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The difference of quality of citrus fruits on different levels of maturity during storage period

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Abstract

This research was conducted at farmers' oranges field in Belantih Village, Kintamani District, Bangli Regency, Bali, and Laboratory of Agriculture Faculty of Warmadewa University. The aim of the study was to know the difference of quality of Siam citrus fruits at different fruit maturity levels during storage period. The experiment used randomized block design. The treatment was fruit maturity, consisting of 4 levels i.e FM1 = harvested 22 weeks after flowering (WAF) with physical appearance of green fruit skin, FM2 = harvested at 24 WAF with green yellowish fruit skin, FM3 = harvested at 26 WAF with yellow-greenish fruit skin, and FM4 = harvested at 28WAF with yellow fruit skin, each repeated 6 times. The results showed, the riper harvested fruit the sweeter the taste, which reflected by the higher total dissolved solids and sugar/acid ratio, but the shelf life was shorter because the fruits were rapidly shrinking and loss of weight and quickly damaged. However, if the fruits harvested too young (before the age of 26 WAF) the quality of the fruits were low reflected by lower of weight per fruit and fruit diameter and decreased the quality of the fruit during storage was faster. Based on the result of this research, to get good quality of Siam Citrus fruit and kept longer on storage the fruit harvest should be done at age 26 WAF with physical appearance characteristic of yellow green fruit skin.

Keywords: Siam Orange; Fruit Skin Color; Storage; Maturity

1. Introduction

Orange is the third most important fruit commodity in Indonesia after bananas and mangoes, both in terms of production quantity and consumption needs as well as in terms of trade value. Siam orange (*Citrus nobilis* var. Microcarpa Hassk) is one of the most cultivated citrus species in Indonesia and dominates 60% of the national and regional citrus market [1].

The production and quality of citrus fruit produced is influenced by the level of technology used by farmers from cultivation process to post-harvest handling. Generally, farmers do not harvest citrus fruits at the right time or not based on physiological ripeness criteria because it places more emphasis on when there is an order from collectors, causing the quality of the fruits marketed to be of low quality. The low quality of citrus fruits produced by farmers will affect consumer interest [2-4].

Good quality citrus fruits, apart from being determined by physical properties such as fruit size, fruit weight, fruit diameter and volume, is also determined by the content of chemical components such as vitamin C and sugar content or total dissolved solids (TDS). Differences in the content of chemical components are also influenced by the level of fruit maturity and environmental factors [5-7]. The level of maturity of citrus fruit is related to the color of the skin so that the skin color can be used to identify the fruit is still unripe, half-ripe, ripe or overripe [4], [8]. According to Hasimi et al. [9], skin color is the main determinant of the quality of Siam oranges, where the uniform yellowish skin color provides the best quality so that it is most favored by consumers.

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Besides the physical and chemical quality of the fruit, the shelf life of the fruit is also very important to note. Good fruits quality and longer shelf life of citrus fruits are obtained when harvesting is carried out at the right maturity level [10]. Harvest time of fruit that is too young tends to provide a longer shelf life but fruit quality, both physical and chemical, is generally low. On the other hand, when the harvest time is too old, the fruit hardness is low and the shelf life is shorter [5], [11]. In tomatoes, overripe harvest will result in decreased vitamin C, high weight loss, and a relatively short shelf life. High weight loss causes fruit to lose its freshness, wrinkled fruit skin so that the appearance of the fruit becomes less attractive and unfit to be marketed [12]. According to Roongruangsri et al. [13] and Kumar and Ramasamy [14], in citrus fruit shelf life is one parameter that has an important role in fruit trade. Fruit with a long shelf life allows for a longer trade distribution channel when marketed.

As a horticultural commodity, fresh Siam oranges generally have a perishable property because they contain a lot of water and after being harvested this commodity is still undergoing a life process such as respiration and ripening. This biochemical process reduces the quality of citrus fruit freshness which can be seen in the physical and chemical properties of the fruit. Siam citrus fruits must get the right postharvest technology and harvest should be done before they are ripe so that the freshness of the fruit and its shelf life can last longer, because storage time greatly affects the physical and chemical properties of the fruit [15].

The right harvest time for Siam oranges is when the fruit is optimally ripe or physiologically ripe, marked by a glossy yellowish green skin [16]. According to Qomariah et al. [5] physiological ripeness of Siam citrus fruit is at 26 weeks after flowering (WAF) with a total dissolved solids (TDS) content exceeding 100 ^{0}Brix. However, the reality at the farmer level is that the right harvest time is often ignored, apart from not knowing the importance of harvesting at the right time, it is also strongly influenced by market prices. If the price is high, the fruit is immediately harvested even though it is not physiologically ripe, but if the price is not good, the citrus fruit is allowed to pass through physiological maturity so that the quality is low and the shelf life is short. Based on that description, the aimed of the study was to study the differences in the quality of Siam oranges at different maturity levels during the storage period.

2. Material and methods

The study was conducted in a farmer's Siam citrus plantation in Belantih Village, Kintamani District, Bangli Regency. Analysis of the physical and chemical properties of fruit was carried out at the Laboratory of the Faculty of Agriculture, Warmadewa University, Denpasar and the Food Analysis Laboratory, Faculty of Agricultural Technology, Udayana University. The study was conducted from November 2021 to May 2022.

The study used a simple Randomized Block Design. The treatments tested were fruit maturity level consisting of 4 levels, i.e harvested at 22 weeks after flowering (WAF) with a physical appearance of green skin (FM_1), harvested at 24 WAF with yellowish green skin (FM_2), harvested at 26 WAF with a greenish-yellow skin (FM_3), and harvested at 28 WAF with an even yellow skin (FM_4). At each level of maturity, the fruit was stored at room temperature and then its physical and chemical quality were observed. Each level of fruit ripeness was repeated 6 times and each experimental unit used 20 fruits as a fixed sample and a destructive sample, placed in a tray, so that a total of 480 fruits were needed.

Citrus plants that will be harvested for fruit sample are properly maintained following the guidelines of Good Agricultural Practices (GAP) for Siam citrus cultivation, including garden cleaning, pest and disease control, weed control, pruning of dead and diseased branches and twigs, fertilization with 10 kg/tree cow manure and 250 g/tree NPK fertilizer. The time of flowering on selected citrus trees was marked to determine the age of the fruit when picking.

Harvest time to get fruit according to FM_1, FM_2, FM_3, and FM_4, carried out simultaneously. The trick was to choose the fruit according to the criteria and the time the flower appears according to the sign given. Before storing, the fruit was cleaned with a tissue to remove dirt on the surface of the fruit skin. The cleaned fruit was placed in a tray and stored at room temperature. Observations were made on day 0 (shortly after harvest), 4 and 8 days after storage (DAS). The variables observed included weight per fruit, fruit diameter, weight loss of fruit, fruit moisture content, total dissolved solids (^{0}Brix), sugar/acid ratio, fruit hardness level, vitamin C content, and percentage of damaged fruit. Observational data were tabulated, then analysis of variance was performed. If the treatment has a significant effect, then a 5% LSD test was carried out.

3. Results and discussion

The results of the analysis of variance showed that the treatment of harvest time had a significant effect on almost all of observed variables, except for the water content of the fruit at 4 DAS and the vitamin C content of the fruit at 0, 4 and 8

DAS was not significant different effect. Table 1 showed that the highest weight per fruit at 0 DAS (at harvest) was 146.26 g obtained in FM_3 treatment (harvested at 26 WAF) and significantly higher than the weight per fruit at FM_1 (harvested at 22 WAF) and WF_4 (harvested at 28 WAF) with weight per fruit of 142.58 g and 143.07 g, respectively. On the 4th and 8th day of observation, there was a decrease in weight per fruit at all levels of fruit maturity. A high decrease in fruit weight from 0 to 8 DAS occurred in WF_1 and WF_4 with decreased values of 19.58 g (13.73%) and 19.19 g (13.41%). This caused the weight per fruit at 8 DAS observations at WF_1 (124.00 g) and WF_4 (123.88 g) to be significantly lower than at WF_3 (128.00 g) and WF_2 (126.58 g). The decrease in weight per fruit at 8 DAS was also followed by the decrease in fruit diameter. The lowest decrease in fruit diameter from 0 to 8 DAS occurred at WF_3 which was only 3.59% and this caused the fruit diameter at 8 DAS at the highest WF_3 (6.71 cm) to be significantly higher than in WF_1, WF_2 and WF_4 with fruit diameters of 6.30; 6.38; and 6.31 g, respectively (Table 1). During storage, the fruit shrinks due to the loss of water and dry matter in the process of transpiration and respiration. Weight loss will increase with the length of storage so that it plays a very large role in determining the shelf life of fruit [11], [14], [17].

Table 1 Effect of maturity level of Siam citrus fruits on weight per fruit, fruit diameter, fruit hardness level and weight loss of fruit during storage

Day after storage (DAS)	Treatments	Weight per fruit (g)	Fruit Diameter (cm)	Fruit hardness level (kg/cm^2)	Fruit weight loss (%)	Percentage of damaged fruit (%)
0	FM_1	141.58 c	6.84 b	4.97 a	-	-
	FM_2	145.10 ab	6.94 b	4.87 a	-	-
	FM_3	146.26 a	6.96 a	4.80a	-	-
	FM 4	143.07 bc	6.84 a	4.48 b	-	-
	LSD 5%	2.70	0.28	0.32	-	-
4	FM_1	132.77 a	6.08 a	4.85 a	7.61 b	3.00 b
	FM_2	135.12 a	6.72 a	4.68 a	6.07 c	3.03 b
	FM_3	134.76 a	6.74 a	4.46 ab	7.32 b	6.67 b
	FM 4	128.40 b	6.66 ab	3.86 b	9.88 a	10.00 a
	LSD 5%	2.50	0.26	0.33	0.68	2.77
8	FM_1	124.00 b	6.30 b	3.89 a	12.99 a	3.30 b
	FM_2	126.58 a	6.38 b	3.82 a	11.80 b	3.33 b
	FM_3	128.00 a	6.71 a	3.70 a	12.88 a	6.97 b
	FM 4	123.88 b	6.31 b	3.06 b	13.11 a	13.33 a
	LSD 5%	2.38	0.31	0.35	0.89	4.89

Note: The numbers followed by the same letter in the same column in each day after storage show no significant effect on the 5% LSD test.

Besides the decrease in fruit weight loss, storage time also causes fruit damage. In Table 1 it can be seen, the age of fruit harvest affects the percentage of damaged fruit during storage and the longer the fruit is stored, the greater the percentage of fruit damage. This is related to the level of fruit hardness. The riper the Siam oranges are harvested, the lower the hardness of the fruit skin and it decreases with the longer the fruit is stored. The highest level of fruit peel hardness at harvest was at WF_1 (4.97 kg/cm2) and was significantly different from WF_4 with the lowest skin hardness being only 4.48 kg/cm2. After being stored for 4 and 8 DAS, the level of fruit hardness in WF_1 decreased to 4.85 and 3.89 kg/cm2, respectively, while at WF_4 decreased to 3.86 and 3.06 kg/cm2, respectively. This shows that harvesting fruit after physiological maturity causes citrus fruits to soften quickly, fruit damage and fruit weight loss during storage is greater. Fruit with an even yellow skin appearance is a fruit that has passed physiological maturity, so that during storage the skin and flesh of the fruit are softer. According to Laurinciana [18], the decrease in the level of fruit peel hardness is caused by changes in the composition of the cell wall composition due to the breakdown of insoluble protopectin into soluble pectin resulting in softening of the fruit due to the decreased amount of pectin. The low shelf life of fruit in WF_4 is due to the fact that the fruit is harvested after passing through physiological maturity/after the end of the ripening phase, so that the shelf life of the fruit is lower than that of WF_3. Siam oranges are non-climacteric fruits,

so harvesting should be done before the end of the fruit ripening phase, so that their shelf life is longer. The existence of the respiration process causes changes in the physical and chemical properties of the fruit [19]. If the respiration process continues, the fruit will wither and eventually decay so that the nutritional content in the fruit is lost [12], [20-21].

Table 2 showed that the TDS were significantly different at different levels of fruit maturity. The riper the fruit, the higher the TDS, and the TDS value increased the longer the fruit was stored. The highest TDS at harvest time was obtained at WF_4 which was 8.40 ^{0}Brix and the lowest was at WF_1 which was 7.48 ^{0}Brix. Similarly, at 4 and 8 DAS the highest TDS was obtained at WF_4 (8.85 and 9.63 ^{0}Brix) and the lowest at WF_1 (7.67 and 8.32 ^{0}Brix). According to Anggraini et al. [22], the sweet taste of citrus fruits comes from sucrose and the higher the TDS, the sweeter the fruit will be. Helmiyesi et al. [23] stated that in the ripening process of Siam oranges there was a change in the sugar content, especially glucose, fructose and sucrose. The increase in total sugar during ripening occurs due to the accumulation of sugar as a result of starch degradation and hydrolysis of polysaccharides into simple sugars, on the other hand the decrease in total sugar occurs because some of the sugar is used for the respiration process, because the sugar is used as a respiration substrate to produce energy.

The highest fruit moisture content at harvest time treatment was obtained at WF_2 which was 90.17% and significantly different from the lowest fruit moisture content at WF_1 which was 88.05%, but the water content of fruit at WF_2 was not significantly different from WF_3. Storage causes the water content of the fruit to decrease, this is evident from the water content of the fruit at 4 and 8 DAS, which is lower than that of at 0 DAS.

The results of this study indicated that the harvest time at FM_3 (harvested at 26 WAF) causes the lowest loss of fruit water content during storage so as to avoid decreasing fruit freshness the best, on the contrary at FM_4 the water content of the fruit has the highest decrease, so that the freshness of the fruit decreases the fastest. In this study, citrus fruits during storage changed their physical appearance to wilt and wrinkle. This change was also followed by an increase in fruit weight loss which continues to decrease during storage which causes the fruit to lose its freshness. The fruit becomes wrinkled with wrinkled skin so that the appearance of the fruit becomes less attractive [8], [17].

Table 2 Effect of maturity level of Siam citrus fruits on total soluble solid, fruit moisture content, vitamin C, sugar/acid ratio and percentage of fruit damaged during storage

Day after storage (DAS)	Treatments	TDS (0brix)	Fruit water content (%)	Vitamin C (%)	Sugar/acid ratiio (%)
0	FM_1	7.48 b	22.03 a	22.03 a	83.69 b
	FM_2	8.00 ab	18.71 a	18.71 a	154.16 a
	FM_3	8.15 a	16.24 a	16.24 a	208.63 a
	FM 4	8.40 a	16.20 a	16.20 a	257.85 a
	LSD 5%	0.65	-	-	69.22
4	FM_1	7.67 b	17.62 a	17.62 a	89.68 c
	FM_2	8.35 ab	16.36 a	16.36 a	195.82 b
	FM_3	8.80 a	15.50 a	15.50 a	253.00 a
	FM 4	8.85 a	14.22 a	14.22 a	292.74 a
	LSD 5%	0.70	-	-	45.97
8	FM_1	8.32 b	16.62 a	16.62 a	99.08 b
	FM_2	8.42 ab	15.15 a	15.15 a	249.36 a
	FM_3	9.48 a	14.74 a	14.74 a	269.77 a
	FM 4	9.63 a	14.13 a	14.13 a	316.46 a
	LSD 5%	0.91	-	-	81.79

Note: The numbers followed by the same letter in the same column in each day after storage show no significant effect on the 5% LSD test.

The riper the fruit at harvest time treatment, the lower the vitamin C content and the higher the sugar/acid ratio. Table 2 showed that the highest vitamin C content at harvest time was obtained at FM_1 (22.03%) and the lowest was at FM_4 (16.20%), but between WF_1 and WF_2, WF_3 and WF_4 the vitamin C content was not significantly different. On the other hand, the highest sugar/acid ratio at harvest was obtained at FM_4 (257.85%) and significantly different from the lowest sugar/acid ratio at FM_1 (83.69%), but between FM_4, FM_3 and FM_2 the sugar/acid ratio was not significantly different. Storage causes the vitamin C content to decrease at all levels of fruit maturity, on the other hand, the ratio of sugar/acid increases. These data indicated, to obtain high vitamin C in Siam citrus fruit, both at harvest and after storage, harvesting should be carried out before physiological maturity, but to obtain a high sugar/acid ratio, fruit harvest should be carried out at physiological maturity. According to Zhang et al. [19], the decrease in vitamin C levels in orange juice took place according to storage time and temperature. The longer the storage time and the higher the temperature, the greater the rate of degradation and decrease in the amount of vitamin C. The same thing was stated by Faramade [24] that the decrease in vitamin C levels in orange juice took place according to a zero-order reaction or the reaction took place at a constant speed, so that the longer the storage, the amount of vitamin C decreased or decreased.

The low shelf life of fruit with an evenly distributed yellow skin physical appearance is caused the fruit is a ripe fruit through the physiological phase/after the end of the ripening phase, so that the shelf life of fruit is low compared to fruit with a yellowish green skin physical appearance, i.e the fruit is harvested in the physiologically ripe phase so the shelf life of the fruit is higher. Citrus fruits, including non-climacteric, should be harvested before the end of the fruit ripening phase, so that the shelf life is longer. The existence of the process of respiration causes changes in the physical and chemical properties of the fruit. If the respiration process continues, the fruit will wilt and eventually decay will occur so that the nutritional content in the fruit decreases [12], [20].

4. Conclusion

Based on the results of this study, it can be concluded that the riper the fruit harvested, the sweeter the fruit taste which is reflected by the total dissolved solids and the higher the sugar/acid ratio, but the shelf life is shorter because the fruit shrinks quickly, loses weight and easily damaged. The best harvest time of Siam citrus fruit was at the age of 26 WAF with a greenish-yellow skin physical appearance because it provided the best physical and chemical properties of the fruit as indicated by the highest weight per fruit and fruit diameter, while the level of fruit hardness was not significantly different from fruit harvested younger, while the total dissolved solids, fruit moisture content, vitamin C content, and sugar/acid ratio were not significantly different from those harvested older. If the fruit was harvested too young (before the age of 26 WAF) or too old (after the age of 26 WAF) the quality of the fruit was low which is reflected by the weight per fruit and lower fruit diameter, the percentage of damaged fruit and the decrease in fruit quality after storage is greater and faster. Based on the results of this study, in order to obtain good quality Siam oranges and last longer, the fruit harvest should be carried out at the age of 26 WAF with the characteristics of the physical appearance of greenish yellow fruit skin.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declared that there is no conflict of interest.

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