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Mango Surface Color Features Measurement Using Digital Image Processing

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SUMMARY

Postharvest processing of agricultural produce is still done the conventional way in Bangladesh. Manual grading of agricultural produce, especially fruits and vegetables, is laborious and costly due to acute shortage of labor during the peak season, as well as difficulty maintaining the product quality. Machine vision system (MVS) applications are widely used nowadays as a non-destructive and cost-effective technology for automatically grading and sorting large volumes of produce in the packing house according to size, shape, color, texture, and surface defects. In this study, a simple MVS was constructed measuring different color features of mango fruit surface as a part of developing an automatic grading system. A CCD camera with a fluorescent lighting system was incorporated for acquiring images of mangos. Different color properties were extracted from the acquired images and analyzed. The best-suited color information (HSI model) was found so that the fruits can be separated from their background easily and differentiated. The measured color information will be further used for developing a grading algorithm based on different features of mango, further aimed to develop an automatic mango grading system.

INTRODUCTION

Mango (*Mangifera indica* L.) is one of the most common and popular fruits produced in Bangladesh. It is one of the most relished fruit crops covering the area 0.0376 million hectares, and the total production is 1.162 million MT, being in the second position after pineapple in Bangladesh (BBS, 2016).

In recent years, mango growers are exporting their products after meeting the local demand. In 2015, about 800 tons of mango were shipped to European countries. However, the quantity exported the following year dropped by 300 tons due to stringent safety blame in the importing countries (Sarkar, 2019). Though a substantial number of mangos are produced every year, post-harvest processing is still a conventional method which is difficult to maintain continuous customer satisfaction. Moreover, to raise its export market, it is important to ensure consistent quality in line with the requirements of foreign countries. Grading is one of the crucial tasks in post-harvest management where manual grading for a large number of fruits is inefficient, labor-intensive, and prone to human error. Furthermore, it is quite difficult to maintain the homogeneity of the graded fruits by the naked eye (Tabatabaeefar et al. 2000; Londhe et al., 2013). An efficient automatic grading system can improve labor productivity and maintain levels of quality.

Some mechanical grading systems based on size that were developed in past decades cause damage to the product surface and do not meet desired expectations in regard to quality. Additionally, in both manual and mechanical grading systems, the appearance and color properties are not considered and cannot reach their capacity (Razak et al., 2012). An alternative way to create an efficient grading system for agricultural produce is the application of a MVS coupled with an image processing technique.

MVS and image processing applications have been found increasingly in the food and agricultural industry for quality inspections and efficient grading (Sarkar, 2017; Brosnan and Sun, 2002; Blasco et al., 2007). MVS consists of a camera and suitable illumination which is incorporated with a digital computing device that enables one to inspect, evaluate, and identify target objects from acquired images or videos non-destructively, efficiently, and accurately. Ogawa et al., (2011) developed an MVS which can identify the fluorescence area on injured or defective citrus surfaces. Saad et al. (2016) reported that the quality of tomato fruits can be determined by using non-destructive MVS using image analysis. The surface color, size, shape, and firmness of mango fruits are dominant characteristics to determine their quality and maturity stages (Jha et al., 2006). Nandi (2016) developed an intelligent MVS for grading of mangos in four different categories according to maturity level in terms of actual-days-to-rot and quality attributes. The overall accuracy of the system was 87% to estimate maturity and quality. In consequence, a mango grading system based on ripeness by using an artificial neural network (ANN) and MVS was developed by Yossy et al. (2017).

Non-destructive postharvest processing technology combined with MVS and image processing capabilities is almost a new concept in Bangladesh agriculture, and there is a tremendous opportunity for academic, collaborative, and interdisciplinary research in this area. Based on private-sector initiatives, the agriculture industry in Bangladesh is rising very rapidly. However, inadequate post-harvest processing is a major constraint in encouraging high-value agro-business and marketing. To address this issue, developing non-destructive technology for the automatic processing of mango fruit will improve the supply chain efficiency and enhance the cost-effectiveness of the packaging process. Moreover, by installing this type of equipment, growers, traders, and processing plants can benefit directly to deliver high-quality produce to the ethnic and mainstream markets of the importing countries.

In this study, a simplified image acquisition system was constructed to acquire good quality images to measure surface color features of mango using an image analysis technique. The analysis of color features could provide an option for an efficient grading system of mangos.

MATERIALS AND METHODS

The study was conducted in the Precision Agriculture Laboratory at the Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh, Bangladesh (24°43'19"N, 90°25'36"E). Different varieties of mangos were collected with the variation of size and ripeness level from a local farmers market in the Mymensingh, Bangladesh during the harvesting period. The samples were washed manually by immersing them into water before image acquisition. To reach an equilibrium temperature, the fruits were stored in the refrigerator at 25°C for 24 hours. After discussion with local mango growers, vendors, and horticulturists, two standard grades, namely matured green and ripe mangos, were set based on color appearance. A total of 80 mangos (40 from each grade) were selected randomly for image acquisition.

For image acquisition, mangos were kept at a height of 22 cm from the lens to the surface of the mango. Camera parameters such as iris, shutter speed, gain, and gamma were adjusted with the trial and error method to acquire a good quality image. The acquired images were saved into computer memory for post-processing. An image of a steel ruler was also captured for measuring image field size and image resolution.

The image acquisition system used for this study was composed of a CCD camera (DFK 41AU0, Imaging Source, Germany), a computer (Intel® Core™ i3-2120 CPU@3.30 GHz), twelve fluorescent lamps (18 Watt each, Philips, China), and a steel frame covered with a black coated iron sheet. The layout of the image acquisition system is shown in Figure 1.

To adjust the focal length, a 6 mm lens was fitted in front of the camera. Additionally, to avoid the reflection of light on the fruit surface, a polarized film filter was placed in front of the lens. The camera was fitted with a mild steel bar. Also, three fluorescent lamps were placed at each side of the frame to ensure equal light distribution on the object surface. This controlled environment allows for acquiring images with minimum interference.

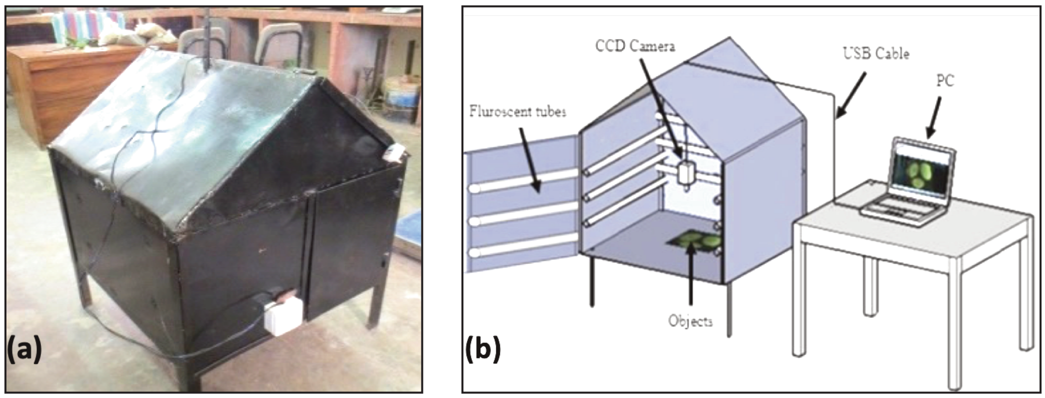

Figure 1. Constructed image acquisition system. (a) Photographic view, (b) Schematic view

The camera was connected to the desktop computer using USB 2.0 interface. Image acquisition and driver software (IC Capture, Ver. 2.3.382.1796, The Imaging Source, Germany) was installed on the computer. After adjusting different camera parameters (e.g. iris in full position, gain of 900 dB, gamma correction of 100 and shutter speed 1/15s) the images were acquired (Figure 2) and saved as in bitmap (BMP) format. The RGB (red, green, and blue; fundamental color components) values on the mango surface and image background were extracted from randomly selected regions of the acquired images. Image processing software WinROOF (Ver.5.7, Mitani Corporation, Japan) was used to extract the RGB values from the acquired images.

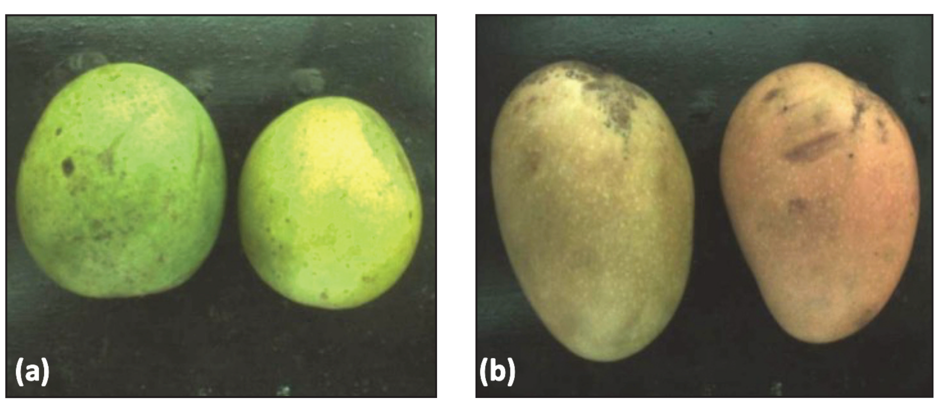

Figure 2. Acquired mango images. (a) Green mango, (b) Ripe mango

Extracted RGB information was then converted into HSI (Hue, Saturation, Intensity) using the color space conversion relationships described in (Gonzalez et al., 2009). For RGB to HSI conversion first RGB color space values were normalized by using Eqn. 1.

$$r = \frac{R}{R+G+B}; g = \frac{G}{R+G+B}; b = \frac{B}{R+G+B} \quad (1)$$

Where r, g, and b are normalized red, green, and blue values respectively, which are in the range of 0 to 1. Each normalized H, S, and I components are then obtained using Eqns. (2) through (5).

$$h = \cos^{-1}\left\{\frac{0.5[(r-g)+(r-b)]}{[(r-g)^2+(r-b)(g-b)]^{1/2}}\right\} h \in [0,\pi] for b \leq g \quad (2)$$

$$h = 2\pi - \cos^{-1}\left\{\frac{0.5[(r-g)+(r-b)]}{[(r-g)^2(r-b)(g-b)]^{1/2}}\right\} \qquad h \in [\pi, 2\pi] for b > g \quad (3)$$

$$s = 1 - \frac{3}{(r+g+b)}[\min(r,g,b)] \qquad s \in [0,1] \quad (4)$$

$$i = \frac{1}{3}(r+g+b) i \in [0,1] \quad (5)$$

For convenience, H, S, and I values converted in the ranges of [0, 360], [0, 100], and [0, 255], respectively using (Eq. 6):

$$H = h \times \frac{180}{\pi}; \ S = s \times 100; \ \mathrm{I} = \mathrm{i} \times 255 \quad (6)$$

These conversion equations were plugged into Microsoft Excel 2007 (Microsoft Corporation, 2006) spreadsheet, and the HSI values were calculated. Finally, image histograms were developed based on the RGB and HSI color information. From the histogram, the suitable color channel and the threshold limits were selected for segmenting the source image and differentiating objects from the background.

RESULTS AND DISCUSSIONS

The measured RGB and HSI values are shown in Table 1. To find the appropriate image threshold values the RGB and HSI color spaces were analyzed.

The relationship of RGB color values of green and ripe mango images is presented in Figure 3. This

Table 1. Measured RGB and HSI color information

Item	Descriptive measure	Color properties					
		R	**G**	**B**	**H**	**S**	**I**
Green Mango	Min	85	107	25	72	50	73
	Max	147	190	64	84	66	131
	Mean	123	159	46	78	58	109
Ripe Mango	Min	56	53	24	30	5	4
	Max	153	120	71	57	56	115
	Mean	99	78	43	40	42	73
Background	Min	3	4	4	30	5	4
	Max	23	32	29	240	42	27
	Mean	12	17	13	123	20	14

explains that object regions can be completely distinguished based on RGB and HSI color information of mango. For example, the mean RGB of image background are 12, 17, and 13, which are ten and eight times lower than the mean RGB values of green and ripe mangos, respectively. This reveals that it is possible to discriminate the target objects from the background illustrated in Figure 3(a). However, RGB information is not quite enough to discriminate the green and ripe mangos properly due to the overlapping of the color spaces as shown in Figure 3(a) and Figure 3(b).

On the other hand, the HSI information from the mango images was found objectively identifiable and reasonable to use for discriminating target objects and background, and the green and ripe mangos. For example, the HSI 72 to 85, 50 to 65 and 72 to 130 was found suitable for separating green mangos from the background and ripe mangos as indicated by the vertical and horizontal blue lines in Figure 3(c) and Figure 3(d).

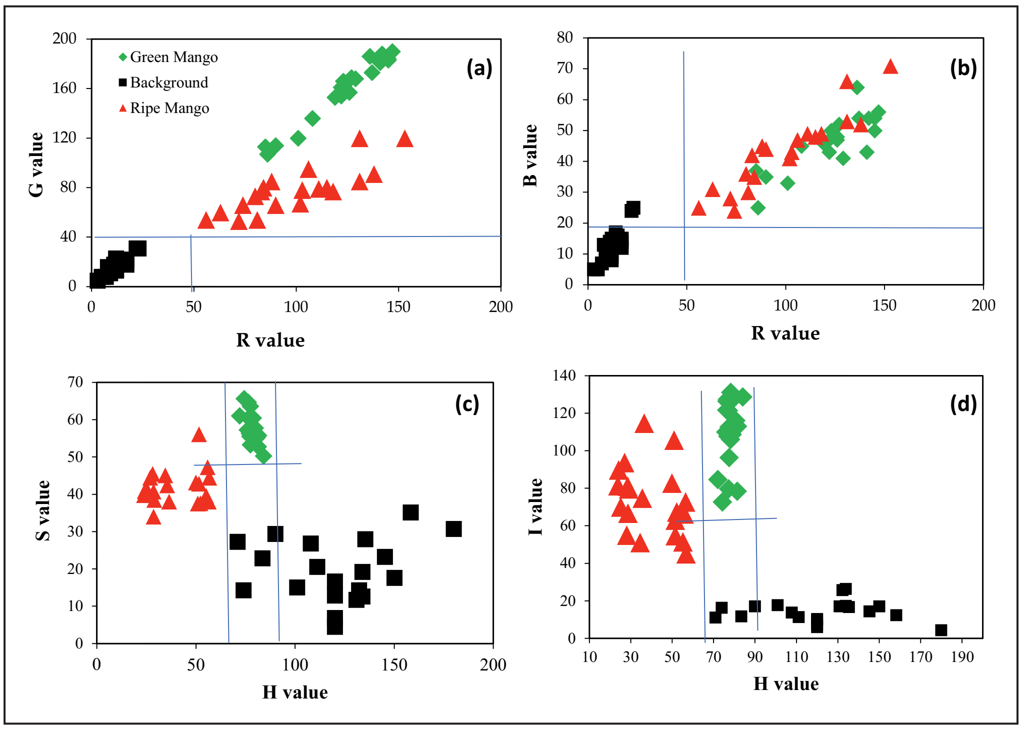

Figure 3. (a) Red vs Green, (b) Red vs Blue, (c) Hue vs Saturation, (d) Hue vs Intensity

It is seen that HSI color space is more suitable than RGB color space. Between two color spaces, the histogram for H vs. S and H vs. I describes the discriminative areas for green and ripe mango also separated from its background. On the other hand, the histogram for R vs. G slightly recognizes discriminative areas, but R vs. B does not make sense at all. Hence, it is easy to detect objects from their background using HSI color properties. It can also have summarized that the fluorescent lighting-based image acquisition system was efficient in providing the necessary illumination to produce good quality images for obtaining color information to grade mangos.

IMPLICATIONS

In this study, it was determined that the developed image acquisition system was suitable to recognize the target objects (e.g., green and ripe mangos) from its background by using image color properties. Moreover, the HSI color threshold information was found more suitable than RGB to identify the green and ripe mangos. Therefore, the color information could be used for developing a mango grading algorithm. The color information can be combined with the physical dimension and defect information for more accurate grading of fruits which is a crucial need in the Bangladesh agriculture sector.

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