

IMAGE PROCESSING METHOD TO CHECK MATURITY INDEX OF 'SEIN TA LONE' MANGO IN MYANMAR

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Abstract

Mango (*Mangifera indica* Linn., Family Anacardiaceae) plays a central role as a favorite tropical fruit crop every year in Myanmar. The objective was to assess the maturity indices of 'Sein Ta Lone' mango with classification of fruit skin color and quality attributes of the mango to generate recommendations. The experiment was conducted on 'Sein Ta Lone' mangoes in Myanmar and arranged with 2×3 factorial experiment in randomized complete block design with five replications. Week of harvest was made as block and as treatments, 'mangoes from three different levels-low, medium and high with bagging and unbagging' were arranged. The collected original images were analyzed by converting to grey-scale images and binary images with Python Language Programming. In image analysis, the color intensity values and size values in pixels were received from the background subtraction process. The change of color intensity value and its physical size from three weeks of bagged and unbagged mangoes were clarified. Identifying parameters to be used for identifying maturity and mango type were revealed via result obtained from analysis of variance. The best color parameters Blue and average of Red, Green and Blue were employed for classifying fruit maturity with K-nearest neighbors (KNN) classifier. For three weeks of harvest, 88.89% accuracy for color intensity B value of bagged mango of same trees and 100.00% accuracy for unbagged mango were achieved and they yielded the highest accuracy, while considering 77.78% accuracy for average RGB value of bagged mango and 88.89% accuracy for unbagged mango.

Keywords: Color intensity values, Physical properties, Image processing, Mango maturity index

Introduction

Among the horticultural fruits, mango (*Mangifera indica* Linn., Family Anacardiaceae) plays a central role as fruit crop in Myanmar. In 2010-2011, it was reported that the total planted area for mango was 79,908 hectares and the area of fruit harvest was 70,084 hectares with total production of 503,676 metric tons. It occupied 11.85% of total

horticultural areas. The majority of mango is consumed as fresh dessert fruit in the ripening stage, as salad in the immature stage, i.e. with the endocarps not yet hardened, and as various types of pickles. People in temperate regions are also increasingly fond of mangoes, due to its attractive flavor, taste, aroma, texture and nutritional value.

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The most popular variety-'Sein Ta Lone' is mainly grown in Mandalay Region where there are more than 18,000 acres of mango plantation, with about 10,000 acres of Sein Ta Lone trees. Consumers are also increasingly fond of Sein Ta Lone, due to its attractive flavor, taste, delightful aroma, texture, sweetness, juiciness, non-fibrous nature and nutritional value (Myat *et al.*, 2013).

In Myanmar, the maturity of mangoes is classified by experienced farmers through sensory evaluation and then they are harvested. The harvesting date of mangoes is decided according to the maturity period which is counted from the day of anthesis or the day of fruit budding (Sivakumar *et al.*, 2011). Then the mangoes will be optimum edible stage when they are arrived at target countries. The optimum maturity of mangoes is selected because proper mature mangoes are good flavor quality (sweetness, sourness, and aroma) than young mangoes (Yimyam *et al.*, 2011). Bagging mango fruits having attractive color with better quality and bigger fruits, this practice has been using to get more market prices (Man, 2014). It can also reduce the incidence of disease, fruit fly damage, bird, other pests, mechanical damage and so on (Sharma *et al.*, 2014). Highly experienced farmers can harvest more properly matured fruits while less experienced farmers get more improperly matured fruits. When an immature mango is harvested, it may not develop a full flavor, aroma and taste, even with ethylene or acetylene treatment. Conversely, an over-ripe fruit will decay rapidly after harvesting, resulting in reduced shelf-life with greater susceptibility to disease.

Maturity is an important factor associated with the quality evaluation of fruits like mangoes. Mangos are needed to be classified according to their maturity stage for commercial use. Physical maturity indices include size, shape, peel/flesh color, peel/flesh firmness and specific gravity (inclusive of weight) (Crisosto *et al.*, 1995).

The optimum maturity of mangoes is selected because proper mature mangoes are good flavor quality (sweetness, sourness, and aroma) than young mangoes. However, they sometimes choose too old mangoes although they would be quickly rotten naturally before export. As most mangoes on a mango tree are not fruited simultaneously; therefore, farmers consider and estimate them by their experience so as to choose appropriate mature ones. Sometimes they may be not sure, so they have to use a general floating method to examine doubtful mangoes. If they sink, it is possible to conclude that they are mature; on the other hand, if it is not, it means they are too young. Farmers have to be expert to estimate maturity of mangoes; otherwise, they may waste a lot of time using the floating

method (Yimyam *et al.*, 2011). Mature mangoes were estimated by floating the mangoes in salt water; nevertheless, it had an impact on taste of them, and it was likely to cause Anthracnose disease to them (Yimyam *et al.*, 2011).

In Myanmar, Myanmar mango growers are holding misleading ideas to harvest fresh mango fruits in maturity level: (1) making wrong decision during harvesting, (2) making early decision for harvest time, (3) early picking to get good price, and (4) labor shortage for harvesting and lately harvest.

Traditional visual inspection is labor intensive, expensive, and prone to human error, leading to variability in the final product. It is difficult to classify the maturity of bagged mangoes based on the firmness or color changes of the fruit. At maturity stage or at harvest, the color of bagged mango is light green or light- yellow but if not bagged, the color is green. As color of bagged fruit is light-yellow, it seems to be ripe, but it may be either mature or immature. Fresh bagged fruits have to be picked on visual judgments _approximately at the age of 100 days from fruit set after blooming. Maturity of bagged mangoes changes from degreening process, which are distinctions needed by growers to determine fruit maturity to market stage. Their harvest can include both mature and immature fruits (Watanawan *et al.*, 2007).

Image processing has been used in many applications on quality attributes of fruit and vegetables. The image processing theories were described so as to extract mangoes' 2D physical properties, and they were used to estimate maturity of mango sample (Yimyam *et al.*, 2011). Using the ENVI software system, the features of Sala mango were extracted from the acquired images with RGB values captured by a mobile phone camera and then used to classify of fruit skin color, which relates to the stages of ripening (Yahaya *et al.*, 2015).

The analysis of Alphonso mango images clearly showed that there were significant changes in red, green and blue color components and hue-saturation-value with ripening process, and all three ratios in RGB method viz. red to green, red to blue and green to blue increased with ripening process but with different rates (Salunkhe and Patil, 2015). It was observed that all three ratios in RGB method viz. red to green, red to blue and green to blue increases with ripening process but with different rates. Also it was demonstrated that blue color has lowest weightage in mango images, green color has highest weightage in not ripen mango and red color has highest weightage in fully ripe mango (Salunkhe and Patil, 2015).

In ripening of Banganapalli mangoes, it was found that, the R and G were more suitable to predict the ripening colour change rather than B

value. In case of ratios, the red ratio (R/B), the green ratio (G/B) and both blue ratios were suitable to predict the ripening of mangoes. These observation were used as one of the nondestructive tool for mango quality evaluation, mango ripening and optimization studies (Nambi *et al.*, 2015). Quality inspection of mangoes and their classification using parameters like size and colour has been done (Vyas *et al.*, 2014). The use of three digital image processing algorithms was explored to determine harvested 'Carabao' mango ripeness stages, and to extract a mango image from its original image with the accuracy of 80.5%, 63.88% and 17.33% (Guillermo *et al.*, 2019).

The effect of amount of ambient light was also studied and it is found that the RGB method has better immunity over the HSV method for ripeness detection. The work proposed here can be applied for automatic classification of mangos in corresponding processing industries. The methods cannot be applied to the mangos which do not change color features with ripening process (Salunkhe and Patil, 2015). Seasonal fruits, like mango, are harvested from gardens or farms in batches; the mangoes present in each batch are not uniformly matured, therefore, sorting of mangoes into different groups is necessary for transporting them to various locations. Extracted image frames from the video signal have been corrected and processed to extract various features, which were found to be more relevant for the prediction of maturity level (Meruliya *et al.*, 2015).

The surface color determination of "all yellow" mango cultivars was studied by using computer vision system (CVS) and the International Commission on Illumination (CIE) $L^*a^*b^*$ color space to acquire color data. Their results showed that CVS can be an alternative way to evaluate the degree of ripeness of the 'Nam Dokmai' and 'Maha Chanok' cultivars (Nagle *et al.*, 2016). It was resulted that digital photometry using a simple digital camera and software for color analysis based on RGB, hue, saturation, and value (HSV), or $L^*a^*b^*$ systems, was a promising method for determining the ripeness degree of 'Carabao' mango fruits (Ilagan *et al.*, 2015).

It was studied that three features namely shape size and maturity were used for mango fruit grading. Fuzzy systems were used for individual feature extraction and decision making theory used for combining features. 96% accuracy for size feature, 92% accuracy for shape feature and 93.5% accuracy for maturity were achieved while considering individual feature (Naik *et al.*, 2015).

Global thresholding segmentation method has been used to segment the mangoes from the background and the ripeness of mangoes was

successfully estimated by extracting 24 color features with 93% of accuracy using K NN Classifier (Ramya and Raghavendra, 2016). The literature survey gives a keen insight into the various studies done in the field of defect identification and maturity detection of mango fruit (Chauhan *et al.*, 2018).

In Myanmar, current harvesting problems of mango are concerned with weakness in use of mango harvest techniques. There are many research papers on ways to maintain quality of fruit. However, these methods cannot be done by most of the producers because they are invasive techniques, high cost and not easily available. Image processing method is one of the effective tools for maintaining quality of fruit. Therefore, the proposed method, the image processing method by using Python Language Programming, has the advantages of low-cost operation and minimal manpower requirement for performing measurements and it is worth to find out the simple, easy and cheap way to check maturity index of mango like Python Language Programming. Moreover, it was found that the previous papers were conducted to research the skin color of unbagged mangoes by using image processing methods. However, in this study, it was attempted to study about the skin color of both bagged and unbagged mangoes. Nowadays, farmers are widely using bagging practices for mango to protect fruit surface from mechanical injuries, to prevent insects, to reduce diseases, and to improve the internal quality of fruit. Hence, this study was conducted to determine the maturity indices of 'Sein Ta Lone' mango variety produced in Myanmar, to classify of fruit skin color of both bagged and unbagged mango, which relates to the stages of ripening of 'Sein Ta Lone' mango and to identify the maturity stages of the mango by using K-NN, and to generate recommendations to strengthen the resilient of 'Sein Ta Lone' mango maturity level in the future.

Materials and Methods

Study Area

For our research, the major 'Sein Ta Lone' production area for exportable and a high potential for 'Sein Ta Lone' mango development were selected particularly in Myanadi Mango Orchard, Myittha Township, Mandalay Region, Central Dry Zone, Myanmar.

Experimental Design

The experiment was conducted on eighteen-year-old Sein Ta Lone mango trees. The experiment was arranged with 2×3 factorial

experiment in randomized complete block design with five replications. The treatment combinations were factor (A): bagging, unbagging and factor (B): three different high levels of mango tree-low (1.83 meter), medium (3.66 meter) and high (5.49 meter). In this experimental layout, block means 'week of harvest' and as treatment, 'mangoes from three different levels (low, medium, high) with bagging and un-bagging' were made in this field experiment. 'Sein Ta Lone' mangoes, one-layer brown paper bags, light box (inspection chamber), Vivo1762 phone and Python Language Programming Software were applied as materials. The size of one-layer brown paper bag was 30 cm×20 cm and egg-sized mangoes were bagged at 55 days after flowering.

Data Collection

The mango fruits were harvested at 3 different maturity stages in three weeks. The first harvest week (Week1) was done at 83 days after fruit set (DAFS), the second harvest week (Week2) at 93 DAFS, the third harvest week (Week3) at 103 DAFS. Dates of bagging and dates of fruit set were noted down for accurate age of the fruits. Data were collected three times not only from three mango trees which were arranged with bagged mangoes and unbagged mangoes but also from three mango trees which were only made with un-bagged ones. For part one data collection, in each level of the mango tree, bagged mango fruits and un-bagging ones were made alternately on the same tree. Therefore, a level had 5 bagged and 5 un-bagging fruits so that they would be compared to each other. For part two data collection, only un-bagging mango fruits were made in each level of the different mango tree. Each level had 5 unbagged mango fruits. Therefore, there were fifteen unbagged mangoes at three levels of the tree so that these unbagged fruits would be compared to the bagged mango fruits from three mango trees which were arranged with bagged mangoes and unbagged mangoes. As part three data collection, 15 unbagged and 15 bagged mango fruits were collected from the market place and the packaging area and these data were used as standard data

Image Acquisition

The images were taken by placing each sample inside an inspection chamber in which contained the phone camera and the lighting system as shown in Figure 1. The size of light box (inspection chamber) was 24.13 cm×27.94 cm and light intensity was applied with input: 110-120 VAC, 200-240 VAC, 50/80 Hz and output: 12 V 3 A. The VIVO phone camera was placed at a distance of 20 cm from the samples. The image of each mango was taken from

one side and then stored with JPEG format. The degrees of ripeness of mangoes was conventionally evaluated manually on the basis of color parameters, but as the image processing method, a simple non-destructive technique using the VIVO mobile phone camera was introduced to replace the destructive technique. In this research, color parameters in terms of RGB values and size values were linked to detect 'Sein Ta Lone' mango quality parameters. The features of mango in different height was extracted from the acquired images and then used to classify of fruit skin color, which relates to the stages of ripening. The mean pixel values in RGB, fruit widths, lengths and area were analyzed using the Python Programming Language to estimate the optimum maturity index of mango fruits and the correct days for picking mature mangoes with the color parameters in terms of RGB values.



Figure 1. The setup used to capture the images in which the size of light box was 24.13 cm×27.94 cm and light intensity

Image Analysis

The collected images of mango were analyzed by using Python Language Programming System. Number of pixels of mango region in the captured image were counted by the software using image processing and analyzing processes. In image analysis, the color intensity values of R(red), G(green), B(blue) in pixels, and physical size of Width(W), Length(L) and Area(A) in pixels were received from background subtraction of mango images (Chityala and Pudipeddi, 2020).

Theoretically, the proposed algorithm of Python Language Program involves three types of processing i.e. low level, intermediate and high-level processing. In low-level processing, input image/dataset is pre-processed. Pre-processing includes RGB to gray conversion, image binarization, and image filtering. Intermediate level processing involves background subtraction and feature extraction. Identification of the maturity level of mango fruit has been performed in high-level processing by KNN-classifier.

Pre-processing

Initially, the original RGB image was converted to grey-scale image by grey-scale image processing as shown in Figures 2 and 3.



Figure 2. Pre-processing converting original bagged mango image to grey-scale image a) and binary image b)

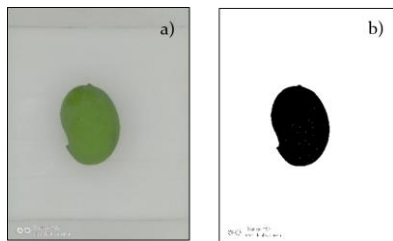


Figure 3. Pre-processing converting original unbagged mango image to grey-scale image a) and binary image b)

Background subtraction

Subtraction of background is essential for proper identification and classification of mango fruits as it is necessary to extract mango images. Background subtraction also reduces the scene complexities such as shading, light variation, background clutter. Original images are subtracted into two background colors-black and white. The preliminary background subtraction serves two purposes. The first purpose is to remove most of the background pixels for determination of the coarse mango regions. The second purpose is to determine whether mango pixels as a whole are darker than the background (Sahu and Potdar, 2017). After pre-processing, the grey-scale image was converted to a binary image by the threshold value so that the mango area is black, the rest of the region is white as shown in Figure 4. Finally, figure reversal is applied, so that black and white color area reversed when the mango area is white, which improves the performance of the classifier (Sahu and Potdar, 2017).

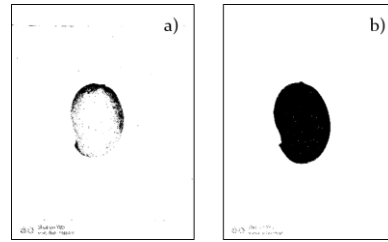


Figure 4. Analysis of bagged mango image a) and unbagged one b) with background subtraction and feature extraction

Feature Extraction

Color intensity pixel values of R (red), G (green), and B (blue) and its physical size pixel values of W (width), L (length) and A (area) were counted from the numbers of pixel on black (Sahu and Dewangan, 2017).

Identification of mango maturity index

With the proposed fruit recognition system, the K-nearest neighbors (KNN) algorithm was used as a classifier to classify fruit maturity index based on mean color values and size values of mango images in pixel (Naik and Patel, 2017).

Statistical Analysis

Data from the analytical determinations were subjected to analysis of variance (ANOVA) by performing with the R program (R i386 3.5.1). Mean comparisons were performed using the Duncan Multiple Range Test ($P < 0.05$).

Results and Discussion

In our research, color parameters in terms of RGB values and size values were linked to detect 'Sein Ta Lone' mango quality parameters. The mean pixel values in R (red), G (green), B (blue), fruit widths (W), lengths (L) and area (A) were analyzed using the Python Programming Language to estimate the optimum maturity index of mango fruits and the correct days for picking mature mangoes with the color parameters in terms of RGB values and size.

According to ANOVA tables, analysis of R values indicated that there was a significant difference between weeks of harvest mango at 95% confidence level as shown in Figure 5(b). The mango images collected by week by week also showed that there was highly significant between bagged and unbagged mango images. However, it

was resulted that there was no significant difference between three different levels of mango tree. Besides, the interaction between two factors was not significant between those factors as shown in Figure 5. It could be recorded that the overall trend of R values for bagging from the first week to the third week showed more and more mango maturation. It was found that R values of unbagged mangoes in the first week was in a stable stage but the R values reached a little smaller in second week, and increased gradually in the third week. It was revealed that color distribution value is high for red color representing over-ripped mangoes (Mohammad *et al.*, 2020). It confirmed that all three ratios in RGB method viz. red to green, red to blue and green to blue increases with ripening process but with different rates. Also it was demonstrated that blue color has lowest weightage in mango images, green color has highest weightage in not ripen mango and red color has highest weightage in fully ripe mango (Salunkhe and Patil, 2015).

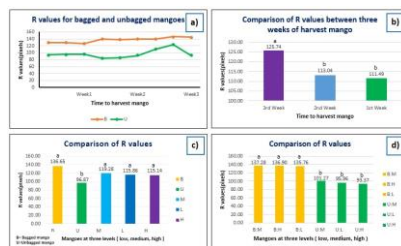


Figure 5. R values of mangoes at three levels of tree under the different maturation stages. Different letters indicate significant differences at $p < 0.05$ using Duncan Multiple Range Test.



Figure 6. G values of mangoes at three levels of tree under the different maturation stages. Different letters indicate significant differences at $p < 0.05$ using Duncan Multiple Range Test.

In the analysis of G values, it was indicated that there was no significant difference between weeks of harvest mango as shown in Figure 6. However, the results showed that there was a highly significant between bagged and unbagged mango images. In three different levels of mango tree, it

was found that there was no significant difference and no interaction between two factors. It was observed that G value of bagged mangoes was larger than that of unbagged mangoes every week of harvest. It meant that depending on the amount of G values, the maturation stages of bagged mangoes week by week was not the same as that of unbagged mangoes.

In result of B value, there was a highly significant difference between weeks of harvest mango as shown in Figure 7. However, there was no significant between bagged and unbagged mango images, no significant difference between three different levels of mango tree, and also no significant between the interaction of two factors. The overall trend of color intensity B values for bagged mangoes decreased continuously from the first week to the third week. Hence, it was noted that the less the color intensity B values of bagged mangoes, the more maturity level these bagged mangoes possessed. Like the bagged mangoes, the overall trend of color intensity B values for unbagged mangoes decreased gradually throughout the weeks. For B values of unbagged mangoes, the more amount of B values decreased, the more maturity it became as shown in Figure 7(a). It revealed that in un-ripped mangoes, color mean value is high for green color and blue color. On the other hand, blue color intensity value was low in more maturity level of mangoes (Chauhan *et al.*, 2018). It was also revealed that decreasing trend was found in both blue ratios and both blue ratios would be suitable to predict the ripening (Nambi *et al.*, 2015). However, it was also evident that the blue component had the lowest weightage in mango images irrespective of its ripening stage (Salunkhe and Patil, 2015). It was also denied that increasing trend was found in both R and G values while no much changes were found in B values and there was no much change observed in B value till the last phase of ripening (Nambi *et al.*, 2015).

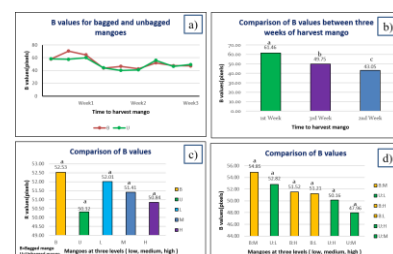


Figure 7. B values of mangoes at three levels of tree under the different maturation stages. Different letters indicate significant differences at $p < 0.05$ using Duncan Multiple Range Test.

In the analysis of average RGB values, there was a significant difference between weeks of harvest mango as shown in Figure 8(b). This result showed that three harvest dates of mango could be interpreted based on the physiologically different maturity stages. There was a highly significant difference between mangoes: bagged mangoes and unbagged mangoes as shown in Figure 8(c). It was found that the optimum maturity of bagged mangoes was not the same as that of unbagged mangoes. Mangoes in the different levels of mango tree indicated that the difference was non-significant at different maturation stages in Figure 8(c). As shown in Figure 8(a), the overall trend of average RGB values for bagged mangoes decreased slightly and slowly from the first week to the third week. Hence, it was noticed that the less the average RGB values of bagged mangoes, the more maturity they possessed. Similarly, the average RGB values of unbagged mangoes in the first week was in higher stage and dropped gradually in the second week and increased slightly to the third week.



Figure 8. Average RGB values of mangoes at three levels of tree under the different maturation stages. Different letters indicate significant differences at $p < 0.05$ using Duncan Multiple Range Test



Figure 9. Width values of mangoes at three levels of tree under the different maturation stages. Different letters indicate significant differences at $p < 0.05$ using Duncan Multiple Range Test

Analysis of W values resulted that there was no significant difference between weeks of

harvest mango. The results showed that it was highly significant between bagged and unbagged mango images as shown in Figure 9. However, in the three different levels of mango tree, there was no significant difference. Moreover, there was no interaction between two factors. Therefore, the Width values of bagged mangoes were larger than those of unbagged mangoes.

Based on the L values of mango images, it was non-significantly different between weeks of harvest mango. Besides, there was no significant between bagged and unbagged mango images, no significant difference in three different levels of mango tree, and no interaction of two factors.

The result of Area values showed that there was no significant between weeks of harvest mango ($p < 0.05$). However, the results showed that there was highly significant between bagged and unbagged mango images as shown in Figure 10(c). In three different levels of mango tree, it was found that there was no significant difference. Moreover, the interaction between two factors was not significant as shown in Figure 10. Therefore, the area of bagged mangoes in the first week of harvest was smaller than that of other two weeks. Among three weeks of harvest, the second week possessed the largest in fruit area. Unlike the bagged mangoes, the overall trend of areas values for unbagged mangoes decreased gradually from the first week to the third week. Moreover, it was also found that the area of unbagged mangoes was larger than that of bagged mangoes from the same tree every week of harvest. It was denied that (Chonhenchob *et al.*, 2011) studied the effects of pre-harvest bagging with different wavelength selective bags on ‘Nam Dok Mai #4’ mango in Taiwan and reported that bagging increased fruit weight, size, and sphericity over un-bagged fruit (Sharma *et al.*, 2014). Moreover, it was reported that in 18-year-old tree, bagging had no significant effect on fruit area. The result of this finding was in line with the findings of (Kim *et al.*, 2003) who found that type of bagging materials had little effect on fruit size (Man, 2014). Pre-harvest fruit bagging has been reported to reduce fruit size and weight in some fruit. For instance, (Xu *et al.*, 2010) attempted to bag ‘Baiyu’ and ‘Ninghaibai’ loquat and reported that bagging decreased the weight of fruit. Similarly, (Hudina and Stampar, 2011) reported that bagging ‘Conference’ pears reduced the fruit weight to such an extent that the fruit were not marketable. Bagging has also been reported to reduce fruit size and weight in pomegranate (Hussein *et al.*, 1994) and in apple (Arakawa *et al.*, 1994; Sharma *et al.*, 2014).

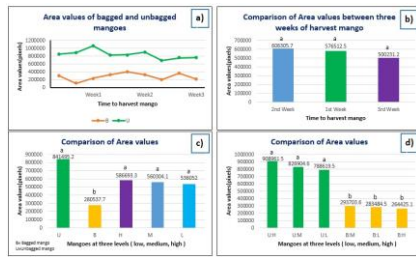


Figure 10. Area values of mangoes at three levels of tree under the different maturation stages. Different letters indicate significant differences at $p < 0.05$ using Duncan Multiple Range Test

In bagging, more R values increased maturity, less G values increased maturity, and decreasing B values made more maturity. Area values during maturation period had changes and it had smaller Area. In unbagging, if G value had more than R, it increased maturity. Decreasing B values made more maturity. Increasing R values, it made more maturity in fully ripe mango. It stated that blue color has the lowest weightage in mango images, green color has the highest weightage in not ripen mango and red color has the highest weightage in fully ripe mango (Salunkhe and Patil, 2015). Different levels of mango tree could not correlate with maturity index and it could not result optimum maturity index based on earlier or later harvest.

For identifying maturity index for the same mango trees, according to block (weeks) of ANOVA, the color intensity values of R, B and RGB were significant difference at 95% confidence level, but other parameters were not significant difference. Therefore, R, B and RGB could be ordered to identify maturity between Week1, Week2 and Week3. However, because P value of B was the most highly significant difference among them, B should be chosen to identify mango maturity in weeks of harvest. Due to mango (bagging and unbagging) of ANOVA, the parameters W, A, R, G and RGB were significant difference at 95% confidence level, but other parameters (L and B) were not significant difference. So, the parameters W, A, R, G and RGB could be ordered to identify maturity between mango (bagging and unbagging). However, because P value of Area (A) was the most highly significant difference among them, Area (A) should be chosen to identify maturity in mango (bagging and unbagging).

For identifying maturity index for the different mango trees, according to block (weeks) of ANOVA, the parameters A, RGB, L, R and B were significant difference at 95% confidence level, but

other parameters were not significant difference. Therefore, A, RGB, L, R and B could be ordered to identify maturity between Week1, Week2 and Week3. However, because P value of B was the most highly significant difference among them, B should be chosen to identify mango maturity in weeks of harvest. Due to mango (bagging and unbagging) of ANOVA, the parameters W, A, R, G and RGB were highly significant difference at 95% confidence level, but other parameters (L and B) were not significant difference. The parameters W, A, R, G and RGB could be ordered to identify maturity between mango (bagging and unbagging). However, because P value of RGB was the most highly significant difference among them, RGB should be chosen to identify maturity in mango (bagging and unbagging).

Hence, the color intensity B value was the common parameter between same and different trees for classification of mango maturity by K-NN classifier. Moreover, one of the color values, RGB value, had to be used to support the color parameter B value without using the size value A which was not color value. According to block (weeks) of ANOVA, the parameters B and RGB were more suitable for identifying maturity in weeks of harvest. Therefore, B and RGB were used for identifying mango maturity by using K-NN classifier.

For bagged B value of same mango tree, 15 data of B value in each week (Week1, Week2 and Week3) was split randomly into 12 data for train set and 3 data for test set to check accuracy percentage of maturity. Test set had 3 data (20 %) and train set had 12 data (80%). The first number value from Test Set subtracted each of 12 number values from Train Set and the sum of all of these differences resulted the first variable number. Also, the second number value from Test Set subtracted each of 12 number values from Train Set and the sum of all of these differences resulted the second variable number. Similarly, the third number value from Test Set subtracted each of 12 number values from Train Set and the sum of all of these differences resulted the third variable number. Among these three variable numbers, the minimum value was the predicted one. When the values of Test Set were the same as the values of predicted (Train Set), these were counted to decide for accuracy percentage. It was found that the accuracy percentage was 1000 times of that of bagged B value of same mango tree. After 1000 replications, average of accuracy of bagged B value of same mango tree was 55.09% and the highest accuracy was 88.89%. The results yielded high accuracy of maturity of bagged mangoes.

For unbagged B value of same mango tree, 15 data of B value in each week (Week1, Week2 and Week3) was split randomly into 12 data for train set

and 3 data for test set to check accuracy percentage of maturity. When the values of Test Set were the same as the values of predicted (Train Set), these were counted to decide for accuracy percentage. After 1000 replications, average of accuracy of unbagged B value of same mango tree was 67.23% and the highest accuracy was 100.00%. The results yielded high accuracy of maturity of unbagged mangoes. It was denied that the weightage of blue color in mango image was drastically dropped as compared to green component with ripening process. There was steep rise in red component whereas gradual fall in green and blue components and the blue component had the lowest weightage in mango images irrespective of its ripening stage (Salunkhe and Patil, 2015). It was also denied that the ripening did not influence the B value more as compare to R and G values and the R and G value might be more efficient to predict the ripening rather than B value (Nambi *et al.*, 2015). However, it was revealed that by using RGB color model, extracted color features in the form of mean values of each color was resulted. In un-ripped mangoes color mean value was high for Green color and Blue color. Color distribution value was high for Red and Green color representing ripped mangoes. Color distribution value was high for Red color representing over-ripped mangoes (Chauhan *et al.*, 2020).

For bagged RGB value of same mango tree, 15 data of RGB value in each week (Week1, Week2 and Week3) was split randomly into 12 data for train set and 3 data for test set to check accuracy of maturity. When the values of Test Set were the same as the values of predicted (Train Set), these were counted to decide for accuracy percentage. It was resulted that this accuracy percentage was 1000 times of that of bagged RGB value of same mango tree. After 1000 replications, average of accuracy of bagged RGB value of same mango tree was 49.51% and the highest accuracy was 77.78%. The results yielded high accuracy of maturity of bagged mangoes.

For unbagged RGB value of same mango tree, 15 data of RGB value in each week (Week1, Week2 and Week3) was split randomly into 12 data for train set and 3 data for test set to check accuracy percentage of maturity. When the values of Test Set were the same as the values of predicted (Train Set), these were counted to decide for accuracy percentage. After 1000 replications, average of accuracy of unbagged RGB value of same mango tree was 59.89% and the highest accuracy was 88.89%. The results yielded high accuracy of maturity of unbagged mangoes. It was confirmed that the trend of Blue value decreased gradually from un-ripped mango stage to overripe mango

stage (un-ripped, ripe and overripe mango stages) and yielded the smallest amount in overripe mango stage. In un-ripped mangoes, B values were higher than R values and G values. The color intensity mean values of B was smaller compared to R values and G values in both ripe mangoes and overripe mango stages. On the other hand, it meant that because average RGB values dropped constantly through stages, average RGB values was the highest in un-ripped mangoes, but the smallest in overripe mangoes (Chauhan *et al.*, 2018; Mohammad *et al.*, 2020).

Conclusions

It was concluded that the change of color intensity value and its physical size from (Week1), (Week2) and (Week3) of bagged and unbagged mangoes were clarified. Identifying parameters to be used for identifying maturity and mango type were revealed via result obtained from analysis of variance. In the experiment, the best color parameters B and RGB were employed for classifying mango fruit maturity. The K-nearest neighbors (KNN) classifier was used for identifying maturity index of mangoes. For three weeks of harvest, 88.89% accuracy for color intensity B value of bagged mango of same trees and 100.00% accuracy for color intensity B value of unbagged mango of same trees were achieved and they yielded the highest accuracy for mango maturation of three weeks of harvest, while considering 77.78% accuracy for average RGB value of bagged mango of same trees and 88.89% accuracy for average RGB value of unbagged mango of same trees. Therefore, it was worth to find out the simple, easy and cheap way to check maturity index of mango by using image processing via Python Language Programming.

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