International Food Research Journal 23(Suppl): S173-S178 (December 2016)

Journal homepage: http://www.ifrj.upm.edu.my

Assessment on the skin color changes of *Carica papaya* L. cv. Sekaki based on CIE L*a*b* and CIE L*C*h color space

[1*]Ruslan, R. and [2]Roslan, N..

[1]*School of Bioprocess Engineering, Universiti Malaysia Perlis, Kompleks Pusat Pengajian Jejawi 3, 02600 Arau, Perlis, Malaysia*

[2]*Institute of Sustainable Agrotechnology, Universiti Malaysia Perlis, Sg. Chuchuh Campus, 02100 Padang Besar, Perlis, Malaysia*

Article history

Received: 27 July 2016
Received in revised form: 2 September 2016
Accepted: 3 September 2016

Keywords

Papaya (Carica papaya L. cv. Sekaki)
Non-destructive technique,
Total soluble solid (TSS)
Colorimeter
Ripening index
Color indicator

Abstract

Papaya cv. Sekaki is one of the Malaysian's favorite commodities with great tropical taste. Generally the papaya ripening determined through skin color changes. Current method for the quality inspection is through the experience of operator. However the inspection from one operator may vary to another. The main purpose of this study is to improve the quality inspection of papaya for an efficient grading system. This study will improve the ripening index developed for papaya by Malaysian Federal Agricultural Marketing Authority (FAMA) on the skin color basis by comparing the color values between CIE L*a*b* and CIE L*C*h color space. Destructive technique usually used to evaluate the chemical parameter such as total soluble solid (TSS) content. A new improvised ripening index chart added with specific TSS content and color values range. The relationship between color values and TSS was developed for CIE L*C*h with R^2=0.9674. The ripening index chart established allows papaya quality attributes to be determined and evaluated nondestructively with the aid of colorimeter.

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Introduction

Papaya is categorized as one of climacteric fruits (Ali *et al*., 2011; Huerta-Ocampo *et al*., 2012; Rahman, 2012; Paul and Pandey, 2014) with the ability to continue ripened off the tree when harvested at the suitable maturity stage. There are a lot of papaya varieties throughout the world such as Solo and Maradol papaya which differ in the total fruit development, ripening period, physical and chemical character (Zaman *et al*., 2006). Earlier, quality of papaya was determined using destructive method (Jha, 2010). The problem with this method is the consistency in sorting and time consuming when dealing with a large scale processing that may contribute to post harvest losses. Due to the advancement in the instrumentation technology, researcher has developed several nondestructive techniques for quality evaluation. The advantages from using nondestructive technique are it is time saving and more efficient compared to traditional method (Jha, 2010). The large scale processing of fruits especially in the sorting, grading and marketing lines need to be measured by nondestructive technique to overcome the problem (García-Ramos *et al*., 2005; Ab Razak *et al*., 2014).

Several physiochemical properties that has been studied by researcher using various type of papaya such as evaluation of the skin color (Basulto *et al*., 2009; Gayosso-García Sancho *et al*., 2010; Schweiggert *et al*., 2011; Jayathunge *et al*., 2014), firmness (Gomez *et al*., 2002), and TSS content present in the fruit (Gomez *et al*., 2002; Zaman *et al*., 2006).

For papaya, its ripening had been commercially described by its skin color (Paull and Chen, 1997). The instruments that widely used to measure skin color of the fruits are colorimeter. The development of colorimeter is to overcome optical illusion because color may appear differently to different individuals. The instruments for color measurements were specially designed similar to human perception of visible spectrum. Moreover, it can give definite value for each measurement (Slaughter, 2009). However, there are some influence factors that can affect the reading such as the light source, direction size, background, observer, and memory of the instruments.

Generally, consumer preference is based on the qualitative aspect of the fruits product (Abbott, 1999). However, visual appearance of the skin color is the core factor that influence customer upon

*Corresponding author.
Email: *rashidahruslan@unimap.edu.my*

purchasing. The two popular color spaces used to expresses color numerically is Hunter Lab and The Commission de International de I'Eclairage (CIE) color space. The difference between the Hunter and CIE color coordinates is on the mathematical calculation (Hunter Laboratories, 2012). However, current recommendation is by using CIE L*a*b* as it is the improved version of Hunter Lab for universal use and have the advantages to measure the difference between any two colors. CIE color space describes color based on three primary stimuli that is red (700 nm), green (546.1 nm), and blue (435.8 nm) which is similar to human eyes. For this CIE L*a*b*, L* represents the luminosity or lightness ranging from 0 to 100, for a*, negative value represents by green color while positive value represents by red color and for b*, negative value represents by blue color while positive value represents by yellow color. CIE L*C*h color space is the transformation from CIE L*a*b*. For CIE L*C*h, C* represents chroma or the saturation of the color while h represents the angle between 0º to 360º of color wheel. At angle 0º represents by red, 90º represents by yellow, 180º represents by green and 270º represents by blue color. The other important parameter that can best indicate the fruits quality is the TSS content. TSS measures the sweetness of the fruits given by unit °Brix. °Brix was determined through the development of starch metabolization in the fruits after harvest (Gomez *et al*., 2002).

In Malaysia, FAMA (2004) had established the ripening index of papaya. That illustrates the external color and half cut picture of the papaya. However, local farmers in Malaysia still sort the fruits traditionally by using visual inspection. This paper concerns on the effectiveness of nondestructive technique to measure Malaysian local papaya quality. In this study, colorimeter is used as a tool to replace the visual inspection by measuring the skin color changes of papaya cv. Sekaki along the ripening period. The relationship between color and TSS content were also established. In addition, the ripening index chart of local papaya variety by FAMA was further developed based on color and TSS content.

Material and Method

Sample preparation

The experiment was conducted at Institute of Sustainable Agrotechnology (INSAT), University Malaysia Perlis (UniMAP). Papaya (*Carica papaya* L. cv. Sekaki) was chosen for this study as a common papaya variety planted in Perlis. A total of 24 fruits sample were taken for analysis. The fruit samples were harvested at early stage with the aid of personal experience. Then, the fruits were transported to laboratory and washed to remove the field heat, dirt, soil particle and latex. Later, the fruit were kept at ambient temperature to allow it ripen naturally. The fruit subjected to color measurement and total soluble solid determination every two day starting from day 0 until day 8 after harvesting.

Color measurement

The papaya skin colors were measured non-destructively by using Minolta Chroma meter (Model CR400) which was set up with D65 illuminant and 10° observer angle. The color values were recorded as L*, a*, b*, C* and h. The reading was set to take average of 6 random points per fruit. The instrument must be completely in contact with the fruits to avoid any light leakage from the light emitted by the colorimeter.

Total soluble solid (TSS) determination

The TSS content (°Brix) of the fruits was measured by using Reichert Hand-held Refractometer (Model R400). The inner part of the fruits were pressed using manual hand press to produce a few drops of clear juice. The juice was homogenized on the refractometer prism. The prism was washed with distilled water and dried for every new sample.

Statistical analysis

The statistical analysis was carry out by using SPSS Statistics software. t-test paired two sample per means (p value<0.05) were conducted to determine mean significance different between the ripening stage. A mean of four fruits per ripening stage were used to represent each ripening index for the color values and TSS content. The relationship of the skin color and TSS content were calculated and established using Multiple Linear Regression (MLR). The analysis were compared with the highest R^2 coefficient of determination closest to 1 for the best fitted line, and the significant correlation for p-value<0.05.

Ripening Index (RI)

Pictures were taken from each of the papaya sample to represent the ripening stage of the fruits prior to the color management. Later, the color values were arranged for its minimum and maximum value range to synchronize with the ripening stage as described by FAMA.

Results and Discussion

The fruits samples were classified into six ripening stage (RS) according to FAMA classification chart. The RS start from ripening stage 1 (RS1), ripening stage 2 (RS2), ripening stage 3 (RS3), ripening stage 4 (RS4), ripening stage 5 (RS5), and ripening stage 6 (RS6). The postharvest shelf life for papaya cv. Sekaki when stored at ambient temperature is 8 days. Similar finding were observed by Schweiggert *et al*. (2011) for Maradol papaya while Chutichudet and Chutichudet (2014) claimed that cv. Holland papaya can maintain up to 7 days only. Usually, the ripening were faster at ambient temperature or at higher temperature (Yao *et al*., 2014) due to increase in enzymatic activity in the fruits. Papaya can ripen naturally when harvested at full maturity.

Color analysis

Papaya ripening best represents through skin color changes. The color value obtained from the study for L*, a*, b*, C*, and h values were recorded as in Table 1. Table 1 show the result obtained from the analysis of the color traits. The color changes classified and ranged from minimum to maximum value varies from each ripening stage.

Table 1 The ranges of color values for each ripening stage

Color Values	RS1	RS2	RS3	RS4	RS5	RS6
L*	41 to 50	44 to 52	45 to 55	56 to 65	62 to 66	60 to 67
a*	-17 to -15	-15 to -13	-13 to -7	-7 to 8	8 to 20	20 to 26
b*	25 to 30	30 to 37	34 to 45	45 to 55	55 to 60	56 to 60
C*	30 to 38	32 to 40	36 to 45	46 to 58	58 to 65	59 to 70
h	116 to 121	100 to 115	99 to 110	80 to 99	70 to 90	60 to 69

Figure 1 illustrate the overall color changes along the ripening period for CIE L*a*b* and L*C*h color values. Each point in the graph represents the mean of four fruits per ripening stage. The trend for the color values shows similar sigmoid curve in which the value increase throughout the ripening period. Only the h value show opposite trend with negative sigmoid as the value decrease along the ripening period. The skin color changes of the papaya is caused by the chlorophyll degradation and also synthesis of lycopene and carotenoid development which later will turns the skin color from green into red (Saad *et al*., 2014).

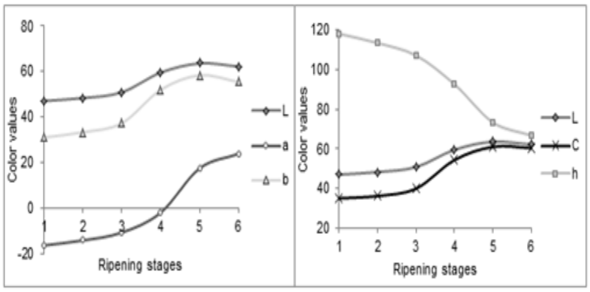


Figure 1. Overall color changes for CIE L*a*b* and CIE L*C*h° along the ripening stage

*The color changes for CIE L*a*b* and CIE L*C*h*

In this study, the green fruits as in RS1 that were harvested at L:16.78, a*:-16.76, b*:25.89, C*:29.76 and h:120.70 unable to ripen correctly with the a value remain negative and almost unchanged throughout the evaluation period. Fruit harvested at L:44.26, a*:-15.01, b*:30.33, C*:32.11 and h:117.87 as in RS2 ripen naturally with their a* value increase steadily.

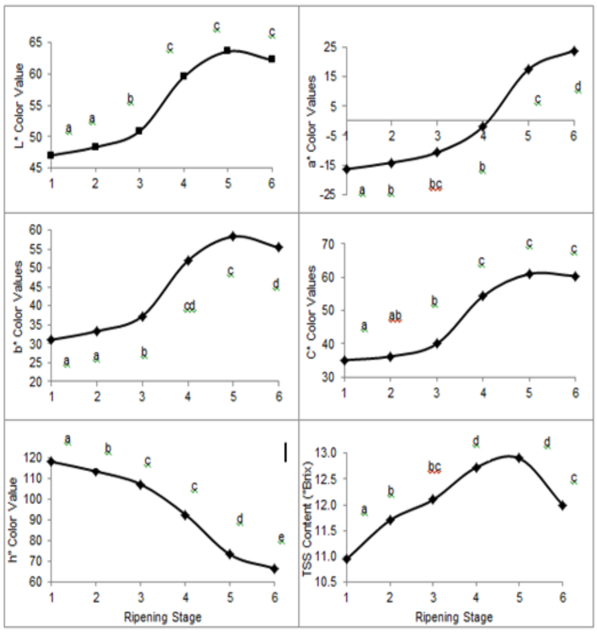


Figure 2. The significance different for CIE L*, a*, b*, C*, h and TSS along the ripening stage

Figure 2 shows L* value increase gradually from RS1 to RS2 with no significance different shown during that stage. However, the value significantly increases from RS2 to RS4. At this instant, the skin color visually illustrates the changing from dark green to light green. The L* value react by either reducing black color or increasing white color for lighter look. Late ripening stage shows no significance different between the ripening stages with slight increase in the L* value. The non-significance different for L* value also obtained in the research by Proulx *et al*. (2005) and Camargo *et al*. (2007).

The trend for the a* color changes shows some significant and non-significant values respectively between early and middle ripening stage while higher significant value obtained during late ripening stage. The skin color significantly illustrate difference during late ripening stage from RS4 to RS6 by the changing from yellow to orange and finally to reddish orange color. The highly significance difference for a* value also obtained by Zuhair *et al*. (2013) and Chutichudet and Chutichudet (2014).

For b* color value, there are no significant different during RS1 to RS2 and RS4 to RS5. The color shows significant changes from the RS2 to RS4. In contrast, Zuhair *et al*. (2013) only obtained significance value in RS5 for the same variety. During that stage, the skin color changes to a yellower color synchronize with the properties for b* value that indicates the yellowness color in the positive value.

As illustrated in figure 2, the skin color for C* value do not show much significance different during that stage similar to the study from Proulx *et al*. (2005) and Camargo *et al*. (2007) with no significance difference for the C* value. The skin color shift obviously to more vivid color from RS3 to RS4 where the skin color of papaya changes to a brighter yellow color.

The change in h value corresponds to the hue angle from the color wheel. h* value is the only variable showing negative trend throughout the ripening period. There was significance different during the early (RS1 to RS3) and late ripening stage (RS4 to RS6). The decreasing of the h color value shows that the skin color moves in negative direction in the color wheel; from green color to yellow and finally to orange color.

Camargo *et al*. (2007) claimed that the overall color changes has a close relationship with chlorophyll degradation which was indicated by the green color of the skin. On the other hand, Schweiggert *et al*. (2011) discussed the correlation of a* value with the carotenoid development in the fruits that responsible for the reddish color of the skin.

TSS analysis

Figure 2 represents the change in TSS content of papaya during the ripening period. There was gradual increase in the TSS content from RS1 until RS5. However, TSS content dropped during RS6. Camara *et al*. (1993) and Schweiggert *et al*. (2011) observed similar gradual increase in TSS content during papaya ripening. The highest average TSS content recorded was 13.5°Brix in RS5. The reason may be due to the method used to obtain the papaya juice. The reading of TSS content obtained always higher when using manual hand squeezing method. Padda *et al*., (2011) claimed that the TSS content at the middle of the fruits is slightly higher due to the ripening behaviour of the fruits which starts from the middle of the fruits. The result showed decrease in TSS content at RS6. At this stage, some of the sugar may be consumed to synthesis sucrose for the respiration of the fruits (Gomez *et al*., 2002; Yao *et al*., 2014). In this study, the best time to consume fresh papaya cv. Sekaki is during RS5 with TSS content ranges from 12.5° to 13.5°Brix. Other studies on the TSS content of fully ripe papaya were 10° to 11.2°Brix for cv. Solo 8 (Yao *et al*., 2014), 10.5° to 11.5°Brix for cv. Pococi (Schweiggert *et al*., 2011) and 9° to 13°Brix for Bangladeshi (Zaman *et al*., 2006).

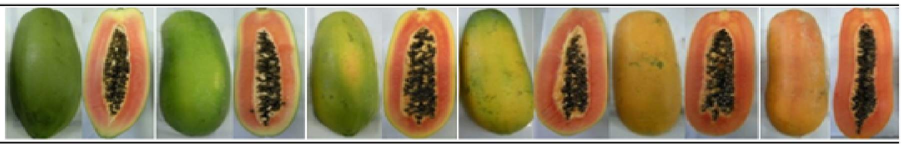
Ripening index

Table 2 shows the improvised ripening index of Malaysian papaya variety, Sekaki with addition of useful information regarding to the ripening stage. The best color indicator also had been selected for the grading of papaya.

Relationship between TSS and color

TSS had nonlinear relationship with color. By using MLR, model generated to enable TSS content predicted from the color value obtained from the colorimeter. TSS content act as dependent variables while color as independent variables. The correlation between TSS and CIE L*a*b* established with

Table 2 Improvised ripening index chart for Malaysian papaya variety, Sekaki

RIPENING STAGE (RS)	RS1	RS2	RS3	RS4	RS5	RS6
Skin Color and Half Cut						
Description	Fully dark green	Green with a yellow strip	Green > yellow	Yellow > green	Yellow with some green	Fully yellow reddish
	Not suitable to harvest	Suitable for export market	Suitable for export market	Suitable for export and local market	Suitable for local market	Suitable for local market
Color indicator	RS1 - RS2: h° values		RS2 - RS3: L* values		RS5 - RS6: h° values	
	116 to 121	100 to 115	45 to 55	56 to 65	70 to 90	60 to 69
TSS (°Brix)	10.5 to 11.5	11.0 to 12.0	11.5 to 13.0	12.0 to 13.5	11.5 to 13.0	11.0 to 12.5

R^2=0.2235 while CIE L*C*h° established with R^2 = 0.9674. Thus, model CIE L*C*h° were selected for the correlation relationship. The model equation generated as below:

$$TSS\ (°Brix) = -16.8155 + 1.0217\ L^* - 0.5758\ C^* - 0.0003\ h°$$

Conclusion

The quality of Malaysian local papaya variety, Sekaki can best be described by the skin color changes. The model equation obtained for CIE L*a*b* is R^2= 0.2235 while CIE L*C*h recorded to be R^2= 0.9938. In conclusion, model CIE L*C*h is best to describe the quality of papaya through the skin color changes. This method is easy, fast and reliable by retaining the physical appearance of the fruits. The h values can be used to indicate early and late ripening stage while the L* color values can best indicate middle ripening stage.

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