regression analysis [8]. In the other case, the change in maturity level of mangoes can be monitored using a computer vision system based on hue angle measurement [9]. Concentration of anthocyanin in mango also was predicted using hyperspectral imaging combined with partial least squares regression analysis [10]. The last, mangoes can be graded based on the red area on the surface of the fruit to imitate the grading process conducted by a human with the naked eye, was also reported [11]. However, all researches mentioned above were conducted on unmoving objects, whereas an image captured by a camera could lose the details in images for moving objects depend on the speed of moving objects.

The use of cameras and belt conveyors in the process of sorting and grading mangoes can increase the speed of the process. However, different speeds of conveyors can cause inconsistencies in the results of image analysis of mango, normally resulting in a decrease in the accuracy of quality parameters assessment. Therefore, it is necessary to calculate the decrease in the accuracy of image processing results on the moving mango fruits according to the speed of the belt conveyor, where the fruit is placed, and its image is captured by the camera. The purpose of this study was to evaluate the
quality of a moving mango on a belt conveyor using a camera and image processing and to find out the level of accuracy of the estimated visual quality parameters of mango fruits at an increased belt conveyor speed.

2. Materials and Method
The research was carried out in the Postharvest Laboratory, Department of Mechanical and Biosystem Engineering, Faculty of Agricultural Engineering and Technology, IPB University, starting from August to November 2017. The main materials used in this study were the gedong mango collected from CV Sumber Buah in Cirebon, West Java Province. A total of 150 samples were used to evaluate the quality of the gedong mango which were placed on a belt conveyor in a state of rest and moving at three different speeds: low, medium, and high speed.

The tools used in this study include a Microsoft LifeCam Studio Win Q2F-00017 USB type camera with 1080p HD specifications, four LED lights with 3W of power (120-240V), a belt conveyor, and a set of computers where the camera was attached.

The study was conducted in several stages; image processing software development, preparation of tools and materials, video capturing and recording, image processing, and data analysis. Image data was obtained from recording video in a state of rest and moving conditions on a belt conveyor with variations in the speed of the belt conveyor when it is moving. Three different speeds were applied to the belt conveyor, 0.080 m/s for low speed, 0.164 m/s for medium speed, and 0.294 m/s for high speed. Data as results of image processing in the form of visual quality parameters of gedong mango such as RGB color index, HSI color value, and the area of projection of gedong mango were analyzed and compared for each recording condition.

2.1. Image processing software development
Two simple software were built using SharpDevelop 5.1 RC as a platform for developing image processing programs. One program was used for video recording of mango fruits, and another one was used for capturing frames with single mango image and quality parameters evaluation.

![Figure 1. Gedong mangoes used in the research](image1)

![Figure 2. Apparatus for image and video acquisition](image2)

2.2. Samples preparation
A number of freshly harvested gedong mangoes with different levels of maturity (to get different sizes and skin colors) were purchased from collectors in Cirebon, West Java and packaged using cardboard boxes that have been layered with styrofoam and used newspaper to reduce shocks during the trip so that the fruits did not experience bruises. After arriving at the laboratory, the packaging was opened, 150 pieces of mango gedong are selected and cleaned of dirt, and then each fruit was given a number (figure 1). Then the gedong mango was weighed using a digital scale and recorded its weight for each fruit individually. Meanwhile, we prepared the image data acquisition system (figure 2) that consists of as follows: a digital camera with 1080p HD specifications for video recording as an image capture
device mounted 12 cm above the belt conveyor, four LED lights with 3W of power (120-240V) with a total of 1400 lux as a lighting tool placed around the camera in a box made of multiplex coated with melamine as a barrier to entry of light from outside, a belt conveyor with adjustable speeds, and a set of computers with applications that have been built to record and analyze video and still images.

2.3. Video capturing and recording
Video of mango was captured and recorded using a camera connected to a laptop via a USB connection. The camera was placed in a box equipped with four 3W LED lamps on the belt conveyor facing the mango, which was placed on the top of the belt conveyor. Recording of the video of the mango was done four times when the belt conveyor was not moving and when the belt conveyor was moving with three different speeds, namely low, medium, and high. Recording of the video without moving of belt conveyor served as a reference for the image with standard quality. The conveyor belt used was purposely assembly, where its speed was able to be adjusted as needed. The belt conveyor has the following general specifications, the length of the belt was 200 cm with a width of 30 cm, the chain and sprocket transmission system with an electric motor as its driving, and there was an inverter as a motor speed regulator to get the desired conveyor speed.

The results of video recording were then used for the capturing process on each fruit sample for each conveyor speed to simulate real-time and continuous image capturing from the camera. Capturing images from zero and three different conveyor speeds were used as image data. The images were then analyzed to determine the accuracy in estimating the quality parameters of gedong mangoes based on the color of the fruit skin and the area of projection (area) of the fruit body above the conveyor at each speed. The image recording tool scheme can be seen in figure 3 and the construction of the fruit image recording chamber can be seen in figure 3. As a background in direct image recording, a tire made of a white belt conveyor was used.

![Figure 3. construction of the fruit image recording chamber](image)

The image recording procedure is as follows; first, the mangoes were placed on a belt conveyor as the background, and the focus of the camera was targeted on the fruit. Next, the image recording was conducted with a resolution of 744 x 480 pixels, which was carried out for all samples. After recording the still image of mango fruits one by one, the recording was repeated for video recording at slow conveyor speed until all samples have been recorded. Then the same procedure was repeated for the other two conveyor speeds, which are medium speed and high speed. The still images were used as references as they gave the best image quality in terms of sharpness and color if compared to streaming video, which has a blurring effect when the object was moving. The blurring effect is bigger for higher speed.

2.4. Image processing
Image processing was carried out using a computer program that has been built in advance with the SharpDevelop 5.1 RC software development kit. The program that was built was then used to analyze the quality characteristics of mango images based on the RGB and HSI color parameters, and the
projection area of the mango fruit to estimate different fruit sizes. The program has the ability to calculate the value of the percentage of red intensity, green intensity, and blue intensity of the RGB color model, also the hue value, saturation, and intensity of the HSI color model, and the projected area of mango fruit.

3. Results and Discussion
The average conveyor speed of 0.080 m/s for low speeds, 0.164 m/s for medium speeds, and 0.294 m/s for high speeds were calculated from known rotating speeds of electric motor controlled by inverter. The lower and upper speeds were chosen for conveyor stability at the minimum and maximum speeds, while the middle speed is about in between the two speeds. As a result, the speed increased 105% from low to medium speed, while from medium to high speed, the speed increased 179%. The image and video capturing and processing results in accuracy were decreasing because increasing in speed for moving object causes increasing blurring effect that change values distribution in pixels on the capturing image. The process of recording the video of mango on the conveyor, captured images, and the developed program to analyze the images, can be seen in figure 4.

![Figure 4. The recording process and the result; (a) moving mango under the camera, and (b) captured mango images (b)](image-url)

It was obvious that the capacity of the belt conveyor in conveying the fruits was increasing with the increase of conveyor speed. By calculation, the speeds of conveyors to convey mangoes is 0.080 m/s for low speed, 0.164 m/s for medium speed, and 0.294 m/s for high speed. The desired capacity of the belt conveyor itself depends on the number of mangoes that need to be processed every day at each exporter or mango collector so that in the process of deciding on a conveyor belt, it can be adjusted to the required speed. In this experiment, low conveyor speed has average travel time for a distance of 0.25 m or in 3.14 seconds per mango, resulting in 150 fruits for 7.87 min or about 19 fruit/min. The medium-speed has an average travel time of 1.53 seconds for the same distance or per mango, resulting in 150 fruits for 3.82 min or about 39 fruit/min. For high-speed conveyor, the average travel time for the same distance or per mango for 0.85 seconds with a total travel time of 150 fruits for 2.14 min or about 70 fruit/min. The capacities of the three conveyor speeds are higher when compared to the manual method which, on average, has a working capacity of 12 fruit/min for one experienced worker. This comparison is important since one of the purposes of applying machinery in agricultural activities is to speed up the process and finally increase productivity. The sorting process itself includes cleaning, estimating weights, packaging, and grading manually using human visuals.

3.1. Image processing algorithm
The results showed that there were differences in image quality in the aspects of saturation, intensity, and contrast in each image taken from different conveyor speeds. There were seven visual parameters used as a comparison to determine the accuracy of the quality parameters evaluation for gedong.
mango. The comparison for color parameters are index values of red, green, and blue, and the components of hue values, saturation values, intensity values. The size of the fruit was represented by the projection area of fruit, which is usually said area for short. Furthermore, the image processing and quality parameters calculation were carried out using the program that has been built in advance for the seven quality parameters evaluation.

3.2. RGB color processing
The results of image processing show that the red color index of mango fruits taken from the unmoving belt conveyor ranged from 0.432 to 0.656 with an average of 0.523, while that at low, medium, and high conveyor speed, respectively, ranged from 0.408 to 0.668 with an average of 0.526, 0.398 to 0.665 with an average of 0.522, and 0.420 to 0.683 with an average of 0.505.

![Figure 5](image.png)

*Figure 5.* Magnitude of error distribution for color extraction from mango images captured at low, medium, and high speed conveyor; (a) red color for low speed, (b) red color for medium speed, (c) red color for high speed, (d) green color for low speed, (e) green color for medium speed, dan (f) green color for high speed

When compared with the results of the analysis at unmoving belt conveyor as a reference, the results of the analysis at low speed had an average error for the red color index value of 2.79%, while at
medium conveyor speed an average error was 4.04%, and at high conveyor speed was 5.87%. This can be caused by differences in image quality and contrast due to the effect of blurring caused by increasing conveyor speeds. The results of measurements of the green color index of mango fruits taken from the unmoving belt conveyor ranged from 0.328 to 0.526 with an average of 0.446, while that at low, medium, and high conveyor speed, respectively, ranged from 0.321 to 0.523 with an average of 0.438, 0.307 to 0.537 with an average 0.439, and 0.304 to 0.559 with an average of 0.436. When compared with the results of the analysis at unmoving belt conveyor as a reference, the results of the analysis at low speed had an average error for the green color index value of 2.18%, while at medium conveyor speed an average error was 2.98%, and a high conveyor speed was 3.57%. All the above results displayed in the graphs, as shown in Figure 5. Blue color was not considered due to its inferior color compared to the red and green components.

![Figure 5](image)

**Figure 5.** Magnitude of error distribution for color extraction from mango images captured at low, medium, and high speed conveyor; (a) hue component for low speed, (b) hue component for medium speed, (c) hue component for high speed, (d) value component for low speed, (e) value component for medium speed, dan (f) value component for high speed

### 3.3. HSI color processing

The measurement results for the hue values on the mango fruit images taken from the unmoving belt conveyor ranged from 29.253 to 69.243 with an average of 51.986, while that at low, medium, and
high conveyor speed, respectively, ranged from 28.549 to 69.826 with an average of 51.210, 26.333 to 73.208 with an average 51.773, and 26.357 to 73.208 with an average value of 52.546. When compared with the results of the analysis at unmoving belt conveyor as a reference, the results of the analysis at low speed had an average error for the hue values of 2.00%, while at medium conveyor speed an average error was 3.10%, and at high conveyor speed was 3.51%.

The results for saturation values in the mango fruit images taken from the unmoving belt conveyor ranged from 0.791 to 0.949 with an average of 0.905, while that at low, medium, and high conveyor speed, respectively, ranged from 0.622 to 0.974 with an average of 0.893, 0.625 to 0.978 with an average 0.885, and 0.623 to 0.981 with an average of 0.823. When compared with the results of the analysis at unmoving belt conveyor as a reference, the results of the analysis at low speed had an average error for the saturation values of 6.85%, while the medium speed has an average error of 9.77%, and at high conveyor speed was 13.97%. All the above results displayed in the graphs, as shown in Figure 6, while the correlations of all conditions are displayed in the graphs, as shown in Figure 7.

![Figure 7](image_url)

**Figure 7.** Magnitude of error distribution for color extraction from mango images captured at low, medium, and high speed conveyor; (a) hue component for low speed, (b) hue component for medium speed, (c) hue component for high speed, (d) value component for low speed

### 3.4. Area projection

The results for area projections in the mango fruit images taken from unmoving belt conveyor were ranging from 43686 to 90278 pixels with an average of 67953 pixels, a while at low conveyor speed were ranging from 44144 to 92014 pixels with an average of 68004 pixels, at medium conveyor speed...
were ranging from 44747 to 96085 pixels with an average of 68814 pixels, and at high conveyor speed were ranging from 41915 to 96517 pixels with an average of 68884 pixels. When compared with the results of the analysis at unmoving belt conveyor as a reference, the results of the analysis at low conveyor speed had an average error for the projection area values of 1.19%, while the medium conveyor speed has an average error of 2.39%, and at a high conveyor speed of 3.98%.

Analysis of the relationship between area projections of the mango fruit (pixel) with the actual weight of the mango fruits (g) obtained by weighing, the values of determination coefficients are 0.955 at the unmoving belt conveyor, 0.952 at low conveyor speed, 0.908 at medium conveyor speed, and 0.850 at high conveyor speed, as shown in figure 7. According to Hasan (2003), the coefficient of determination value more than 0.70 has a high level of correlation, which means that the relationship between the projected area (pixel) of the mango fruit with the mango weight (g) has a high correlation in all conditions, but the accuracy is decreasing as belt conveyor moving at higher speeds.

4. Conclusions
When compared with the results of the analysis of the quality parameters of the mango fruit image recorded from unmoving belt conveyor, the average value of the calculation of the red index error rate at low speed was 3.56%, at medium conveyor speed was 4.76%, and high conveyor speed was 6.27%. For the green index, the error rate at low conveyor speed was 2.39%, at medium conveyor speed was 3.66%, and at high conveyor speed was 3.95%. For hue values, the error rate at low conveyor speed was 2.13%, at medium conveyor speed was 3.35%, and at high conveyor speed was 3.56%. For saturation values, the error rate at low conveyor speed was 8.98%, at medium conveyor speed was 12.15%, and at high conveyor speed was 15.26%. For the intensity value, the error rate at low conveyor speed was 15.48%, at medium conveyor speed was 23.89%, and at high conveyor speed was 17.84%. For the projected area of the fruit, the error rate at low conveyor speed was 2.34%, at medium conveyor speed was 2.83%, and at high conveyor speed was 4.78%. Based on the data above, all the color components can be used in analyzing the quality parameters of gedong mango on a conveyor belt, with a small decrease in accuracy with the increase of conveyor speed. The relationship of the mango fruit projection area with the weight of the mango fruit, the coefficient of determination were 0.955 at the unmoving belt conveyor, 0.952 at low conveyor speed, 0.908 at medium conveyor speed, and 0.849 at high conveyor speed, which means still good even at the highest conveyor speeds tested.

5. References
[1] Satuhu S. 2000. Penanganan Mangga Segar untuk Ekspor (Handling of fresh manggoes for export). Jakarta (ID): Penebar Swadaya.
[2] Kader AA. 1992. Preventing of ripening in fruits by use of controlled atmosphere. Food Technology, 34(3):51-54.
[3] Quane. 2002. Preventing of ripening in fruits by use of controlled atmosphere, Food [4] Ahmad U. 2005. Pengolahan Citra Digital dan Teknik Pemrogramannya. Yogyakarta (ID): Graha Ilmu.
[5] Suhandy D, Ahmad U. 2003. Pengembangan algoritma image processing untuk menduga kemasakan buah manggis segar. Jurnal Keteknikan Pertanian (JTEP). 17(2): 29-38.
[6] Purnomo M, Muntasa A. 2010. Konsep Pengolahan Citra Digital dan Ekstraksi Fitur. Yogyakarta (ID): Graha Ilmu.
[7] Malevski, Y., Gómez, B.L., Peleg, M. and Silberg, M. (1977) External Color as Maturity Index of Mango. Journal of Food Science, 42, 1316-1318. http://dx.doi.org/10.1111/j.1365-2621.1977.tb14486.x
[8] Jha, S.N., Chopra. S. and Kingsly, A.R.P. (2007) Modeling of Color Values for Nondestructive Evaluation of Maturity of Mango. Journal of Food Engineering, 78, 22-26. http://dx.doi.org/10.1016/j.jfoodeng.2005.08.048
[9] Kang, S.P., East, A.R. and Trujillo, F.J. (2008) Colour Vision System Evaluation of Bicolour Fruit: A Case Study with “B74” Mango. Postharvest Biology and Technology, 49, 77-85. http://dx.doi.org/10.1016/j.postharvbio.2007.12.011
[10] Makino, Y., Isami, A., Suhara, T., Goto, K., Oshita, S., Kawagoe, Y., Kuroki, S., Purwanto, Y.A., Ahmad, U. and Sutrisno (2015) Nondestructive Evaluation of Anthocyanin Concentration and Soluble Solid Content at the Vine and Blossom Ends of Green Mature Mangoes during Storage by Hyperspectral Spectroscopy. Food Science and Technology Research, 21, 59-65. http://dx.doi.org/10.3136/fstr.21.59

[11] Kikuchi, K., Nakamura, T. and Taira, E. (2011) Problems and Prospects Associated with the Mango Producing District in Okinawa – Towards Tropical Fruit Tree Branding. Agriculture & Forestry Statistics Publishing Inc., Tokyo.