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Evaluation of colour behavior during ripening of Banganapalli mango using *CIE-Lab* and RGB colour coordinates

V. Eyarkai Nambi*, K. Thangavel, S. Shahir and V. Geetha

Department of Food and Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore, India.
**E-mail: eyarkainambi@gmail.com*

Abstract

Machine dependent (RGB) and machine independent (CIE-Lab) colours were measured during ripening of Banganapalli mangoes, at 24 h interval and evaluated throughout the ripening period. The machine dependent colour coordinates red (R), green (G) and blue (B) were extracted from the digital images of mangoes taken every day. All the colour coordinates were increasing significantly during the ripening of mango. In total colour difference, major change was observed during 10th day. A steep rise was found in hue angle between 10-11th day of ripening. Croma was increasing up to 20th day and started decreasing. It was found that, the R and G would be 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 would be suitable to predict the ripening of mangoes. These observation could be used as one of the nondestructive tool for mango quality evaluation, mango ripening and optimization studies.

Key words: Banganapalli, ripening, RGB, Lab colour values, colour coordinates, ripening prediction, colour changes, total colour difference

Introduction

India is well known for the production of tropical and subtropical fruits like banana, mango, papaya and citrus fruits. Among these, mango (*Mangifera indica* L.) is considered as most important and is called as king of fruit. It has great demand in world market due to its distinct taste, flavor and colour. India is top fresh fruit prducer of mangoes but rank fifth in exports of fresh mangoes and processed products to more than 50 countries. India produced more than 18 million tons of mangoes in the year of 2013-14 (Tiwari, 2014).

Ripening is an important senescent process which increases the commercial value of the fruits. Since mango is a climacteric fruit, the ripening should be properly controlled to get high value produce. Fruit ripening is a highly co-ordinated, genetically programmed, irreversible phenomenon involving a series of physiological, biochemical, and organoleptic changes that lead to the development of a soft and edible ripe fruit with desirable quality attributes (Prasanna *et al.,* 2007). During ripening, fruits undergoes a series of biochemical, physiological and structural changes which make the fruit attractive to the consumer (Jiang *et al.,* 1999).

During ripening, colour development depends on external conditions and is an important factor in determining the quality of fruit for marketing (Hewage *et al.,* 1996; Marriott and Palmer, 1980). Fruits undergo significant textural and colour transformation as they pass through ripening process. Generally, the colour conversion is from dark green to pale green and then to slight yellow or orange colour from unripe to ripe stage. This is due to chlorophyll degradation, which subsequently reveals the yellow carotenoid pigments (Marriott and Lancaster, 1983; Seymour *et al.,* 1993; Stover and Simmonds, 1987).

Therefore, the study about the changes in colour during the ripening process is of prime importance to predict the quality. Many researchers reported about the changes in colour value in fruits (Collin and Dalnic, 1991; Li *et al.,* 1997; Madrid and Lopez-Lec,1996; Chen and Ramaswamy, 2002; Shahir and Visvanathan, 2014). But reports about colour changes of Indian mangoes during ripening is limited.

Some of the popular colour systems are RGB (red, green and blue), CIE-L*a*b*, CIE XYZ, CIE L*u*v*, CIE Yxy, and CIE LCH (Pathare *et al.,* 2013). Each colour space has its own advantage and disadvantage. Out of these colour spaces, CIE-Lab or L*a*b* colour space and RGB are easy to use, the earlier one is device independent and another one is device dependent. Lightness ('L^*') value, greenness ('a^*') value and yellowness ('b^*') value were useful to determine the development of peel colour of banana and could be a useful replacement of subjective method of colour charts (Kajuna, 1998).

Though CIE-Lab colour space is extensively used for all measurement of colour changes in foods, it should be accentuate that many excellent results have been reported with RGB colour with image processing (Laykin *et al.,* 2002; Ishikawa and Hirata, 2001; Polder *et al.,* 2002). More over the colour measurement in RGB space is easy and cheaper than any other space. Limited reports are available on RGB colour space, especially during ripening of mangoes.

With this perspective, a study was carried out to determine the changes in external peel colour of Banganaplli mangoes during ripening in both CIE-Lab as well as RGB colour space.

Materials and methods

Raw material selection: Fully matured, raw Banganapalli mangoes were harvested at 100-105 DFFB (days from full bloom) from the University orchard and desapping was done in the field

itself. Mangoes were taken to lab in a plastic crates with proper cushioning. Then the mangoes were treated with ethylene at 200 ppm for 24 h at 20 ^{0}C and 85 percent RH. After the treatment, mangoes were kept in temperature controlled chamber (20 ^{0}C and 85 percent RH) for ripening. Every 24 h interval, mango samples were taken for imaging and colour measurement. The measurements were taken till decay of the fruit.

***CIE-Lab* colour measurement:** Colour coordinates were recorded on the surface of the mango using Hunter LAB colour meter (Hunter Associates Laboratory, Inc. USA). Three measurements were taken for each mango at three different places and average value was recorded.

Total colour difference was calculated using following equation,

$$\Delta E = \sqrt{(L_f^*-L_i^*)^2+(a_f^*-a_i^*)^2+(b_f^*-b_i^*)^2} \quad 1$$

$$\text{Chroma} = ((a^*)^2+(b^*)^2)^{0.5} \quad 2$$

$$\text{Hue Angle} = \tan^{-1}(b^*/a^*) \quad 3$$

where, L^* is degree of lightness to darkness, a^* is degree of redness to greenness, b^* is degree of yellowness to blueness, the subscript f and i denotes final and initial value.

Imaging chamber: Shade free image capturing chamber was made with the dimension of 20"x20"x18" (Fig. 1). DSLR camera (Nikon D60) equipped with CMOS sensor was fixed on the top center of the chamber. The circular florescent lamp was used to get proper lighting. Mango fruits were placed in its natural rest position on the flat platform with black background. All the images were taken at constant light intensity (820 lux), constant focal length and constant exposure value.

Image processing: The captured images were transferred to the computer and image processing was done using MATLAB (The Math Works, Inc., USA). Thresholding technique and morphological operations were done to separate the region of interest (ROI) from the background. From the images, three channels were segmented and named as R,G and B for red, green and blue channels respectively. The mean values of each channel inside the ROI were calculated with the help of *for loop* command. The corresponding ratios were found using the following equations.

Red Ratio (RR) = R/G and R/B 4

Green Ratio (GR) = G/R and G/B 5

Blue Ratio (BR) = B/G and B/R 6

Statistical analysis: Single way ANOVA was used to check the level of significance on RGB and $L^*a^*b^*$ values with the ripening days. Statistical analysis and graphical representation were done in Microsoft Excel.

Results and discussion

The total ripening period existed around 23 days for the Banganapalli mangoes. The $L^*a^*b^*$values and RGB values were highly significant (P<0.01) over ripening period.

Changes in *CIE-Lab* values: The changes in L^*, $b^*$and a^*values during the ripening are given in Fig. 2. From the Fig. 2, it could be noticed that all the three colour coordinates ($L^*a^*b^*$) were increasing during the ripening of mango. This may be due to the chlorophyll degradation, which subsequently reveals the yellow carotenoid pigments.

L^* value increased linearly up to 13th day and after that not much increase was found. After 19th day, reduction was observed in L^* value. The b^* values increased drastically up to 14th day and after that, decreasing trend was observed. In case of a^* value, steady increase was found up to 10th day. Drastic increase in a^* was found in the next 10 day, then it was decreasing till end of ripening. The

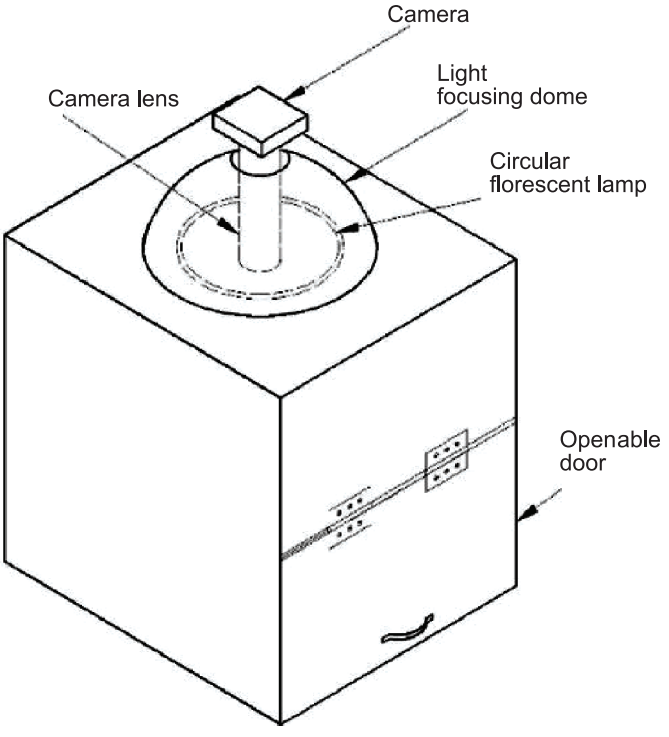

Fig. 1. Schematic diagram of image capturing setup

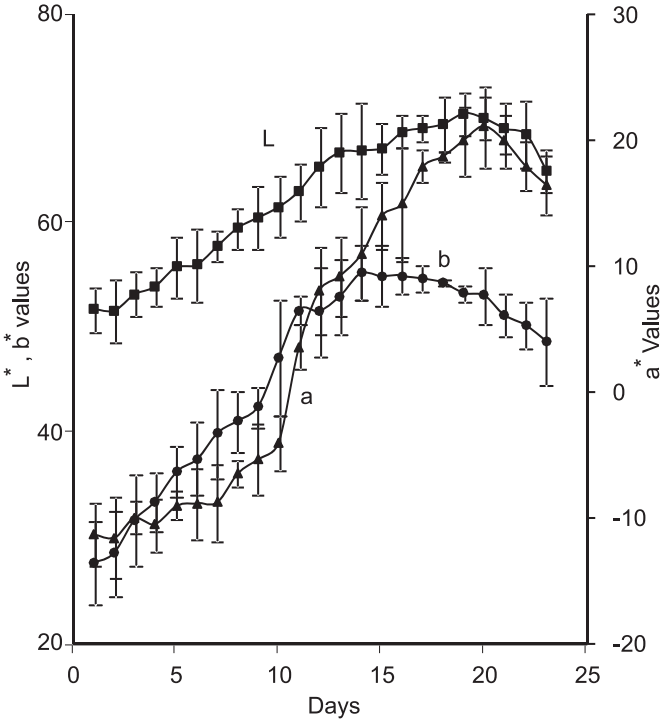

Fig. 2. Change in L^*,$a^*$and b^* during the whole ripening period of Banganapalli mangoes

reduction in L^*, a^* and b^* values during the end phase of ripening is the evidence of decay and fruits spoilage. The L^*a^* b^* values for raw and ripe mangoes are given in Table 1.

Total colour difference is the measure of deviation of individual colour values. Total colour change was calculated for every 24 h interval and plotted with ripening days (Fig. 3). In the initial days the total colour difference was lower and during mid-days higher colour difference was observed. In 10th day major change was recorded in total colour difference. During this period, the ripening process might be accelerated thus lead the higher change in all the three colour coordinates. Similar parabolic curve pattern was reported by Shahir and Visvanathan (2014) in banana.

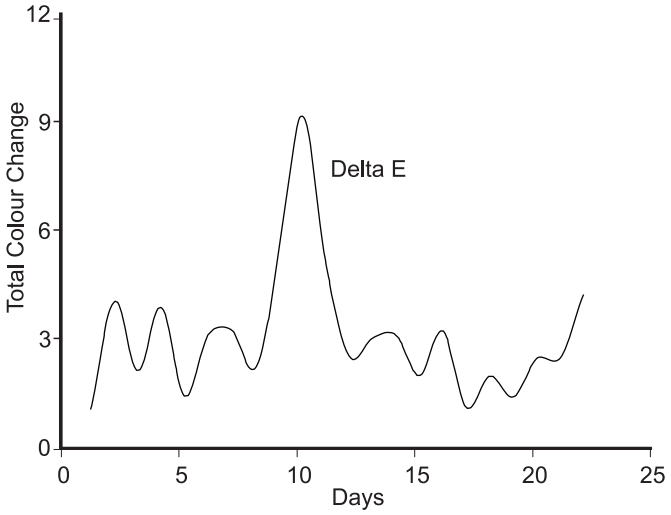

Fig. 3. Change in total colour difference during the whole ripening period of Banganapalli mangoes

Changes in croma and hue angle: The changes in croma and hue angle were calculated using equation 2 & 3 and plotted against ripening period (Fig. 4). Ripening had significant (P<0.01) effect on both the croma and hue angle value.

The croma increased gradually with advancement of ripening and in the later stage of ripening it decreased. But hue angle was in negative side till the maximum colour change. When the mango attained maximum colour change during 10th day (Fig. 4), the hue angle steeply increased to a maximum value and after that, no much changes was observed in hue values. It can be inferred that, when the ripening expedites, the hue value increases drastically.

Changes in RGB values: The changes in RGB values in each day during ripening were plotted with error bars and shown in Fig. 5.

From the ANOVA, it was found that the ripening days significantly influenced (P<0.01) the colour change which lead to change in RGB values. The ripening did not influence the B value more as compare to R and G values. Increasing trend was found in both R and G values. At the same time, no much changes were found in B values. It was observed that the R value had taken lead to G value after 19th day of ripening. There was no much change observed in B value till the last phase of ripening. The raw mango had lower R value than G value. Contrary to this, the ripe mango had higher R value than G value (Table 1). From these findings it could be concluded that the R and G value may be more efficient to predict the ripening rather than B value.

Changes in red ratio (RR): The red ratios were calculated

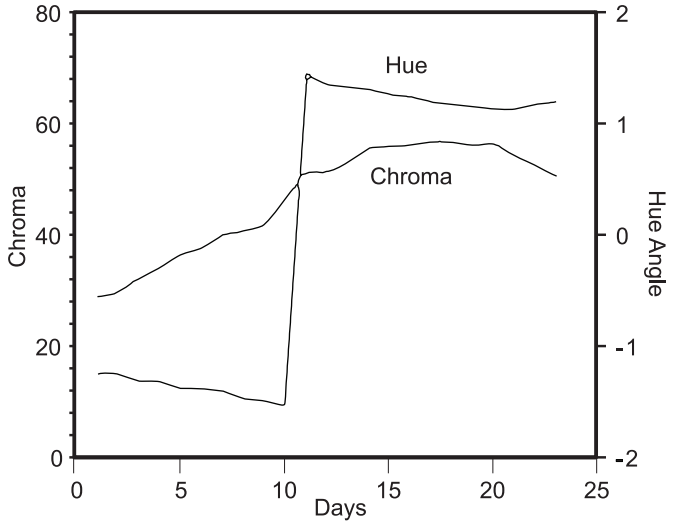

Fig. 4. Change in chroma and hue angle values during ripening of Banganapalli mangoes

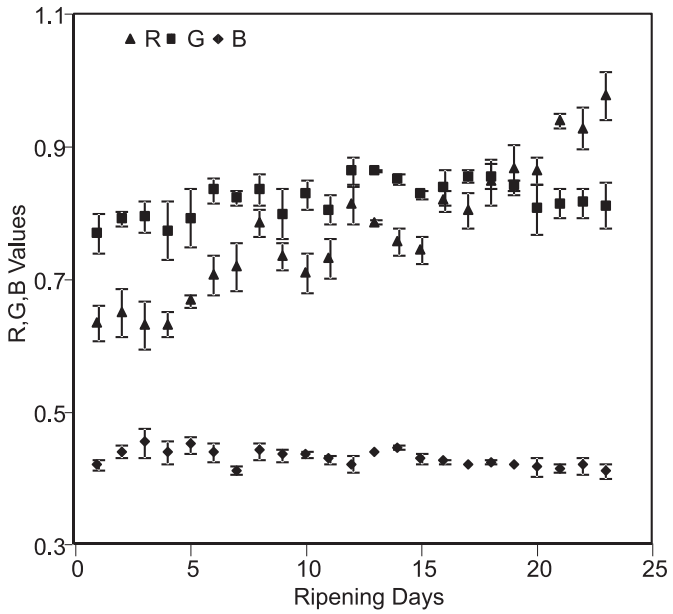

Fig. 5. Changes in R, G and B values of Banganapalli mango during ripening

Table 1. The CIE-Lab and extracted machine dependent colour values and its ratios for raw and ripe mangoes

Parameters		Raw Mango	Ripe Mango
L^*		51.86±2.13	65.05±2.02
a^*		-11.32±2.55	16.43±2.41
b^*		27.75±3.95	48.81±4.12
R		0.63±0.03	0.98±0.03
G		0.77±0.03	0.81±0.04
B		0.42±0.01	0.41±0.01
Red Ratio	R/B	1.51±0.05	2.38±0.11
	R/G	0.82±0.12	1.20±0.03
Green Ratio	G/B	1.83±0.05	1.98±0.01
	G/R	1.21±0.06	0.83±0.06
Blue Ratio	B/R	0.66±0.07	0.42±0.06
	B/G	0.55±0.02	0.51±0.02

Values are means ± SD

using Eq. 4. The changes in red ratios (RR) values in each day during ripening were plotted with error bars and shown in Fig. 6. From the ANOVA, it was found that both the red ratios were significantly influenced ($P<0.01$) during ripening. Increasing trend was found in both the ratios. The rate of increase was more in R/B than R/G ratio. Very low rate of increase was found in R/G. This may be due to the more change in red value and less change in blue value. The R/B was higher for both raw and ripe mango than R/G (Table 1). From these results, it could be concluded that, R/B would be more suitable to predict the ripening rather than R/G ratio.

Changes in green ratio (GR): The green ratios were calculated using Eq. 5. The changes in green ratios (GR) values in each day during ripening with error bars are shown in Fig. 7. From the ANOVA, it was found that both the red ratios were significantly influenced during ripening. Increasing trend was found in G/B ratio whereas decreasing trend was found in G/R ratio. This may be due to the more change in red value during ripening than other two colours. From these results, it could be concluded that, G/B would be more suitable to predict the ripening rather than G/R ratio.

Changes in blue ratio (BR): The blue ratios were calculated using Eq. 6. The changes in blue ratios (BR) values in each day during ripening were plotted with error bars and shown Fig. 8. From the ANOVA, it was found that both of the red ratios were significantly influenced ($P<0.01$) during ripening. Decreasing trend was found in both blue ratios. From these results, it could be concluded that, both blue ratios would be suitable to predict the ripening.

The *CIE-Lab* and machine dependent colour coordinates (R,G and B) were measured throughout the ripening period of Banganapalli mangoes. The change in all the colour parameters was highly significant with ripening period. From the results, it was found that the both the *CIE-Lab* and RGB colour parameters can be used as a nondestructive tool to predict the level of ripening. RGB colour measurement would be more suitable, since it need simple image processing algorithm and low cost instrumentation than *CIE-Lab* colour measurement.

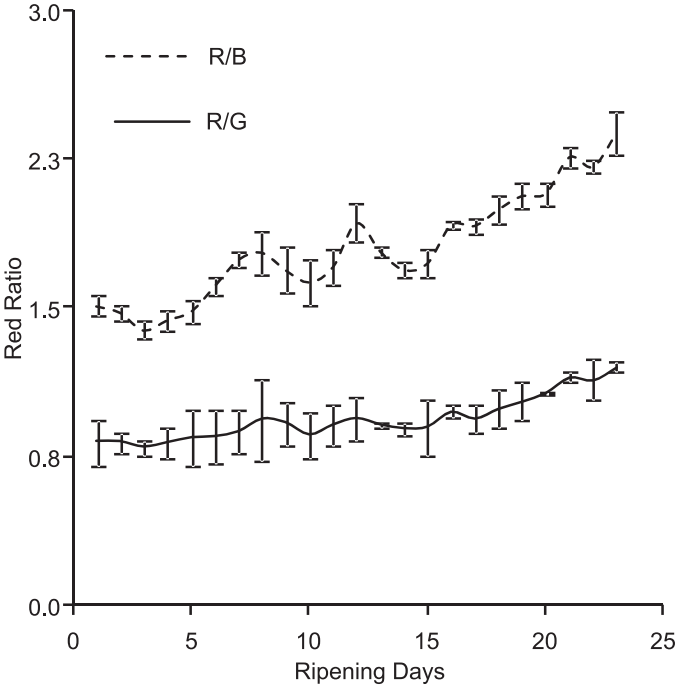

Fig. 6. Changes in red ratio values of Banganapalli mango during ripening

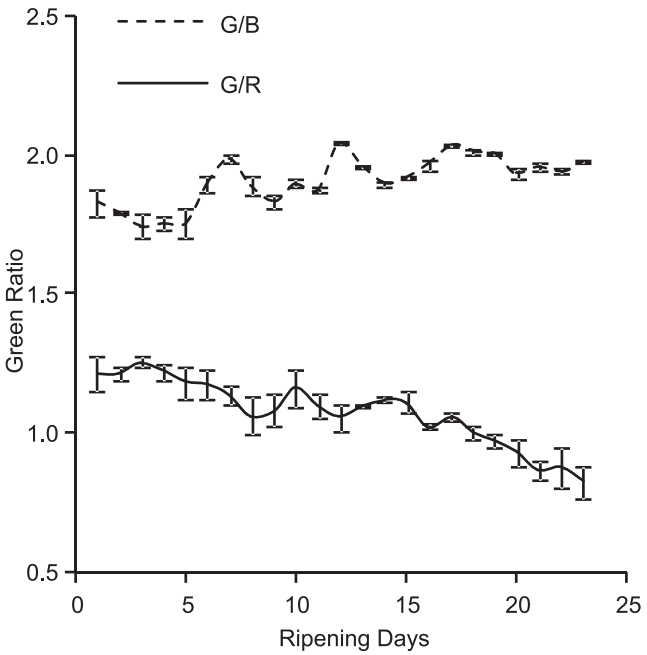

Fig. 7. Changes in green ratio values of Banganapalli mango during ripening

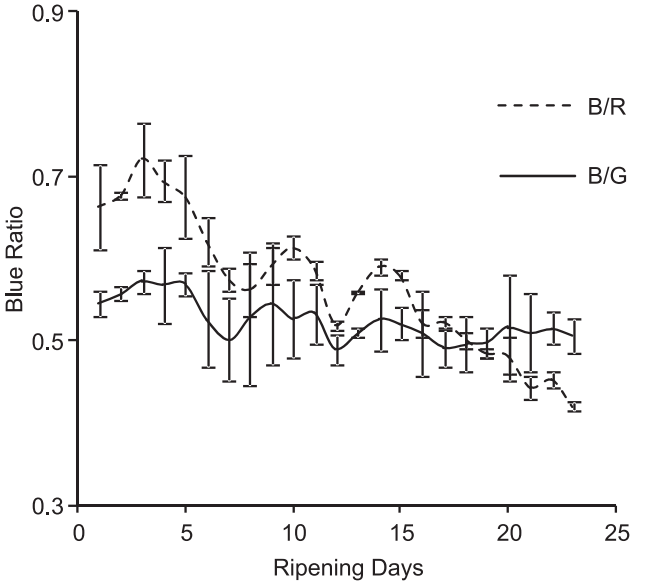

Fig. 8. Changes in blue ratio values of Banganapalli mango during ripening

References

Chen, C. and H. Ramaswamy, 2002. Color and texture change kinetics in ripening bananas. *LWT-Food Science Technology*, 35: 415-419.

Collin, M.N. and R. Dalnic, 1991. Evolution de quelques critères physico-chimiques de la banane plantain (cultivar *Orishele*) au cours de la maturation. *Fruits*, 46: 13-17.

Hewage, K., H. Wainwright and R. Wijeratnam, 1996. Quantitative assessment of chilling injury in bananas using a colorimeter. *Journal Horticultural Science*, 71(1): 135-139.

Ishikawa, Y. and T. Hirata, 2001. Color change model for broccoli packaged in polymeric films. *Transactions ASAE*, 44: 923-927.

Jiang, Y., D.C. Joyce and A.J. Macnish, 1999. Responses of banana fruit to treatment with 1-methylcyclopropene. *Plant Growth Regulation*, 28: 77-82.

Kajuna, S.T. 1998. Color changes in bananas and plantains during storage. *Journal Processing Preservation*, 22: 27-40.

Laykin, S., V. Alchanatis, E. Fallik and Y. Edan, 2002. Image-processing algorithms for tomato classification. *Transactions ASAE*, 45: 851-858.

Li, M., D.C. Slaughter and J.F. Thompson, 1997. Optical chlorophyll sensing system for banana ripening. *Postharvest Biology Technology*, 12: 273-283.

Madrid, M. and F. Lopez-Lee, 1996. Differences in ripening characteristics of controlled atmosphere or air-stored bananas. Paper read at International Postharvest Science Conference Postharvest, 464.

Marriott, J. and P. Lancaster, 1983. Bananas and Plantains. In: *Handbook of Tropical Foods*. Edited by Harvey T and Chan Jr, Marcel Dekker, Inc. New York.

Marriott, J. and J.K. Palmer, 1980. Bananas—physiology and biochemistry of storage and ripening for optimum quality. *Critical Reviews Food Science Nutrition*, 13: 41-88.

Pathare, P.B., U.L. Opara and F.A.-J. Al-Said, 2013. Colour measurement and analysis in fresh and processed foods: a review. *Food and Bioprocess Technology*, 6: 36-60.

Polder, G., G. Van der Heijden and I. Young, 2002. Spectral image analysis for measuring ripeness of tomatoes. *Transactions-American Society of Agricultural Engineers*, 45: 1155-1162.

Prasanna, V., T. Prabha and R. Tharanathan, 2007. Fruit ripening phenomena–an overview. *Critical Reviews Food Science Nutrition*, 47: 1-19.

Seymour, G.B., J.E. Taylor and G.A. Tucker, 1993. *Biochemistry of Fruit Ripening*: Chapman & Hall. New York.

Shahir, S. and R. Visvanathan, 2014. Changes in colour value of banana var. grand naine during ripening. *Trends Biosciences,* 7: 726-728.

Stover, R.H. and N.W. Simmonds, 1987. *Bananas.* Longman Scientific & Technical, Essex UK.

Tiwari, R.K. 2014. *Indian Horticulture Database 2013*. New Delhi: National Horticulture Board, India.

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