Physical quality change in orange fruit (RGL variety): effects of different temperatures in storage

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Abstract. This research aimed to study the right temperature to extend the shelf life of RGL oranges. The experimental treatments were arranged using a two-factorial Completely Randomized Design (CRD). The factors were washing treatments, namely washing with water and washing with fruit washing solutions, and storage temperatures, namely room temperature (25±30°C) and cold temperature (10±10°C). The treatment was repeated four times. The variables observed included weight loss, diameter, fruit height and fruit sensory. Data were analyzed using analysis of variance (ANOVA) and followed by the DMRT test with a confidence level of 95%. The results showed that washing treatment and storage temperature had a significant effect on fruit weight loss inhibition, namely 4.72%, 8.58%, and 13.06% at day 5, 10, and 15. Hedonic test showed that the sensory attribute score in washing treatment was significant but was not significant on storage temperature. The panelists' preference for citrus fruit treated with fruit washing solution and stored at cold temperatures until the 15th day showed the highest score compared to other treatments (skin color 3.93, smoothness 3.83, texture 3.86 and overall 3.76). Thus, the physical quality of citrus fruits freshness last longer if treated with fruit washing solution and stored at cold temperatures.

1. Introduction
The citrus commodity has the potential to be developed in Indonesia considering that the citrus commodity plays a very important role in meeting the people's fruit consumption needs, creating job opportunities, and increasing people's income. National tangerine production in 2019 has reached 2.44 million tonnes, originating from almost all provinces, which is 1.52% increase compared to 2018 production of 2.41 million tonnes. However, the increase in national citrus fruit production has also been accompanied by an increase in citrus imports. Every year the import of citrus fruit has increased by 11% during the past ten years [1]. The trend of increasing imports indicates that there are certain consumers who want the type and quality of the citrus fruit. The demand for oranges for households has increased by around 4.93% per year for the last five years (2016-2020). The quality of local oranges is not sufficient to compete with the quality of imported oranges in fulfilling the demand for oranges, especially in terms of physical appearance, while in terms of taste, local oranges are not inferior to imported oranges.
Bengkulu Province is a superior local citrus producer known as RGL oranges. In accordance with its nature, RGL oranges are well adapted to medium to high plains with an altitude of 900-2,100 masl and have the advantage of being able to bear fruit throughout the year with an average production of citrus farmers is 35-40 kg/stem/year [2]. RGL oranges also have a competitive advantage, namely yellow-orange fruit which tastes sweet, sour, fresh, total dissolved solids contained ranges from 12-16o Brix, contain 89.20% water, 0.92% acid, and 18.34 mg/100 grams of vitamin C, large fruit size 200-350 grams [3], and have a good market potential. Good market potential is supported by the availability of fruit produced throughout the year. Usually, in one tree, there are 4-6 generations that consist of flowers, young fruit, up to fruit that is ready for harvest [4].

RGL citrus fruit is easily damaged because it contains a lot of water and after being harvested this commodity still undergoes respiration, transpiration, and ripening processes, so that it has a low shelf life. Citrus fruits require relatively fast cooling to maintain their quality, so that to extend the shelf life of fresh oranges requires proper post-harvest handling and storage [5]. This research aimed to study the right temperature to extend the shelf life of RGL oranges.

2. Methodology

2.1. Time and location
The research was carried out at the Postharvest Laboratory of the Agricultural Technology Research Institute (BPTP) Bengkulu from May to June 2019. The equipment used were a digital scale, digital calipers, napkins, buckets, fruit baskets, scissors, thermometers, refrigerators, and recording devices. The materials used were RGL citrus fruit, water, and fruit washing solution.

2.2. Research method
Post-harvest handling flow refers to the post-harvest handling of oranges developed by SARDI (South Australia Research and Development) [6]. The citrus fruit quality standard refers to the SNI 01-3165-1992 tangerine quality standard. Handling of RGL oranges started from the process of harvesting, sorting, and washing with water and fruit washing solution circulating in the market. Washing is carried out with the aim to remove dirt and pesticide residues (insecticide or fungicide) [7]. RGL citrus fruits were harvested from cooperator farmers’ gardens in Pal VII Village, Bermani Ulu Raya District, Rejang Lebong Regency, Bengkulu Province. The criteria for harvested fruit is physiologically ripe fruits, which are yellowish green at the age of ± 27-34 weeks from the blooming flowers [8]. The selected citrus fruits were free from pests and diseases of citrus plants such as fruit flies, the weight of the citrus fruit ranges from 150-250 grams. The experimental design used was a two-factorial Completely Randomized Design (CRD). The first factor was washing with two levels, namely washing with water and washing with fruit washing solution. The second factor was the storage temperature with two levels, namely room temperature (25 ± 30C) and cold temperature (10 ± 10C), the combination of each treatment was repeated four times. The observed variables included changes in weight loss, diameter, fruit height and fruit sensory. Data were analyzed using analysis of variance (ANOVA) and followed by the DMRT test with a confidence level of 95% (P <0.05). Washing procedure was carried out for 120 second, using running water or using a fruit washing solution 5%, then rinsed with water, dried, and stored in two different temperatures, namely room temperature (25 ± 30C) and cold temperature (10 ± 10C). Measurement of citrus fruit weight was carried out using digital scales. The diameter and height of the fruit were measured using a digital caliper. The calculation of weight loss in fruit used following formula:

\[
\% \text{ weight reduced} = \frac{B_0 - B_t}{B_0} \times 100\%
\]

Information:
B0 = initial weight of fruit on day 0 (g)
Bt = Weight of fruit on day n (g)
The organoleptic test involved 30 semi-trained panelists. Samples were presented randomly and panelists were asked to test the panelists' preference for the physical sensory attributes of RGL oranges including fruit skin color, skin smoothness, fruit texture, and overall fruit. Tests were carried out one by one or simultaneously and without making comparisons between samples, so that it was a spontaneous response to the preferences of citrus fruit. The panelists' favorite scores include 5 scale ranges, namely scale 1 (very dislike), scale 2 (dislike), scale 3 (neutral), scale 4 (like), and scale 5 (really like). Organoleptic data analysis was carried out using ANOVA, if the test results show a significant difference, then it is followed by a further DMRT test with a confidence level of 95% (P < 0.05) to determine the differences between treatments.

3. Results and discussion

3.1. Fruit weight reduce

The metabolic activity of fresh fruit is characterized by the respiration process. Storage of RGL oranges at room temperature and cold temperature still decreased the physical fruit. Figure 1 shows the percentage of weight loss of RGL oranges during storage.

![Weight Reduce of RGL Citrus](image)

Information:
A: stored at room temperature, washing with water,
B: stored at room temperature, washing with a fruit washing solution,
C: stored at cold temperature, washing with water,
D: stored at cold temperatures, washing with a fruit washing solution,

Figure 1. Weight reduced of RGL oranges during storage

Figure 1 shows that the weight loss increased with the length of storage. At room temperature storage conditions of normal air concentration, the respiration process runs normally at a fast rate which results in more loss of water content. During storage the fruit experienced shrinkage due to loss of water in the process of transpiration and respiration [9]. This causes weight loss to increase with the length of storage [10]. During storage, citrus fruits experience changes that are detrimental to the quality of the fruit. The longer the fruit is stored, the lower its weight value. It is also followed by an increase in fruit weight loss and a decrease in water content which continues to decrease, so that the
citrus fruit’s physical appearance becomes wilted and wrinkled. This is because after harvested, the fruit is still alive and continues its metabolic function [11].

| Treatment | Observation of weight reduced (%) during storage on day |
|-----------|--------------------------------------------------------|
|           | 5           | 10          | 15          |
| A         | 8.15 b      | 14.31 b     | 20.93 b     |
| B         | 7.08 b      | 14.07 b     | 20.69 b     |
| C         | 6.53 ab     | 10.51 a     | 14.25 a     |
| D         | 4.72 a      | 8.58 a      | 13.06 a     |

The numbers in the same column followed by the same letter are not significantly different on Duncan test level of 95% (P <0.05).

Information:
A: stored at room temperature, washing with water,
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The data in Table 1 shows that the weight loss of RGL oranges stored at room temperature was much lower than the weight loss of RGL oranges stored at room temperature. This is because storage in cold temperatures can inhibit the transpiration process. Water loss, as a result of the evaporation process, is altered by the differences in RH and room temperature and the respiration process after the fruit is harvested from the tree that cause fruit weight loss [12]. The washing treatment with fruit washing solution and stored at low temperature resulted in the lowest weight loss of 13.06% for 15 days of storage. This is inversely proportional to the washing treatment with water stored at room temperature that resulted in the largest weight loss of 20.93%. In this study, the percentage of weight loss of RGL oranges from storage on the 5th, 10th to 15th day of the washing treatment either with water or with fruit washing solution and stored at cold temperature showed a lower weight loss value than storage at room temperature. Treatment washing with a fruit washing solution and stored at cold temperatures gave the best results with the lowest reduction in weight loss. Washing citrus fruit with fruit washing solution and combined with cold storage until the 15th day of storage was still fresh and did not experience damage. It is possible because the content of fruit washing solution as an antibacterial can prevent damage and rotting of the fruit so that water transpiration from citrus fruit runs slower and resulting in the lowest reduction in weight loss compared to other treatments. [13] stated that after hydrocooling, storage at low temperatures can prolong the life span of tissues in foodstuffs because respiration activity decreases and inhibits the activity of microorganisms. Cold storage does not kill microbes, but only inhibits their activity, therefore any food that is refrigerated must be cleaned first. Based on the results of analysis of variance, it can be seen that the washing treatment did not significantly affect the weight loss of RGL oranges during storage at the 95% confidence level (P <0.05). However, storage temperature significantly affected the weight loss of RGL oranges during storage at the 95% confidence level (P <0.05). In addition, the interaction between washing treatment and storage temperature had a significant effect on weight loss at the 95% confidence level (P <0.05). From the results of the research, it can be seen that the critical limit for the shelf life of oranges was 15 days of storage which showed from the results of weight loss data that has reached 20.69% at room temperature storage. It is reinforced by the results of research by [14] which states that the freshness of citrus fruit without treatment at room temperature can be maintained for up to 9 days with a maximum weight loss of 10%, and the next day the fruit has decreased in quality. [15] added that oranges harvested at the optimum ripening phase and packed in ventilated cardboard packaging can extend the shelf life of the fruit up to 16 days of storage at room temperature. Naturally, the fruit that has undergone a decline in quality causes changes in physiological aspects that affect the nutritional value of the fruit. Citrus fruits that experience quality decline will lose weight, become wrinkled, and the nutritional content will decrease. Losing weight of RGL citrus fruit has an effect on weight loss during storage. The results showed that the weight loss at room temperature storage was higher than cold...
storage. This happens because of the higher evaporation process which results in reduced water content of the fruit. Fruits with high weight loss will cause the fruit to lose its freshness, the fruit becomes wrinkled so that the appearance of the fruit becomes unattractive and no longer fit for the market. In general, weight loss is an indication or indicator of a decline in fruit quality.

3.2. Diameter and height of fruit
The physical changes of the fruit during storage reduce the prime appearance of the fruit so that the selling price of the fruit decreases. Losing a lot of water due to the respiration process causes the fruit to shrink and the skin of the citrus fruit wrinkled, so that fruit weight, diameter, and height decrease. The performance changes in the diameter and height of RGL oranges during storage at room temperature and cold temperature at day 5, 10 and 15 can be seen in Table 2.

| Treatment | Observation during storage on day | Observation during storage on day |
|-----------|-----------------------------------|-----------------------------------|
|           | 5       | 10     | 15     | 5       | 10     | 15     |
| A         | 7.48 a  | 7.28 a | 6.24 a | 5.74 a  | 5.52 a | 4.72 a |
| B         | 7.44 a  | 7.22 a | 6.31 a | 5.55 a  | 5.42 a | 4.61 a |
| C         | 7.66 a  | 7.42 a | 6.66 a | 6.18 a  | 5.54 a | 4.94 a |
| D         | 7.67 a  | 7.45 a | 6.68 a | 5.58 a  | 5.45 a | 4.70 a |

The numbers in the same column followed by the same letter are not significantly different on Duncan test level of 95% (P <0.05).

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The data presented in Table 2 shows that there was a slightly decrease in the diameter and height of RGL oranges during storage. The longer the storage was, the less the circumference of the fruit. It is directly proportional to the height of the fruit which also decreased, so that there is a change in the physical appearance of the fruit to become wilted and wrinkled. The skin of the fruit that has wrinkled can cause the natural protective function to be disrupted so that it is unable to prevent loss of moisture and results in weight loss and reduce the circle size and height of RGL oranges during storage. The results showed that the reduction in diameter and fruit height during storage for 5, 10, 15 days were very small, respectively 0.02-0.24 cm, 0.21-0.24 cm and 0.76-1.03 cm for the reduction in diameter, while for the reduction in height ranged from 0.02 -0.16 cm, 0.12-0.63 cm, and 0.60-0.81cm. Based on the results of analysis variance, it can be seen that the washing treatment and storage temperature did not significantly affect the diameter and height of RGL oranges during storage at the 95% confidence level (P <0.05). This is possible because the RGL orange fruit peel is thick enough so that it can hold the respiration rate into the pulp. The longer storage time resulted in a decrease in the physical appearance of citrus fruits which became wilted and wrinkled, causing a decrease in the diameter and height of the citrus fruit. This is explained by [16] who stated that the longer the storage is, the higher the respiration rate process, so that the remodeling process will increase the overhaul of organic materials from food ingredients such as carbohydrates, proteins and fats produces CO2 and H2O which causes a decrease in water content in the citrus fruit.

3.3. Organoleptic test
Organoleptic test conducted was the hedonic test or consumer preference. The test parameters were color, smoothness, texture and overall fruit (overall). An organoleptic evaluation was carried out every 5 (five) days until the citrus fruit was declared no longer fit for consumption. This test was carried out to ensure the critical limit of the shelf life of oranges and the suitability of the treated fruit to be accepted and liked by consumers. The consumer preference test data can be seen in Table 3.
Table 3. The results of the panelist preference level advanced test for RGL oranges at various washing treatments and storage temperatures

| Treatment | Panelists' preference score for RGL oranges during storage on day - |   |   |
|-----------|---------------------------------------------------------------|---|---|
|           | Colour                                                        | 5 | 10 | 15 |
| A         | 4.13 a                                                       | 2.50 a | 2.00 a |
| B         | 4.16 ab                                                     | 3.03 b | 2.03 a |
| C         | 4.06 a                                                       | 4.10 c | 3.80 b |
| D         | 4.43 a                                                       | 4.40 c | 3.93 b |
|           | Smoothness                                                   |   |   |
| A         | 4.13 a                                                       | 2.57 a | 2.06 a |
| B         | 4.06 a                                                       | 2.89 a | 2.00 a |
| C         | 4.03 a                                                       | 4.23 b | 3.76 b |
| D         | 4.43 b                                                       | 4.16 b | 3.83 b |
|           | Texture                                                      |   |   |
| A         | 4.13 a                                                       | 2.78 a | 2.13 a |
| B         | 4.16 a                                                       | 2.85 a | 2.06 a |
| C         | 4.20 a                                                       | 4.23 b | 3.70 b |
| D         | 4.46 b                                                       | 4.20 b | 3.86 b |
|           | Entirety                                                      |   |   |
| A         | 4.03 a                                                       | 2.71 a | 2.13 a |
| B         | 4.06 a                                                       | 2.96 a | 2.06 a |
| C         | 4.06 a                                                       | 4.16 b | 3.73 b |
| D         | 4.50 b                                                       | 4.23 b | 3.76 b |

The numbers in the same column followed by the same letter are not significantly different on Duncan test level of 95% (P <0.05).

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3.4. Color
The first impression you get from food is color. Color is a characteristic that determines the acceptance or rejection of a product by consumers. [17] states that the assessment of foodstuff quality is generally very dependent on several factors, including taste, color, texture, and nutritional value. The orange color is one of the main qualities consisting of the accumulation of carotenoids and C30 apocarotenoids derivatives. The formation of the orange color in orange peels is caused by two dyes, namely β-imageurin and criptoxanthin. β-citraurin makes orange peels reddish, while criptoxanthin makes orange peels yellow.

The data presented in Table 3 shows that there was a decrease in the value of the panelists' preference for the color attribute during storage. At room temperature storage on the 5th day the panelists still gave an average score rating of 4 (like) to 5 (very like), after storing the 10th and 15th days, the panelists' preference for fruit skin color ranged from (2.00-3.03) neutral. This is reinforced by the results of study using Chokun oranges that stored at room temperature shows a faster color change to orange compared to storage at 18oC. The color of orange peel on washing treatment with fruit washing solution and stored at cold temperature until the 15th day of storage was the most preferred by panelists with an acceptance level of 3.93 (liked). The sensory test results showed that cold temperatures by washing the fruit washing solution had no significant effect on the washing treatment with water, but had a significant effect on room temperature storage. [16] states that the
advantage of low temperature is to reduce the activity of respiration enzymes with other enzymes in fruit tissue.

3.5. Smoothness

The quality of stored fruit is closely related to the processes of respiration and transpiration, where cold storage can reduce respiratory and metabolic activities, softening, loss of water and withering damage due to microbial activity. Changes in the shape (appearance) of the fruit into less attractive, wrinkled, and lose freshness result in a decrease in the quality of the commodity [19]. The level of acceptance of the panelists on the smoothness of the citrus fruit’s peel was largely determined by the quality of the oranges from the planting and storage temperature. The smoothness quality of RGL orange peels is not intact like imported oranges, so storing room temperature in RGL oranges will accelerate the appearance of the skin to become dull, wrinkled and withered.

To maintain the freshness of the citrus fruit, the citrus fruit was stored at cold temperatures and washed with a fruit washing solution. The panelists’ assessment results on citrus fruits stored at cold temperatures until the 15th day of storage was 3.70 - 4.46 (like to very much), but at room temperature storage the panelists gave a score of 4.13 (like) on the storage day-5, then on the 10th and 15th day of storage there were lower rate of panelist preference with a score of 2.06 (dislike). It is because physically, oranges stored at room temperature are not smooth and look wrinkled. [20] reported that the best composition to maintain the quality of Binjai rambutan is 4-6% O2, 2-4% CO2 at 1000 C. [21] studied perception of consumers assessing the attributes of local and imported fruit products. The result showed that consumers prefer imported citrus fruit peels that have almost no spots compared to local citrus fruit peels that still have spots on the fruit skin.

3.6. Texture

Texture is one of the most important parameters of fruit and vegetables that is often used to determine the freshness [22]. The texture or hardness of citrus fruit is greatly influenced by storage temperature. Citrus fruits with washing treatment and stored at cold temperatures until the 15th day were preferred by panelists with an acceptance rate of 3.70-3.86 (like-very much like) compared to room temperature storage with panelist acceptance scores in the range of 2.06-2.13 (dislike-very dislike). Orange fruit stored at room temperature resulted in a decrease of the hardness/texture of the fruit peel because the respiration rate of the fruit stored at room temperature was higher, and vice versa. The results of research by [23] stated that large chilies stored at cold temperatures had a significantly lower average rate of hardness reduction than those stored at room temperature. This is reinforced by the statements of [24] that found the respiration process increases fruit softness as there is hydrolysis of pectin in the cell wall and increasing water soluble component.

3.7. Overall assessment

Overall assessment of RGL citrus fruit with washing treatment and storage temperature showed the best result was washing treatment and stored at cold temperatures until the 15th day with a score range of 3.73 and 3.76 (neutral-like). Based on the results of the analysis variance, it can be seen that the overall panelist assessment of RGL oranges in the washing treatment did not have a significant effect during storage at the 95% confidence level (P <0.05). However, storage temperature significantly affected the overall panelist assessment of RGL oranges during storage at the 95% confidence level (P <0.05). In addition, the interaction between washing treatments and storage temperatures significantly affected the overall assessment of the panelists at the 95% confidence level (P <0.05).

4. Conclusion

Washing treatment with fruit washing solution and stored at cold temperatures can inhibit the decline in fruit quality more effectively than other treatments. Likewise, the hedonic test results show that up to the 15th day of storage the panelists still liked and gave scores more favorably than other treatments. Thus, it can be said that changes in the physical quality of citrus fruits can be inhibited by
washing treatment with fruit washing solution and stored at cold temperatures.

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