Effect of storage temperature and type of packaging on physical and chemical quality of carrot

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Abstract. Carrot can get damaged during harvesting or during storage which can reduce the quality. The research was conducted in the laboratory of post-harvest Vegetable Crops Research for the month of May-July 2016. The research aimed to analyze the effect of storage temperature and type of packaging on the characteristic of carrot. Factorial randomized block design with 4 x 4 and 2 replications was used in the study. The first factor was storage temperature consisted of 5 °C, 10 °C, 15 °C and room temperature. The second factor was the packaging comprised of polypropylene, polyethylene, wrapping, and non-packaging. Results showed that storage temperature affected water content, respiration rate, hardness, and weight loss in 3 weeks and 4 weeks of storage. Packaging affected on water content, vitamin C, respiration rate, and weight loss in 3 weeks, and 4 weeks. The temperature of 5 °C was the storage temperature that could maintain changes in the characteristics of the carrot. Polypropylene plastic type was an excellent package in maintaining changes in the characteristics of carrots during the storage process.

Keywords: Daucus carota L., storage, packaging

1. Introduction
One type of vegetable that has a very high vitamin A content is carrots. In every 100 grams of ingredients, there are 8285.00 mg β-carotene, 3477.00 mg α-carotene, and 1.0 µg lycopene. Carrots are often used by people to diet because in addition to containing vitamin A, it also contains vitamins and minerals that are quite complete [1]. Carrots are a source of carotene [2,3].

Carrots can damage both during planting, harvesting, and storage and can reduce quality. Losing the yield of vegetables and fruits before consumption in developing countries reaches 20–40%. Post-harvest handling through storage is an action to maintain tomato quality [4]. In improving the quality of production and utilization of carrots to meet nutritional needs and as raw material for agro-industry and agribusiness, it is necessary to package appropriate technology, and one of them is storage and packaging techniques.

Storage will extend usability and, in certain circumstances will maintain quality [5]. Also, storage also avoids the abundance of products to the market, provides extensive opportunities to buy throughout the year, helps regular marketing, increases producer profits and maintains product quality. The main purpose of fresh product storage is to control the transpiration, respiration, disease infection rates, and maintain the most useful quality for consumers.
Shelf life can be extended by cooling. Cooling is the only economical way to store long-term fresh vegetables, including carrots. Basically cooling is the use of low temperatures (below room temperature) and is generally intended to maintain the freshness of the material. Cut and uncut carrots stored on 32°F storage with a relative humidity of 90–95%, estimates of cut carrot storage 4–5 months, while carrots are not cut 10–14 days [6]. Carrots should be wrapped in plastic in order to survive and the quality remains good during storage [7].

Types of plastic that are often used in food packaging and are easily obtained include polyethylene and polypropylene. This plastic contains thin, flexible plastic (flexible films) that has several special properties including absorption of water, gas and vapor permeability and resistance to chemicals. Packaging materials suitable for packaging fresh tomatoes are polyethylene (PE) and polypropylene (PP) [8]. Polyethylene (PE) has flexible properties, low water and water vapor permeability, and is suitable for packing tomatoes. The most important properties of packaging materials used include the permeability of gas and water vapor, its shape and surface. Water and gas vapor permeability, as well as packaging surface area, affect the amount of gas that is good, and a small surface area causes a longer shelf life of the product [9]. The use of polypropylene (PP) plastic is effective in suppressing the percentage of weight loss, and the use of plastic high-density polyethylene (HDPE) is effective in delaying discoloration of tomatoes (Lycopersicon sculentum, Mill) [1]. Packaging commonly used for packaging vegetables and fruits is PE plastic. Polyethylene is a soft, transparent, and flexible film, has good impact strength and tear strength, good mechanical properties, polyethylene is widely used as food packaging, because it is thermoplastic, polyethylene is easily made with a good degree of density [11].

Information about the packaging technique of Arumanis mangoes wrapped tightly per fruit with polyethylene plastic (PE) can last up to 4 weeks [12], packaging using polyethylene bags in Carabao mangoes can delay fruit ripening [13]. The use of 0.04 mm PE plastic is good enough for a controlled air storage system because its permeability to CO₂ gas is greater than O₂, so the rate of CO₂ gas accumulation around the material is lower than O₂ absorption [14, 15]. The purpose of this study is to determine the right temperature and length of time for carrots, so those good quality carrots are obtained by consumers.

2. Materials and methods
The research material was the Sibayak variety of organic carrots obtained from Pangalengan farmers. Information is obtained that the average organic vegetable has a higher content of vitamins and minerals compared to similar vegetables that are non-organic [16]. This is because organic vegetables that use manure and have good soil efficacy have better nutrient absorption systems in soil than non-organic farming systems [17]. The research was carried out in the post-harvest laboratory of the Vegetable Crops Research Institute from the months of May-July 2016. The design used was a factorial randomized block design. Each treatment combination was repeated 2 times. The main factor is storage temperature (T), which consists of t₁ (5 °C), t₂ (10 °C), t₃ (15 °C), t₄ (room temperature). The second factor is the type of packaging (K) which consists of k₁ (polypropylene measuring 20 cm x 35 cm, thickness 0.3 mm), k₂: polyethylene (measuring 20 cm x 35 cm, thickness 0.3 mm), k₃ (wrapping plastic), k₄ (without packaging = control). Based on the design, a variance analysis can be made to obtain conclusions about the effect of treatment.

Thus there are 16 combinations of treatments. For each treatment combination 6 carrot tubers are needed so that for 16 experimental plots it takes 16 x 2 x 6 tubers = 192 carrot tubers x 4 weeks of observation = 768 carrot tubers. The number of carrot tubers plus 16 x 2 x 6 = 192 pieces (for weight loss). So the total number of carrot tubers is 960 pieces.

The parameters observed in the study were: weight loss (%) (intact means separate samples), texture/hardness (probe), respiration rate, moisture content (%), total sugar in carrots (° Brix), vitamin C (mg/100 g), beta-carotene (in carrots), organoleptic characteristics of carrots including color, taste, freshness and appearance (Hedonic Test).

The procedure for analyzing the determination of β-carotene carrot levels was carried out by the spectrophotometer method [18]. β-carotene is a simple form of carotenoids, which has the molecular
formula $C_{40}H_{56}$. β-carotene has 11 double bonds, which are orange pigments that can be found in fruits and vegetables. β-carotene can bind to chlorophyll and xanthophyll in fruits and vegetables. The sample (0.5 gram) was homogenized with 0.1 gram Na$_2$CO$_3$ in 5 ml of acetone (100% v/v). Homogenate is filtered, and the filtrate is used to determine chlorophyll and carotenoids.

Chlorophyll and carotenoids in microgram/mg fresh weight (fw), are calculated based on the following equation [18]:

- Chlorophyll $a$ (ca) = $11.75 \times A_{662} - 2.35 \times A_{645}$
- Chlorophyll $b$ (cb) = $18.61 \times A_{645} - 3.96 \times A_{662}$
- Total Chlorophyll = klorofil $a$ (ca) + klorofil $b$ (cb)
- Carotenoid $\{A_{470}-2.27 (ca)-81.4 (cb)\} / 227$

3. Results and discussions

Analysis of the content of carrot raw materials was carried out on β-carotene levels, water content, vitamin C, total dissolved solids (TPT), respiration rate, hardness, and weight loss at room temperature. Determination of β-carotene levels was carried out using a spectrophotometer, water content with gravimetry, vitamin C with iodimetry, total dissolved solids (TPT) with a refractometer, respiration rate with closed method, hardness with penetrometer and weight loss with analytic balance. Based on the determination of the content of organic carrots raw materials obtained results as can be seen in table 1.

| Contents               | Results       |
|-----------------------|---------------|
| β-carotene            | 3.456 µ/mg    |
| Moisture content      | 90.28%        |
| Vitamin C             | 10.200 mg/100 g |
| Total soluble solids (TSS) | 6.40 °Brix     |
| Respiration rate      | 8.15 CO$_2$/kg/hour |
| Hardness              | 1.64 mm/10 second/100 g |
| Weight losses         | 0%            |

3.1. Weight loss

Analysis of weight loss was carried out at weeks 3 and 4 of storage. The results of the statistical analysis showed that the storage temperature and type of packaging showed no interaction at week 3 (table 2), whereas in week-4, storage interaction between the two factors occurred to the weight loss of carrot (table 3).
Table 2. Effect of storage temperature and packaging type of carrot on weight loss on week-3 storage.

| Treatment                     | Week-3 (%) |
|-------------------------------|------------|
| **Storage Temperature**       |            |
| t₁ (5°C)                      | 0.39 a     |
| t₂ (10)                       | 0.79 b     |
| t₃ (15°C)                     | 1.21 c     |
| t₄ (Ambient Temperature)      | 1.59 d     |
| **Type of Packaging**         |            |
| p₁ (PP)                       | 0.84 a     |
| p₂ (PE)                       | 0.94 b     |
| p₃ (Wrapping)                 | 1.05 c     |
| p₄ (Without Packaging)        | 1.14 d     |
| KK/CV (%)                     | 3.22       |

Mean followed by the same letters on the same columns are not significant according to Duncan’s multiple range test at 0.05 level.

In table 2, the temperature of 5 °C shows the lowest weight loss and significantly different compared to the other three temperatures, whereas in the type of polypropylene packaging shows the lowest weight loss and significantly different compared to the other three types of packaging. The weight loss of fresh carrots at the 3rd week of storage at room temperature showed an increase in a weight loss of 1.59%. Storage of carrots at higher temperatures results in weight loss due to respiration and transpiration in carrots during storage. Carrots stored at room temperature and without packaging for respiration and transpiration will take place faster. The results showed that tomatoes stored at 10 °C and 12.5 °C could maintain better sensory quality than those stored at room temperature [19]. Storage at room temperature can accelerate the process of respiration, the rate of transpiration and increase yield loss [2]. Water loss due to high transpiration causes loss of weight and the fruit tissue becomes wrinkled. Weight loss occurs because some of the water in the carrot tissue is lost due to the processes of respiration and transpiration [21]. Generally, weight loss increases with storage time and is higher in open containers stored at room temperature and coolant [22]. Weight loss is one component that is influenced by storage temperature and the save temperature affects the rate of respiration [23].

Based on table 3, at 5 °C, the type of polypropylene packaging has the smallest weight loss (0.28%) and is significantly different from polyethylene packaging, wrapping and without packaging. During storage weight loss increase from fresh conditions, and treatment without packaging shows the highest increase in weight loss. In the type of polypropylene packaging, the storage temperature of 5 °C has the smallest weight loss and is significantly different from the weight loss of other temperature treatments during storage. The use of polypropylene (PP) plastic packaging materials affected the percentage of weight loss and discoloration of tomatoes. The use of polypropylene (PP) plastics is effective in reducing the percentage of weight loss [24].

The percentage of weight loss has increased during storage. This is because agricultural products experience water loss due to respiration and transpiration activities [25, 26]. In the respiration process complex compounds commonly found in cells such as carbohydrates will be broken down into simple molecules such as carbon dioxide and volatile water, so that the commodity will lose its weight water loss in commodities depends on the deficit of water vapor pressure between the commodity and the surrounding air at the relative humidity of air (RH) and the rate of air movement, water loss from commodities will increase with increasing temperature. Respiration and transpiration processes result in loss of substrate and water so that changes in the weight of fruits and vegetables always decrease during ripening and storage.
Table 3. Interaction effect of storage temperature and packaging on weight losses of carrot (week 4).

| Storage Temperature | Type of Packaging          | p1 (PP) | p2 (PE) | p3 (Wrapping) | p4 (Without Packaging) |
|---------------------|----------------------------|---------|---------|---------------|-------------------------|
| t1 (5°C)            | A                          | 0.28 a  | 0.39 a  | 0.54 a        | 0.46 a                 |
|                     | B                          | D       | C       |               |                         |
| t2 (10°C)           | A                          | 0.65 c  | 0.76 b  | 0.91 b        | 1.07 b                 |
|                     | B                          | C       | D       |               |                         |
| t3 (15°C)           | A                          | 1.19 b  | 1.30 c  | 1.45 c        | 1.61 c                 |
|                     | B                          | C       | D       |               |                         |
| t4 (Ambient)        | A                          | 1.68 d  | 1.79 d  | 1.94 d        | 2.10 d                 |
| Temperature         | B                          | C       | D       |               |                         |
| KK/CV (%)           |                            |         |         |               | 2.68                    |

Mean followed by the same letter on the same column and the same big letter on the same row are not significantly different according to 5% DMRT.

3.2. Hardness

Hardness analysis was carried out at the 3rd and 4th weeks of storage. The results of the statistical analysis showed that there was no interaction between storage temperature and type of packaging at week 4 (table 4), while interactions occurred at week-3 (table 5).

Table 4. Effect of storage temperature and packaging type on hardness of carrot at week-4 storage.

| Treatment                  | Hardness (Week-4) |
|----------------------------|-------------------|
| Storage Temperature:       |                   |
| t1 (5°C)                   | 2.14 b            |
| t2 (10°C)                  | 2.30 b            |
| t3 (15°C)                  | 2.43 b            |
| t4 (Ambient Temperature)   | 0.00 a (Rot)      |
| Type of Packaging          |                   |
| p1 (PP)                    | 1.48 a            |
| p2 (PE)                    | 1.63 a            |
| p3 (Wrapping)              | 1.67 a            |
| p4 (Without Packaging)     | 2.09 a            |
| KK/CV (%)                  | 31.99             |

Mean followed by the same letters on the same columns are not significant according to Duncan’s multiple range test at 0.05 level.

From table 4 it can be seen that there is a tendency for the lower the storage temperature, the slower the decline in the value of hardness [27]. Hardness is related to water content, the higher the level of carrot water, the higher the hardness of carrots, besides the water content that affects the value of hardness is the decomposition of vitamin C and the total dissolved solids contained in the carrot.

Soft carrot texture is mainly caused by the overturning of insoluble protopectin into soluble pectin by the protoplastinase enzyme. This results in decreased cell wall cohesion that binds one cell wall to another cell wall. With the magnitude of the polysaccharide being overwritten, the fruit texture will be softer [28]. The texture changes of agricultural products during storage are mainly due to changes in the middle lamellae and primary cell walls caused by enzymes that degrade and dissolve pectin material.
[29]. This condition promotes cell separation and reduced resistance to external pressure. Chemical changes also occur in cell walls composed of complex compounds from structural carbohydrates, cellulose, hemicellulose, pectin and lignin [3].

The use of polypropylene packaging shows a longer shelf life than polyethylene packaging [31]. The use of polypropylene packaging can reduce water loss by respiration and transpiration because it has a higher permeability so that it can maintain carrot turgor pressure. This also causes carrots not to be damaged quickly. Therefore in this study, polypropylene plastic is recommended as the best packaging for carrot packaging.

There are differences in the hardness of different types of packaging due to the transluency of each different plastic so that the respiration rate that affects the hardness of organic carrots is different [32]. Closed packaging and low storage temperatures because of the type of polypropylene, polyethylene and wrapping plastic can affect changes in organic carrots. The properties of the plastic used are also different, especially the nature of permeability which allows substances to get out or into the plastic packaging [33].

Based on the effect of average treatment in table 4, at week 4 storage has an average value of carrot hardness increases with the length of storage, if seen in table 1 analysis of fresh raw materials (the results of the week-0 analysis) indicates the longer storage then the value/the score of carrot hardness is increasing, this indicates that carrots begin to lose their rigidity along with the length of storage.

Table 5. Interaction effect of storage temperature and packaging type on physical hardness of carrots response (week 3).

| Storage Temperature | Type of Packaging | p1 (PP) | p2 (PE) | p3 (Wrapping) | p4 (Without Packaging) |
|---------------------|-------------------|---------|---------|---------------|------------------------|
|                     |                   | .... mm/100 g/10 second..... |         |               |                        |
| t1 (5 °C)           |                   | 1.78 a  | 1.91 ab | 2.36 a        |                        |
|                     |                   | A       | A       | A             | B                      |
| t2 (10 °C)          |                   | 1.87 ab | 2.01 ab | 2.19 a        |                        |
|                     |                   | A       | AB      | AB            | B                      |
| t3 (15 °C)          |                   | 2.12 b  | 2.16 b  | 2.11 a        |                        |
|                     |                   | A       | A       | B             | A                      |
| t4 (Ambient)        |                   | 2.97 c  | 1.88 a  | 2.18 a        |                        |
| Temperature         |                   | C       | A       | A             | BC                     |
| KK/CV (%)           |                   |         |         |               | 11.59                  |

Mean followed by the same letter on the same column and the same big letter on the same row are not significantly different according to 5% DMRT).

From table 5, at 5 °C, wrapping packaging has the smallest hardness value (1.77 mm) and is significantly different from without packaging, but not significantly different from polypropylene and polyethylene. In wrapping packaging, the temperature of 5 °C has the smallest hardness score and is significantly different from other temperatures.

The active pectinmethylesterase enzymes, namely in the results of plants in the cooking process, it turns out that the pectin has been broken down or broken down into other compounds causing changes in the texture of the crop, usually the plant yields that are hard will turn soft. Texture changes will take place faster when the crop results are in storage. The principle of measuring hardness with a probe is on deeper penetration indicating that the tissue is more easily penetrated or weak. Increasing the value of hardness shows the softening of organic carrot networks.

3.3. Respiration rate

Respiration rate is one of the physiological properties that greatly influence the shelf life of vegetables and fruits. The respiration rate determines the durability of the product being stored so that products
with low respiration rates are generally stored longer in good conditions. Respiration rate is influenced by temperature. At temperatures between 0–35 °C the reaction speed will be two or three times greater for each 10°C temperature increase. In table 6, at 5 °C, the carrot respiration rate in polypropylene packaging is the smallest and is significantly different from wrapping, but not significantly different from polyethylene and without packaging. In polypropylene packaging, a temperature of 5 °C is not significantly different from 10 °C and 15 °C except for room temperature. So the best treatment is 5 °C with polypropylene packaging at 3 weeks.

Table 6. Interaction effect of storage temperature and packaging type response against chemical carrots respiration rate (week 3).

| Storage Temperature | Type of Packaging | p1 (PP) | p2 (PE) | p3 (Wrapping) | p4 (Without Packaging) |
|---------------------|-------------------|---------|---------|---------------|-------------------------|
| t1 (5 °C)           |                   | 8.48 a  | 8.51 a  | 9.91 c        | 8.51 a                  |
|                     |                   | A       | A       | B             | A                       |
| t2 (10 °C)          |                   | 8.55 a  | 9.84 b  | 8.49 a        | 9.86 c                  |
|                     |                   | A       | B       | A             | B                       |
| t3 (15 °C)          |                   | 8.64 a  | 8.66 a  | 9.76 c        | 9.24 b                  |
|                     |                   | A       | A       | B             | B                       |
| t4 (Ambient Temperature) |               | 10.33 b | 10.15 c | 9.14 b        | 9.37 b                  |
| KK/CV (%)           |                   | B       | B       | A             | A                       |

Table 7. Interaction effect of storage temperature and packaging type response against chemical carrots respiration rate (week 4).

| Storage Temperature | Type of Packaging | p1 (PP) | p2 (PE) | p3 (Wrapping) | p4 (Without Packaging) |
|---------------------|-------------------|---------|---------|---------------|-------------------------|
| t1 (5°C)            |                   | 8.71 a  | 8.74 a  | 10.07 b       | 8.72 a                  |
|                     |                   | A       | B       | C             | B                       |
| t2 (10°C)           |                   | 8.78 a  | 10.16 b | 8.67 a        | 10.18 b                 |
|                     |                   | B       | C       | A             | C                       |
| t3 (15°C)           |                   | 10.70 b | 10.65 d | 10.58 c       | 10.61 c                 |
|                     |                   | B       | AB      | A             | A                       |
| t4 (Ambient Temperature) |     | 10.78 c | 10.55 c | 10.69 c       | 10.62 c                 |
| KK/CV (%)           |                   | C       | A       | B             | B                       |

Mean followed by the same letter on the same column and the same big letter on the same row are not significantly different according to 5% DMRT.

Based on table 7, at 5 °C, polypropylene packaging is significantly different from polyethylene, wrapping and without packaging. In the treatment of polypropylene packaging, temperatures of 5 °C and 10 °C were not significantly different, but were significantly different from the temperature of 15 °C and room temperature. Conclusions from tables 6 and 7, the best treatment for respiration is the temperature of 5 °C and 10 °C with polypropylene packaging.
3.4. Moisture content

Water content is the amount of water contained in food. Determination of water content in food products needs to be done because of its influence on the stability and quality of the product itself [34]. Water content analysis was carried out at weeks 3 and 4 of storage. The results of week 4 statistical analysis can be seen in table 8, while the week-3 statistical analysis in table 9.

During 4 weeks storage of moisture content decreased from fresh conditions in table 1 by 90.28%. The decrease in water content in carrots is due to transpiration in the carrot. The process of transpiration causes a loss of water content, so that agricultural products wither. Transpiration is the evaporation process of plants which results in water loss products [35]. Decreasing water content during storage occurs due to various factors, including evaporation, relative humidity, the environment of storage, and acidity of the material.

Table 8. Effect of temperature and type of packaging on moisture content carrot (%) week 4.

| Treatment                | Moisture content (Week 4) |
|--------------------------|---------------------------|
| **Temperature:**         |                           |
| 5 °C                     | 56.76 a                   |
| 10 °C                    | 67.83 a                   |
| 15 °C                    | 67.68 a                   |
| **Ambient Temperature (24 °C)** |                           |
| **Type of Packaging:**  |                           |
| Polypropylene            | 56.76 a                   |
| Polyethylene             | 67.83 a                   |
| Wrapping                 | 67.68 a                   |
| Without Packaging        | 78.94 a                   |
| KK/CV (%)                | 31.99                     |

Mean followed by the same letters on the same columns are not significantly different according to Duncan’s multiple range test at 0.05 level.

Table 9. Interaction effect of storage temperature and packaging on the moisture content of carrots (week 3).

| Storage Temperature | Type of Packaging |
|---------------------|-------------------|
|                     | p1 (PP) | p2 (PE) | p3 (Wrapping) | p4 (Without Packaging) |
| t1 (5°C)            | 90.60 c  | 89.67 a  | 90.09 b       | 90.12 b             |
|                     | C       | A       | B             | B                  |
| t2 (10°C)           | 90.45 c  | 90.52 c  | 89.70 a       | 90.27 c             |
|                     | C       | C       | A             | B                  |
| t3 (15°C)           | 89.61 b  | 90.22 b  | 90.62 c       | 89.72 a             |
|                     | A       | B       | C             | A                  |
| t4 (Ambient Temperature) | 0.00 a  | 90.23 b  | 91.20 d       | 90.38 c             |
| KK/CV (%)           | A       | B       | D             | C                  |

Mean followed by the same letter on the same column and the same big letter on the same row are not significantly different according to 5% DMRT.

Increased water content in organic carrots at 3-week storage is presumed because at cold temperatures the carrot surface will absorb water from the environment because if the environmental rH is higher than the water content in the material, the food will absorb water from the surrounding air resulting in an increase in the water at these food ingredients. However, the water content has decreased again in the
4th week of storage. It is thought that the water content between the cells will become larger by absorbing water from the surrounding cells so that the cells become dry. As a result of dehydration, this causes the enzyme to lose its function so that the metabolism stops and the cells will die, then rot. There are differences in water content in different types of packaging due to the translucency of each different plastic so that the respiration rate that affects the water content is different. The use of plastic is based on the permeability value of each packaging between wrapping and polypropylene [36]. Plastic wrapping has a low permeability value, while polypropylene has a higher permeability. The properties used are also different, especially the permeability properties that allow substances to come out or enter into this plastic packaging. A low humidity of storage space results in the absorption of water from material stored by storage space so that the stored material becomes dry (water content decreases). If there are barriers such as packaging, of course the water absorbed is water that comes from carrots and will eventually dry up can be minimized, because of the packaging the surrounding air is not easy to enter into the material.

In table 9, at 5 °C, the water content of the polyethylene treatment (89.67%) is significantly different from polypropylene, wrapping and room temperature. However, if we look at the data in table 9, the water content of various temperature and packaging treatments is not much different from the initial water content = 90.28%. Thus acceptable treatments are 5 °C and polypropylene, 5 °C and polyethylene, 5 °C and wrapping, 5 °C and room temperature, 10 °C and polypropylene, 10 °C and polyethylene, 10 °C and wrapping, 10 °C and room temperature, 15 °C and polyethylene, 10 °C and wrapping, 10 °C and room temperature. In table 9, the water content of various temperature and packaging treatments is not much different from the initial water content = 90.28%. Thus acceptable treatments are 5 °C and polypropylene, 5 °C and polyethylene, 5 °C and wrapping, 5 °C and room temperature, 10 °C and polypropylene, 10 °C and polyethylene, 10 °C and wrapping, 10 °C and room temperature, 15 °C and polyethylene, 10 °C and wrapping, 10 °C and room temperature.

3.5. Total soluble solids (TSS)

Analysis of total soluble solids (TSS) was carried out at weeks 3 and 4 of storage. Analysis of statistical results at week-4 did not occur in interaction (table 10), while week-3 interaction occurred (11).

Table 10. Effect of storage temperature and packaging type on TSS of carrot (week-4) storage.

| Treatment                  | Average TSS (°Brix) /Week-4 |
|----------------------------|-----------------------------|
| **Storage Temperature**    |                             |
| t₁ (5 °C)                  | 6.45 b                      |
| t₂ (10 °C)                 | 6.48 b                      |
| t₃ (15 °C)                 | 5.68 b                      |
| t₄ (Ambient Temperature)   | 0.00 a                      |
| **Type of Packaging**      |                             |
| p₁ (PP)                    | 4.03 a                      |
| P₂ (PE)                    | 4.90 a                      |
| p₃ (Wrapping)              | 4.83 a                      |
| p₄ (Without Packaging)     | 4.85 a                      |
| KK/CV (%)                  | 37.07                       |

Mean followed by the same letters on the same columns are not significantly different according to Duncan’s multiple range test at 0.05 level.

From table 10, room temperature shows the highest decrease in total soluble solid and significantly different compared to the other three temperatures, whereas in polypropylene packaging shows the lowest total soluble solids, and not significantly different from other packages. The results showed that during 4 weeks of storage, total soluble solid tended to decrease and increase. A decrease in the value of total soluble solid in line with the length of storage time. A decrease in the total soluble solid is
possible because there is a loss of nutrient components during the storage process. Besides that it is possible because dehydration occurs and the sugar content decreases so that the total value of soluble solid also decreases (table 10). In addition, a decrease in the total value of soluble solid also occurs because during storage there is an activity of enzymes and microbes that damage and decompose nutrients, resulting in a decrease in total soluble solids. In this study, carrots with a total soluble solids content of around 5.40 °Brix to 8.60 °Brix were still good and organoleptically acceptable to consumers. Vegetables store carbohydrates as a supply of ingredients and energy, which are then used to carry out the activities of the rest of their lives. Therefore, in the ripening process, the content of solids such as sugar and carbohydrates always changes. The increase in total soluble solids during storage is caused by the degradation of starch into simple sugars, while the decrease is due to the sugar being used as a respiration substrate to produce energy. The sugar and amino acid content of carrots depends on the type of carrot variety, environment, agriculture, and storage. Rooting roots such as carrots store considerable amounts of sucrose and sugar, causing sweetness in these vegetables [37].

The main content of total soluble solid of carrots is sugar. Components of reducing sugars and total sugar in carrots cause the carrot to taste sweet. During this storage, there is an increase in the total sugar in organic carrots. Storage at low temperatures will increase sugar levels in carrots. Storage at low temperatures (4.4 °C) or lower causes sugar accumulation because metabolic activity takes place rather slowly. Hydrolysis of starch will continue as long as organic carrots are stored. This will cause a change in the total value of soluble solids, because the starch that was not dissolved in water through the hydrolysis process will be broken down into simple sugars which are soluble in water. The increase in sugar is caused by hydrolysis of starch into sucrose compounds, glucose and fructose, and the rate of hydrolysis is greater than the speed of converting glucose into energy and water so that sugar deposits accumulate in the tissues during irregularities [38]. Based on the results of this study, total soluble solids (TSS) in organic carrots after storage 1, 2 and 4 weeks are in the range of the initial TSS which is 6.40°Brix, which means TSS from temperatures of 5 °C, 10 °C and 15 °C acceptable.

Table 11. Interaction effect of storage temperature and packaging type on TSS of carrots (week 3).

| Storage Temperature | Packaging Type | p1 (PP) | p2 (PE) | p3 (Wrapping) | p4 (Without Packaging) |
|---------------------|----------------|---------|---------|---------------|-------------------------|
| t1 (5°C)            |                | 6.40 b  | 6.50 a  | 6.40 a        | 6.20 a                  |
| t2 (10°C)           |                | 6.70 c  | 6.20 a  | 6.30 a        | 6.20 a                  |
| t3 (15°C)           |                | 6.20 b  | 6.50 a  | 6.30 a        | 6.40 a                  |
| t4 (Ambient)       |                | 0.00 a  | 6.40 a  | 5.40 a        | 6.00 a                  |
| KK/CV (%)           |                |         |         |               | 4.90                    |

Mean followed by the same letter on the same column and the same big letter on the same row are not significantly different according to 5% DMRT.

From table 11, at 10 °C, polypropylene, polyethylene, wrapping and without packaging were not significantly different on total soluble solid at 3 weeks. In polypropylene, a temperature of 10 °C is significantly different from a temperature of 5 °C, 15 °C and room temperature. Based on table 11, the totalsoluble solid (TSS) is relatively the same as the initial TSS (6.40 °Brix): 5 °C and polypropylene, 5 °C and polyethylene, 5 °C and wrapping, and 5 °C and without packaging, 10 °C and polypropylene, 10
°C and polyethylene, 10 °C and wrapping, 15 °C and without packaging, 15 °C and polyethylene, 15 °C and wrapping, 15 °C and without packaging.

3.6. Vitamin C
Statistical analysis of vitamin C was carried out at week 4 and no interaction occurred (table 12), while week-3 interaction occurred (table 12). From table 12, at room temperature shows the lowest vitamin C content and significantly different compared to the other three temperatures. In the packaging, treatment showed vitamin C was not significantly different.

In table 12, it can be seen that at room temperature shows the lowest levels of vitamin C (rot) and significantly different compared to the other three temperatures 5 °C, 10 °C and 15 °C. Decreased vitamin C levels in carrots caused by transpiration in the carrot.

Table 12. Effect of storage temperature and packaging type on vitamin c on (week 4) storage.

| Treatment                | Vitamin C (Week-4) |
|--------------------------|--------------------|
| Storage Temperature      |                    |
| t1 (5 °C)                | 13.31 b            |
| t2 (10 °C)               | 13.53 b            |
| t3 (15 °C)               | 12.75 b            |
| t4 (Ambient Temperature) | 0.00 a             |
| Type of Packaging        |                    |
| p1 (Polypropylene)       | 8.43 a             |
| p2 (Polyethylene)        | 10.53 a            |
| P3 (Wrapping)            | 10.31 a            |
| p4 (Without Packaging)   | 10.31 a            |
| KK/CV (%)                | 26.66              |

Mean followed by the same letters on the same columns are not significant according to Duncan's multiple range test at 0.05 level.

Storage temperature affects the vitamin C content of carrots (Safaryani 2007), that the stability of vitamin C usually increases with a decrease in storage temperature. Given the volatile nature of vitamin C due to oxidation obtained accelerated by high temperatures, light and also heat but stable if it is a crystal (pure), then this loss can be prevented by storage in cold temperatures (5 °C).

The increase and decrease in vitamin C is caused by vitamin C being unstable, easily oxidized when exposed to air (oxygen) that is why temperature regulation and how to handle carrots with packaging will help maintain vitamin C in carrots, vitamin C is easily oxidized because compounds contain hydroxy functional groups (OH) which is highly reactive in the presence of a hydroxy group oxidizer or oxidized to a carbonyl group. The oxidation process will be inhibited if vitamin C is in a low temperature state.

Decreasing vitamin C during storage occurs due to the oxidation process, vitamin C is very easily oxidized to L-dehydroascorbic acid which tends to undergo further changes to L-dehydroascorbate. The tendency of increasing vitamin C levels in the 3 weeks of storage occurs during the winding process. An increase in the content of vitamin C usually occurs with the length of storage time, but if the substrate formation of vitamin C is no longer available, the content of vitamin C will decrease. Vitamin C in horticultural products is synthesized from hexose, where the hexose content will increase during storage so that the vitamin C content of horticultural products will also increase. Increased vitamin C content during the fruit maturation phase occurs due to the formation of vitamin C derived from glucose substrate 6-PO4-. The formation of vitamin C occurs in the pentose phosphate pathway and involves lactone intermediates 6-PO4- [39].
Polypropylene packaging has higher permeability to water vapor, \( \text{O}_2 \) and \( \text{CO}_2 \) so that it can inhibit the process of respiration and transpiration which ultimately can maintain the vitamin C content of carrots, so that polypropylene packaging is more effective at inhibiting respiration and transpiration [4].

| Storage Temperature | Type of Packaging | Vitamin C (mg/100 g) |
|---------------------|-------------------|----------------------|
| \( t_1 (5^\circ C) \) | \( p_1 \) (PP) | 14.64 c |
|                     | \( p_2 \) (PE)  | 13.31 a |
|                     | \( p_3 \) (Wrapping) | 13.75 b |
|                     | \( p_4 \) (Without Packaging) | 13.75 b |
| \( t_2 (10^\circ C) \) | B | A |
|                     | A | A |
| \( t_3 (15^\circ C) \) | B | B |
|                     | C | A |
| \( t_4 \) (Ambient Temperature) | C | B |

Mean followed by the same letter on the same column and the same big letter on the same row are not significantly different according to 5% DMRT.

In table 13, in polyethylene packaging, the highest vitamin C (15.081 mg/100 g) is found at 15 \( ^\circ \)C and is significantly different from 5 \( ^\circ \)C and 10 \( ^\circ \)C, but not significantly different from room temperature. At 15 \( ^\circ \)C, the highest vitamin C was found in polyethylene packaging (15.081 mg/100 g) and was significantly different from wrapping and packaging without packaging, but not significantly different from polypropylene packaging.

3.7. \( \beta \)-carotene

The results of statistical analysis on carrots after 4 weeks of storage showed that the treatment of storage temperature had a significant effect on carrots \( \beta \)-carotene, while treatment of packaging types was not significantly different. The difference in the storage temperature treatment of \( \beta \)-carotene carrots which gave a real effect then Duncan's advanced test was carried out with the results as in table 14. Based on table 14, at the storage temperature that \( \beta \)-carotene carrots stored at temperatures of 15 \( ^\circ \)C, 10 \( ^\circ \)C, and 5 \( ^\circ \)C differ significantly from room temperature. In the treatment of packaging types showed no significant difference in the packaging of polypropylene, polyethylene, wrapping and packaging without the level of each treatment was not significantly different.
Table 14. Effect of storage temperature and packaging type on β-carotene of carrots (week 4).

| Treatment                  | β-carotene average at Week-4 (µ/mg) |
|---------------------------|-------------------------------------|
| **Storage Temperature**   |                                     |
| t1 (5 °C)                 | 1.54 b                              |
| t2 (10 °C)                | 1.61 b                              |
| t3 (15 °C)                | 1.66 b                              |
| t4 (Ambient Temperature)  | 0.19 a                              |
| **Packaging Type**        |                                     |
| p1 (Polypropylene)        | 1.45 a                              |
| p2 (Polyethylene)         | 1.24 a                              |
| p3 (Wrapping)             | 1.16 a                              |
| p4 (Without Packaging)    | 1.35 a                              |
| KK/CV (%)                 | 22.16                               |

Mean followed by the same letters on the same columns are not significantly different according to Duncan’s multiple range test at 0.05 level.

Based on the results of this study, β-carotene in carrots after 4 weeks of storage ranged from 0.194 to 1.657 µ/mg. During 4 weeks of storage, β-carotene decreased from fresh conditions (3.456 µ/mg) in table 1. In table 14, it can be seen that at cold temperatures 5 °C, 10 °C, 15 °C shows the highest β-carotene levels and significantly different compared at room temperature while the type of polypropylene packaging shows the highest tendency of β-carotene levels but not significantly different compared to the other three packages. The decrease in β-carotene in carrots is due to transpiration in the carrot so the use of low-temperature storage is very suitable to inhibit unwanted changes. Enzymatic carotene damage can occur due to the activity of the lipoxygenase enzyme. The enzyme can catalyze oxidative carotene damage. To maintain retention of β-carotene, more can use low temperatures as storage temperatures. The levels of pigment beta carotene between weeks 0 and 4 weeks of storage decreased in all temperature treatments. This is because the degradation of β-carotene during cold storage and room temperature also states that at the stage of storage with low temperatures and room temperature, beta carotene pigments are very easily damaged.

From table 14 it can be seen that polypropylene tends to have higher β-carotene. The permeability of polypropylene plastic (0.3963 gr H₂O/jam. m²) is higher compared to polyethylene plastic (0.2642 gr H₂O/jam. m²). Likewise, with the permeability constant, polypropylene plastic (0.0191 gr H₂O/jam. m². mmHg. jam) is higher than polyethylene plastic (0.0128 gr H₂O/jam. m². mmHg. jam). Low moisture permeability will increase the moisture in the packaging. This will reduce the temperature during packaging, so it will suppress the process of losing water due to transpiration. Water vapor will move directly to low concentrations through the pores on the surface of the fruit if the concentration of water vapor during the high packaging will reduce evaporation by carrots [41].
There are several provitamin A which include the most important carotenoid pigment, beta-carotene. Damage can occur at high temperatures if there is oxygen. This compound is also susceptible to oxidation by lipid peroxidase and which promotes lipid oxidation which results in the breakdown of vitamin A. Vitamin A is also very susceptible to light and light.

4. Conclusion
At week 3, a good storage temperature is 5 °C with polypropylene packaging. At week 4, treatments that can maintain the quality of carrots are 5 °C and 10 °C with polypropylene packaging.

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Figure 1. The beta carotene content of carrots week 0 and 4.
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