International Journal of Agriculture, Environment and Biotechnology
Citation: IJAEB: 8(1): 83-87 March 2015
DOI Number: 10.5958/2230-732X.2015.00011.X
©2015 New Delhi Publishers. All rights reserved

HORTICULTURE

Seasonal variations in peel colour in relation to fruit development of grapefruit (*Citrus paradisi* Macf.)

Sukhchain Singh*, Pushpinder Singh Aulakh and Parmpal Singh Gill

Department of Fruit Science, Punjab Agricultural University, Ludhiana – 141004, Punjab, India.

*Corresponding author: boparai.sukhchain@yahoo.com

Paper No. 295 Received: Accepted: Published: 25 March 2015

ABSTRACT

The studies on seasonal variations in peel colour of grapefruit cv. Star Ruby were carried out in order to explain the relationship between fruit growth and colour development. The fruit diameter of the grapefruit increased from 90 days after fruit set to the maturity of fruit. The seasonal variation in fruit diameter was recorded 12.83% during fruit development. The increase in a* coordinate, which represented the gradual loss of greenness, continued until mid-November at 210 DAFS. Calorimetric coordinate b* values always remained positive and increased until the fruit maturity and showed yellow tinge. The hue angle values decreased continuously from start of sampling to the harvest of fruit with appearance of pinkish-yellow tone. Seasonal variation in the hue angle was recorded 26.80%. The negative correlation was observed between hue angle and the fruit development with the advancement of fruit maturity. However, studies have reported positive correlation was recorded between colour space values (L*, a*, b* and C*) with fruit development. The maximum seasonal variation was noted in colour parameter a* (CV = 189.99%) and minimum seasonal variation was noted in L* (CV = 9.42%).

Highlights

- Grapefruit peel colour changed from green to pinkish-yellow at maturity.
- Higher seasonal variation in colour parameter a* and hue angle were recorded.

Keywords: Grapefruit, colour, fruit development, correlation, seasonal variations.

Citrus fruits occupy a key position among the tropical and sub-tropical fruits of the world (Jawandha *et al.*, 2014). Among citrus fruits, grapefruit (*Citrus paradise* Macf.) is consumed widely in today's health conscious world as a protector against cardiovascular diseases and cancers (Kiani and Imam 2007). Under sub-tropics of India, the main flowering period of grapefruit occurs during the month of March with a winter harvest period. Harvest maturity for grapefruit has been based on visual and destructive tests. Palma *et al.*, (2011) described that ripening occurs in the final phase of fruit development, and involves deep metabolic changes in the biochemistry, physiology and gene expression of the fruit in the form of chlorophyll degradation and pigment biosynthesis. The colour of fruit is derived from natural pigment and changes as the fruit proceeds towards maturity. The primary pigments imparting colour quality are the fat soluble chlorophylls, carotenoids and water soluble anthocyanins, flavonoids. Grapefruit should meet some quality standards such as colour intensity and size at harvesting to ensure good returns to growers.

Fruit colour is important harvest index with L*, a* and hue values being the best parameters to discriminate among different maturity stages (Mercado-Silva *et al.*, 1998) and the colour measuring instruments are

commonly used in developing countries to detect the fruit maturity (Jha *et al.*, 2009). Fruit colour is a key attributes because it is the first property observed by growers and consumers to judge maturity stage and quality. The values of colour difference, chromaticity difference (C*) and hue difference showed differences between mature green and yellow fruit as a function of ripeness stages (Kovacs *et al.*, 2010. The aim of the study was to ascertain relationship between stages of fruit development of grapefruit and colorimetric coordinates L*, a* and b*.

Materials and Methods

Experimental site and peel colour measurements

Fresh fruits of grapefruit cv. Star Ruby were collected from well managed plants growing at Regional Station of Punjab Agricultural University at Abohar, Punjab (India). Fruits were harvested manually at monthly intervals from July to December and peel colour was determined at 90, 120, 150, 180, 210 and 240 days after fruit set (DAFS). At each sampling time, the diameter of fruit was measured with digital vernier's caliper's (Mitutoyo, Japan). Similarly, the rind colour was measured by using a Hunter Lab (model ColorFlex, Reston, USA), with reflectance mode (RSIN), CIE Lab scale (L*, a* and b*). The instrument was calibrated with a standard white ceramic tile and black tile and set up for D65 as illuminate and a 10° observer angle. Sampling was carried out by loading the quartz cuvettes with fruit peel sample. The colour was determined using a CIE L*, a*, b* colour system, where L* indicate luminosity or lightness (L* = 0 for black and L* = 100 for white), and the chromatic parameters a* represent the proportion of redness. On horizontal axis, positive a* indicate a Hue of red-purple; negative a*, of bluish-green. On the vertical axis, b* represent the proportion of yellowness and varies from blue (-) to yellow (+). The colour purity indicated as chroma C* is calculated as C* = (a*2 + b*2)1/2 and colour tone indicated as Hue angle (h°) in a colour wheel of 360° (0° = red-purple, 90° = yellow, 180° = bluish-green and 270° = blue) is calculated as h° = arctan (b*/a*) described by McGuire (1992).

Statistical analysis

The data were analyzed with SAS software version 9.3 (SAS Institute Inc., Cary, NC, USA) using one-way analysis of variance. The differences between means were tested using the LSD test at 0.05 significance level. The mean and standard errors of means are also tabulated. Regression analysis was undertaken to find the relative correlation for seasonal variation between fruit development and colour.

Results and Discussion

Fruit diameter

In general, the fruit diameter increased with advancement of season and it was minimum (62.85mm) at 90 DAFS and maximum (90.48mm) at 240 DAFS (Figure 1). The first sharp fruit growth phase was recorded from 90-150 DAFS. Second growth phase was recorded from 150-180 DAFS and this phase showed less increase in average diameter as compared to first growth phase. The third growth phase was noted from 180-210 DAFS and thereafter, non-significant increase in diameter was noted. The increase in fruit diameter might be due to an increase in cell size because of cell division and cell elongation, which enabled the maximum accumulation of food materials. The present result was in conformity with the findings of Dalal *et al.*, (2013) in Kinnow and Lamare *et al.*, (2013) in Sohshang. Seasonal variation of 12.83% was recorded in the fruit diameter during fruit development.

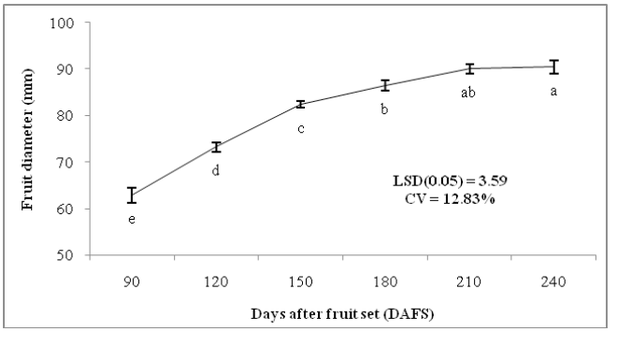

Figure 1. Fruit diameter of grapefruit at different periods of fruit development. LSD indicates the least significant difference test at $p<0.05$. Values are means ± SE and with a common letter are not significantly different at 5% level.

Table 1 Peel Colour properties (L*, a*, b*, C* and h0) of grapefruit at different periods of fruit development.

Days After Fruit Set (DAFS)	L*	a*	b*	Chroma (C*)	Hue angle (h°)
90	44.32±1.09c	-6.53±0.00e	19.67±0.39d	20.73±0.37e	108.39±0.33a
120	49.40±0.81b	-6.12±0.80e	22.88±0.39c	23.70±0.59d	104.89±1.63a
150	50.02±0.38b	0.24±0.04d	24.69±0.02b	24.69±0.02d	89.29±0.08b
180	55.12±0.65a	10.95±1.21c	25.27±0.41b	27.57±0.82c	66.71±2.02c
210	56.94±0.73a	14.93±1.27b	28.91±0.94a	32.56±1.39b	62.81±1.32d
240	57.20±0.28a	20.82±0.09a	28.69±0.64a	35.45±0.57a	53.99±0.52e
LSD (0.05)	2.45	2.67	1.76	2.33	3.74
CV (%)	9.42	189.99	13.59	19.59	26.80

LSD indicates the least significant difference test at $p<0.05$. Values are means ± SE and with a common letter are not significantly different at 5% level. CV indicates coefficient of variation.

Fruit colour parameters (L*, a*, b*, C* and h°)

Changes in colour are an important factor which determines the fruit quality (Kaur *et al.*, 2013). Use of Hunter Lab is non destructive determination of fruit colour for reliable harvest index in grapefruit. A gradual change in fruit colour from dark green to pinkish-yellow was observed with the advancement of maturity towards ripening. The change in skin colour towards fruit maturation is shown by the overall significant increases in the L*, a*, b*, C* and decreases in hue angle (h°) values of fruit peel (Table 1). The greater change in rind colour of fruit was observed from 90 DAFS to 180 DAFS for values of L*(44.32±1.09 to 55.12±0.65), a*(-6.53±0 to 10.95±1.21) and b*(19.67±0.34 to 25.27±0.41). Thereafter, a complete colour development stage was noticed at 210 DAFS with values of L*, a* and b* were recorded 56.94±0.73, 14.93±1.27 and 28.91±0.94, respectively. The increase in a* coordinate, which represents the gradual loss of greenness and appearance of pinkish-yellow tinge on fruits during mid November at 210 DAFS. Similar results were recorded by Machado *et al.*, (2011) in grapefruit, who reported that peel colour varied from yellow to pinkish. Calorimetric coordinate b* always remained within yellow (positive) values, although masked at the beginning by the green colour of chlorophylls (coordinate a*) and continued to increase until the mid of November at 210 DAFS and showed yellowish tinge. The loss of green colour with advancement of fruit maturation may be attributed to decreased chlorophyll content as reported by Deka *et al.*, (2006) in Khasi mandarin and Ram *et al.*, (2005) in Kinnow mandarin. A non-significant changes about the value of L* from 180-240 DAFS and from 210-240 DAFS for the value of b* was observed. But a* value changed significantly with season till the last date of sampling at 240 DAFS. Similar results observed by Rosalizan *et al.*, (2010) in Morinda citrifolia.

The chroma values (C*) were increased from minimum of 20.73±0.37 at 90 DAFS to the maximum value of 35.45±0.57 at 240 DAFS. Similarly, the other important colour parameter in grapefruit is hue angle, which is the attribute of perceived colour. It was recorded that the hue angle values decreased continuously from 90 DAFS to the maturity of fruit at 240 DAFS and the colour of the fruit was recorded between yellow to red region in a colour wheel of 360°. Similarly in Mosambi, Ladaniya and Mohalle (2011) reported that hue angle (h°) declined with

maturation and fruit colour turned yellow after 250 days. The minimum hue angle (h°=53.99±0.52) of fruit peel was recorded at the 240 DAFS. But the maximum hue angle (h° = 108.39±0.33) was noted at 90 DAFS in the green region during the initial stage of fruit development. The maximum seasonal variation was noted in colour parameter a* (CV = 189.99%) and minimum seasonal variation was noted in L* (CV = 9.42%). Similarly, Alam-Eldein (2012) showed that peel colour index is an indicator of early changes, to some extends and as such may be used as a quick and easy tool to determine the level of peel maturity.

Relationship between fruit colour parameters (L*, a*, b*, C*, ho) and fruit development

Regression equations for the prediction of fruit maturity based on L*, a*, b*, chroma and hue values are given in Figure 2. Studies revealed there exit strong correlations between colour space values (L*, a*, b*, C* and ho) with the fruit development period. All of these changes were highly significant ($p < 0.05$) and fruit maturity had effect on colour parameters. The strong linear relationship, in present study was found between a* and fruit development ($R^2 = 0.96$). The R^2 value indicates that 96% of the variation can be accounted for the change in a*. The colour values b* ($R^2 = 0.94$) and L* ($R^2 = 0.93$) were also strongly correlated with fruit development period. The R^2 values indicate that 94% and 93% variation in data can be accounted by the change in b* or L*, respectively. Similarly, the positive correlation was recorded in the chroma and fruit development. The determination ratio was recorded $R^2 = 0.97$, which accounted 97% variability in data. The negative correlation was recorded between hue angle and the fruit development, which implies that hue angle decreased with the advancement of fruit maturity. The study suggests that fruit development correlated with fruit peel colour and this may be useful for establishing harvest guidelines to avoid harvesting too early (immature fruit) or too late (senescent fruit) so that less postharvest injuries occur while the fruit still has acceptable quality (Sirisomboon and Theamprateep, 2012).

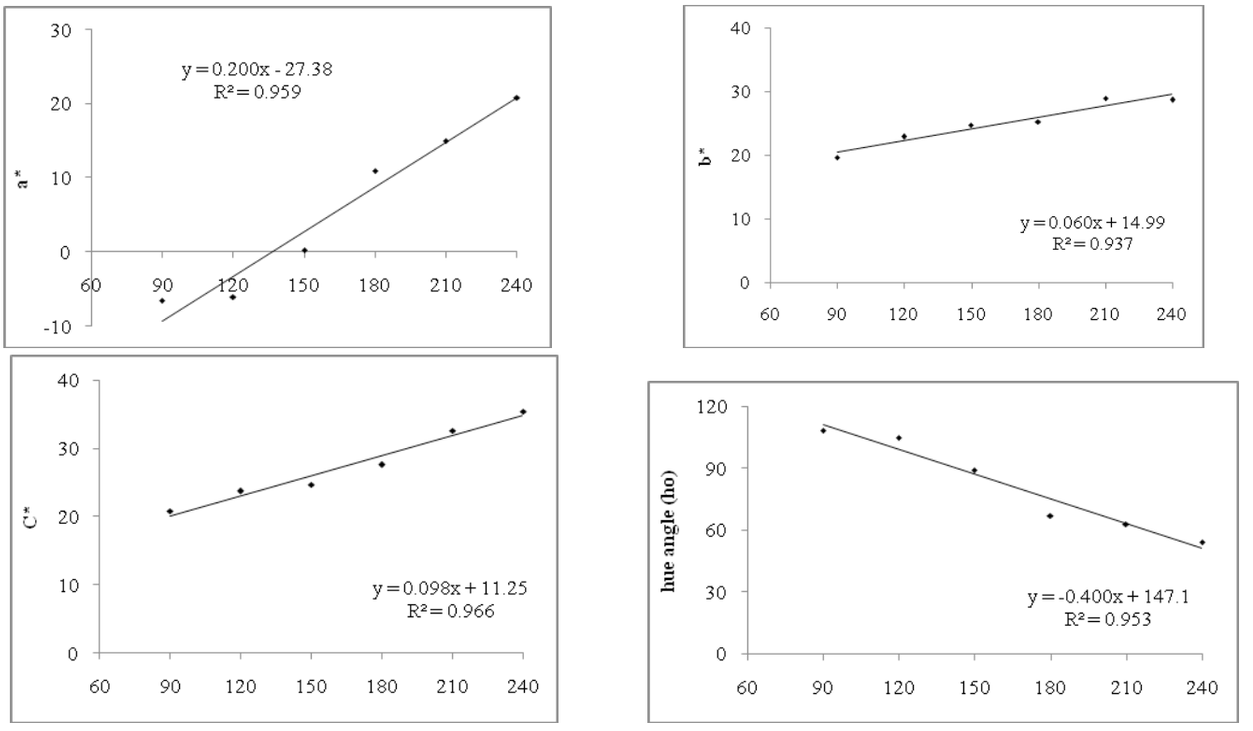

Figure 2 Relationship between colour parameters (L*, a*, b*, C* and h°) and fruit development. R^2 indicates dynamic intensity.

Conclusion

It can be concluded that there exists linear relationship between fruit peel colour parameters and fruit development. The coordinate a*, which represents the gradual loss of greenness and hue angle represents colour tone, which is 62.81° during maturity period and showed pinkish-yellow tone.

References

Alam-Eldein SM, Albrigo LG (2012) Characterization of 'Marsh' grapefruit peel maturation and its relationship to postharvest handling and keeping quality. *Acta Horticulture* **945**: 157-164.

Dalal RPS, Beniwal BS, Sehrawat SK (2013) Seasonal variation in growth, leaf physiology and fruit development in kinnow, a mandarin hybrid. *J Plant Stud* **2**(1): 72-77. doi:10.5539/jps.v2n1p72

Deka BC, Sharma S, Borah SC (2006) Post-harvest management practices of mandarin. *Indian Journal of Horticulture* **63**: 251-255.

Jawandha SK, Singh Harminder, Arora Anita, Singh Jagjit (2014) Effect of modified atmosphere packaging on storage of baramasi lemon (Citrus limon (L.) Burm). *International Journal of Agriculture, Environment and Biotechnology* **7**(3): 635-638. doi: 10.5958/2230-732x.2014.01369.2

Jha SN, Chopra S, Kingsly ARP (2009) On-farm non-destructive determination of maturity of intact mango fruits. *Indian Journal of Horticulture* **66**: 353-357.

Kaur B, Jawandha SK, Singh Harminder, Thakur Anirudh (2013) Effect of putrescine and calcium on colour changes of stored peach fruits. *International Journal of Agriculture, Environment and Biotechnology* **6**(2): 301-304.

Kiani J, Imam SZ (2007) Medicinal importance of grapefruit juice and its interaction with various drugs. *Nutrition Journal* **6**: 33. doi: 10.1186/1475-2891-6-33

Kovacs E, Siddiqui S, Kristof Z, Toth-Markus M, Roth E (2010) Physiological and ultrastructural changes in Ber (Zizyphus mauritiana Lamk.) fruits during ripening. *Acta Aliment Hung* **39**: 109–118. doi: 10.1556/aalim.39.2010.2.16

Ladaniya MS, Mahalle BP (2011) Fruit maturation and associated changes in mosambi orange (Citrus sinensis). *Indian Journal of Agricultural Science* **81**: 494- 499.

Lamare RL, Deka BC, Nath A, Patel RK (2013) Dynamics of physico-chemical values in Sohshang (Elaegnus latifolia L.) across Maturity. *Indian J Hill Fmg* **26**: 49-53.

Machado FLC, Oliveira VS, Costa JMC (2011) Postharvest quality of grapefruit (Citrus paradisi Macf.) produced from initial planting in Ceara State, Brazil. *Rev Cienc Agron* **42**: 965-970. doi: 10.1590/s 1806-66902011000400019

McGuire RG (1992) Reporting of objective color measurements. *Horticulture Science* **27**: 1254-1255.

Mercado-Silva E, Benito-Bautista P, Garcia-Velasco MA (1998) Fruit development, harvest index and ripening changes of guavas produced in central Mexico. *Postharvest Biol Tec* **13**: 143–150. doi: 10.1016/s0925-5214(98)00003-9

Palma JM, Corpas FJ, Del-Rio LA (2011) Proteomics as an approach to the understanding of the molecular physiology of fruit development and ripening. *Journal of Proteomics* **74**: 1230–1243. doi: 10.1016/j.jprot.2011.04.010

Ram L, Godara RK, Siddiqui S, Sharma RK (2005) Changes in physiological traits in Kinnow mandarin at various stages of fruit maturity. *Indian Journal of Horticulture* **62**: 133-136.

Rosalizan MS, Rohani MY, Khatijah I (2010) Physico-chemical characteristics of Morinda citrifolia fruit during growth and maturation. *Journal of Tropical Agriculture and Food Science* **38**: 21–30.

Sirisomboon P, Theamprateep C (2012) Physicochemical and textural properties of pomelo (*Citrus maxima* Merr. cv. Kao Nam Pueng) fruit at preharvest, postharvest and during the commercial harvest period. *Philipp Agric Scientist* **95**: 43-52.