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Combination of Osmotic Dehydration and Further Drying to Improve the Quality of Dried Carrots

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ABSTRACT

The food industry needs carrots as a processed product for dry products using drying technology to maintain product quality. The aim of the research was to examine the effect of osmotic dehydration temperature with ternary solution on the quality of carrots. The treatments studied were osmotic media temperatures of 25°C and 50°C combined with oven drying and infrared until the water content reached ±10%. Parameters measured after osmotic dehydration were loss of water and increase in solids, quality parameters after further drying were water content and post-storage quality parameters were carotenoids and rehydration test. The dehydration treatment resulted in a reduction of water of 27.25%-44.24% and addition of solids of 15.37%-18.31%. The initial water content of carrots before osmotic treatment was 90%, the water content after osmotic at 25°C was 65.72% and 50°C was 63.29%. Combination of osmotic with oven requires 22-24 hours of drying time while infrared requires 8-10 hours of drying time. The best carotenoid value was osmotic dehydration at 25°C followed by an oven or infrared with a value of 32.95(mg/100g)–31.94(mg/100g). Whereas at 50°C the rehydration values were in the range 271.14%-301.42%.

1. INTRODUCTION

Drying for carrot is mostly performed conventionally, namely by using hot air technology which results in changes of chemical properties and decrease the quality of the final product. The chemical changes affect the organoleptic characteristics of dried carrots, such as color, aroma, and taste (Wani *et al*., 2015). Effective drying can be achieved with low temperatures, namely vacuum dryers, but vacuum drying equipment is relatively more expensive when compared with conventional drying. Sumnu *et al*. (2004) stated that drying using a microwave has higher rehydration and less color loss, as well as reducing water content in a short time. However, if microwave drying continues to be used, the dried product can easily become too hot, which will result in the quality decreasing. Huang *et al*. (2021) suggested that freeze drying is able to remove water from materials by sublimation of solid ice. This process provides relatively high rehydration capabilities, but requires long drying times and high drying costs. Apart from that, freeze drying has limitations in production due to the high cost, making it only applied to high value dry food products (Ishwarya *et al*., 2015). Hasbullah & Putra, (2022) stated, however, that products can be stored for a long time using freeze drying technology. In addition, this technology can prevent microbes from growing and slow lipid oxidation. There are still weaknesses in the quality of dried carrots, so a drying system that combines osmotic dehydration followed by oven and infrared drying is proposed. Dehydration to reduce the amount of water in the material before the drying process. Oven drying represents industrial drying for MSMEs (mini, small, and medium enterprises), while infrared can be applied in industry.

Osmotic dehydration is the process of reducing the water content in a material through a semipermeable wall layer by immersing the product in a hypertonic solution. According to Jannah (2011) the transfer of water in materials through an osmotic process does not change phase so that the color, aroma and texture can be maintained. The disadvantage of this process is that the introduction of osmotic media into the ingredients in certain quantities can affect the taste. Osmotic dehydration is used as a pre-treatment before drying with the aim of producing better quality of dried carrots, especially in retaining carotenoids and maintaining color, taste, aroma, and reducing energy consumption (Gomes *et al*., 2007; Levent & ferit, 2012). Osmotic dehydration followed by oven drying can shorten drying time even though the temperature used is low and there is a decrease in the energy required when drying the material, but the resulting quality changes.

The osmotic media commonly used in osmotic dehydration are salt or sugar (binary solution) or a combination thereof which is called a ternary solution. Ternary solutions have the advantage of higher dehydration rates. If the product is salted inexcessively, the total concentration of dissolved substances can increase without exceeding the saturation limit. Therefore, osmotic dehydration of vegetables is very effective using ternary solutions (Spiess & Behsnilian, 2006). One factor that influences osmotic dehydration is temperature. The high temperature of the osmotic media causes the process of water loss in the material to occur more quickly, but if the temperature used is more than 50°C it can result in cooking and browning of the dried food. The result of osmotic dehydration is a semi-wet product, so further drying is carried out to obtain the final dry product with the specified water content.

Several carrot drying technologies that have been studied are hot air drying, vacuum drying, and microwave drying. The advanced drying used is oven drying and infrared. Oven drying technology was chosen because the temperature of the drying process can be adjusted according to needs and is not affected by the weather. Infrared drying technology was chosen because it has high advantages with short drying times, effective material heating and the quality of the final product can be maintained. The vitamin A content in carrots dried using infrared technology is higher than those dried using sunlight. Apart from that, infrared technology can reduce water activity, reduce color changes, and increase nutrition (Aktas *et al*., 2017). Drying technology is important because drying reduces the water content of the material to a certain extent and results in inhibiting the activity of microorganisms which extend the shelf life of the products (Effendi *et al*., 2022). The aim to be achieved in this research is to determine the best quality of drying products with different osmotic medium temperatures and to combine osmotic dehydration with infrared or oven drying to improve the quality of dried carrot carotenoids.

2. MATERIALS AND METHODS

2.1. Materials and tools

The main material used was fresh carrots with a harvest age of 60-85 HST from farmers in Pagaralam, South Sumatra. The carrot variety was Nantes, grade B with a length of 15-22 cm and a diameter of 3-4 cm (SNI 3163:2014). Other ingredients included distilled water, fine salt, and granulated sugar (Gulaku brand). The measuring instruments used were measuring cups (pyrex), analytical scales, oven, infrared dryer and thermometer. The supporting equipment included cups, cutter, desiccator, filter paper, aluminum foil, slicer and water bath.

2.2. Research location and time

Research was carried out from May to August 2022 at the Biosystems Laboratory, Agricultural Chemistry Laboratory, and Heat and Mass Transfer Laboratory, Department of Agricultural Technology, Faculty of Agriculture, Sriwijaya University (Indralaya).

2.3. Research methods

Osmotic experiments involved temperature treatment of osmotic media, namely 25 °C (A1) and 50 °C (A2), the data of which was analyzed using a comparison of two different mean values. Experiments for drying and storage used a

Completely Randomized Factorial Design (CRFD) with two factors. The first factor was the temperature of the osmotic media and the second factor was further drying at a temperature of 50°C (B1: oven drying; B2: infrared drying) where the data was analyzed using ANOVA and if there were significantly different effects it was further analyzed using the Tukey's Honest Significant Difference (HSD) test at the α=5% level. Treatment coding was A1B1, A1B2, A2B1 and A2B2.

2.4. Research procedure

The research was divided into 4 stages, namely the material preparation process, osmotic dehydration process, further drying process (oven or infrared), and storage. The research flow diagram can be seen in Figure 1. The parameters tested after osmotic dehydration were water loss and increase in solids. Advanced post-drying parameters include water content, and post-storage parameters are carotenoids and rehydration.

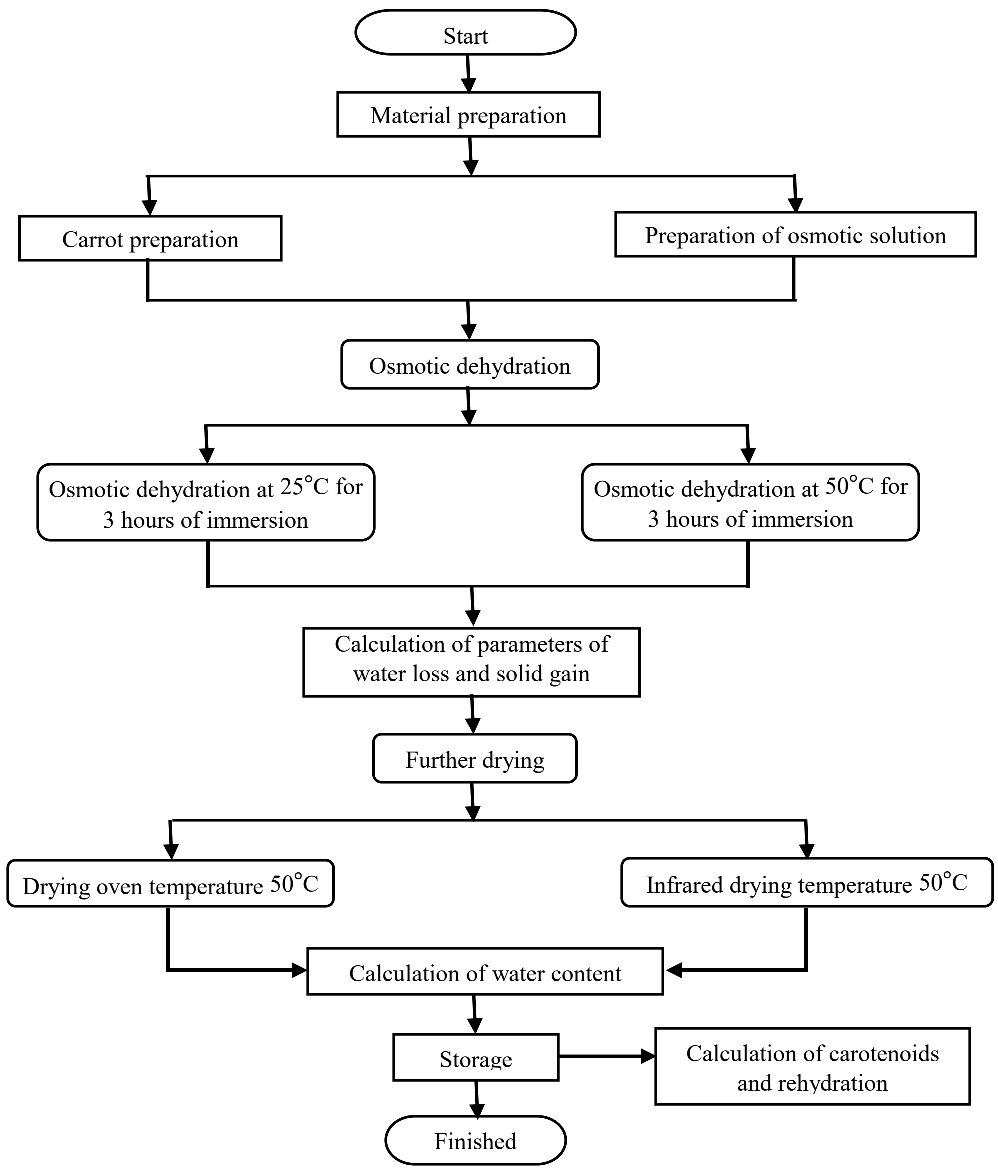

Figure 1. Flow chart of experimental

2.4.1. Preparation of materials

This stage included preparation of osmotic media and preparing carrots for the dehydration and drying process. The ingredients were granulated sugar, fine salt and distilled water. The osmotic solution was made by dissolving granulated sugar using distilled water with a ratio of 1:2 (w/v) and 3% salt (w/v) stirring until it produces a perfect solution with a value of 50°Brix (no sugar and salt particles visible) (Selvakumar, 2011). On the same time, carrots were washed with running water, peeled, then cut into slices of 3 mm thick and was blanched at 60 °C for 3 min.

2.4.2. Osmotic dehydration process

Blanched carrot slices of 300 g were soaked in 600 ml osmotic solution. Osmotic soaking used a water bath with soaking temperatures A1 (25°C) and A2 (50°C) with each soaking time of 3 h. Samples that had been given osmotic dehydration treatment were washed and drained for 5 minutes until there was no solution on the surface of the carrots. Water loss and increase in solid content were measured every hour. The carrot samples used to measure these parameters were prepared separately and were not part of the samples used for the further drying process.

2.4.3. Advanced drying process

The further drying tested was oven drying and infrared drying at a temperature of 50°C to achieve a moisture content of ±10%. Drying oven used the OV-30 model with internal dimensions of the oven 310 × 310 × 310 mm while the outer dimensions of the oven are 450 × 490 × 685 mm with a power of 800 W. Carrot drying was done by placing carrot slices on 2 drying racks. After that, the dried carrots are put in a desiccator for 30 minutes before quality analysis is carried out and packaged for storage.

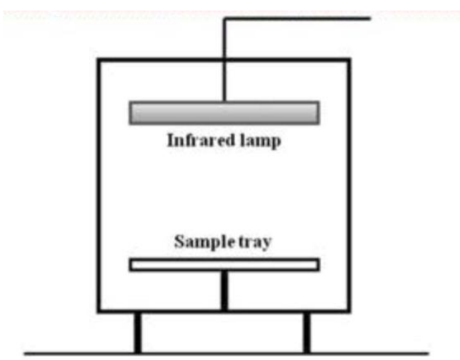

Figure 2. Scheme of dryer and infrared heating lamp (drying box dimensions: 60 × 41 × 32 cm).

Infrared drying used an infrared heating lamp. The schematic of the infrared dryer and heating lamp can be seen in Figure 2. The heating element used an infrared lamp with a wavelength of 2,000-10,000 nm and a power of 150 W for 3 lamps, each lamp has a power of 50 W which was set to a temperature of 50 °C. Infrared lamps used an electric heating source. The fan for hot air circulation used a computer fan measuring 340 × 260 × 381 mm (air speed data was not measured, because the scope of this research was quality of the product produced, not calculating energy consumption). The distance between the shelf and the lamp was 14 cm, the distance between the shelf and the fan was 7 cm, the distance between the lamp and the product was 11 cm. The temperature sensor used a digital thermostat (STC-1000) which was placed directly on the surface of the material. Drying was done by placing the carrot slices on a rack.

2.4.4. Storage process

Evaluation of drying results is not only carried out after drying, but continues with storage. Dried carrot samples were weighed ± 20 grams and packed in plastic zipper bags then stored for 14 days at room temperature (22-26 °C).

2.5. Observation Parameters

2.5.1. Water loss

Water loss is the ratio of the weight of water that comes out of the material to the initial weight of the material. The formula for calculating water loss in materials during osmosis was as follows (Souza *et al*., 2007):

$$WL = \frac{W_i M_i - W_f M_f}{W_i} \quad (1)$$

where WL is the water loss (%), M_i is the water content of the fresh sample (%wb), M_f is the water content of the sample after osmotic (%wb), W_i is the initial sample mass (g) and W_f is the mass of the sample after osmotic (g).

2.5.2. Increase in solid material (Solid Gain)

Solids increase is the ratio of the weight of solids entering the material compared to its initial weight. The formula for measuring the increase in material solids was as follows (Souza *et al*., 2007):

$$SG = \frac{W_f(1-M_f) - W_i(1-M_i)}{W_i} \quad (2)$$

where *SG* is the increase in material density (%) on a solid basis, M_i is the water content of the fresh sample (decimal), M_f is the water content of the sample after osmotic (decimal), W_i is the initial sample mass (g), and W_f is sample mass after osmosis (g).

2.5.3. Water content (AOAC 2005)

Water content was measured using the gravimetric method based on (AOAC, 2005). Percent water content (*KA*) was calculated from the initial mass (*BB*), and the dry mass (*BK*) of the material using the following formula:

$$KA = \frac{BB - BK}{BB} x100\ \% \quad (3)$$

2.5.4. Carotenoids

Carotenoid measurements used a spectrophotometric method at a wavelength of 450 nm. 1 g of the ground sample was put into an Erlenmeyer flask, 7.5 ml of acetone and petroleum ether (PE) were added each. The sample was shaken for 4 hours then filtered, the resulting filtrate was put into a 25 ml volumetric flask and PE:acetone 1:1 was added. 25 ml of filtrate and distilled water were put into an Erlenmeyer flask to form an ether layer and a water-acetone layer. The resulting ether layer was washed 2 times with 25 ml of distilled water. The washing filtrate was added with sodium sulfate anhydrite 1.25 grams per 25 ml. The resulting filtrate was put into a 10 ml volumetric flask and PE:acetone was added to the mark (pigment extract). 10 ml pigment extract was added to the chromatography column. After the pigment extract in the column is used up, PE:acetone is added to the column until the solution that comes out of the column becomes colorless. The eluate in the volumetric flask was added with PE–acetone (10:1) until the tera mark. The absorbance of the eluate containing carotenoids was read using a spectrometer (Nurcahyono & Zubaidah, 2014).

2.5.5. Rehydration test

A sample of 5 grams was placed in 50 ml of distilled water at a temperature of 80°C for 10 minutes, then drained for 5 minutes. Rehydration was calculated by comparing the final mass of the sample after rehydration with the initial mass of the sample before rehydration. Equation 8 is used to calculate rehydration in materials (Octavia, 2002):

$$Rd = \frac{M_1}{M_0} \times 100\ \% \quad (4)$$

where *Rd* is rehydration, M_1 is the mass of the sample after rehydration (g), and M_0 is the mass of the sample before rehydration (g).

3. RESULTS AND DISCUSSION

3.1. Water loss (%)

The total water loss of carrots during the 3 h osmotic process is presented in Figure 3. Water loss at high temperatures is greater than that of low temperatures for the same solution concentration and soaking time. Based on the results and statistical analysis, the temperature of the osmotic media had a significant effect on carrot water loss with a temperature of 50°C producing the highest water loss, namely 44.24%. This is because the high temperature of the medium makes the pores or semi-permeable membrane open more quickly. The pores of the material will enlarge as the solution temperature increases (Lestari, 2017).

Wirawan (2013) stated that the temperature applied during osmotic dehydration has an influence on water loss, because cell walls and the distance between cells are influenced by the immersion temperature in the osmotic medium. In the high temperature soaking process, heat is induced which is accompanied by changes in the solubility, size, and charge of the polysaccharides which causes the carrots to soften. Temperature affects the permeability of the membrane by making it more permeable to water coming out of the product. Higher temperatures promote faster water loss through swelling and plasticization of cell membranes as well as better water transfer characteristics at the product surface due to the lower viscosity of the osmotic medium. Thus, high temperatures will release trapped air from the tissue so that water loss is more effective with osmotic pressure (Saputra, 2001). The higher the temperatures, also result in the higher the osmotic pressure. Magdalena (2014) stated that a greater difference in osmotic pressure between the sugar solution and water in the material causes increased water loss. This difference causes the water mass in the material to flow out of the material into the solution medium. This causes the water in the carrots to come out, while the mass in the osmotic solution is absorbed into the carrots more quickly (Danang, 2012).

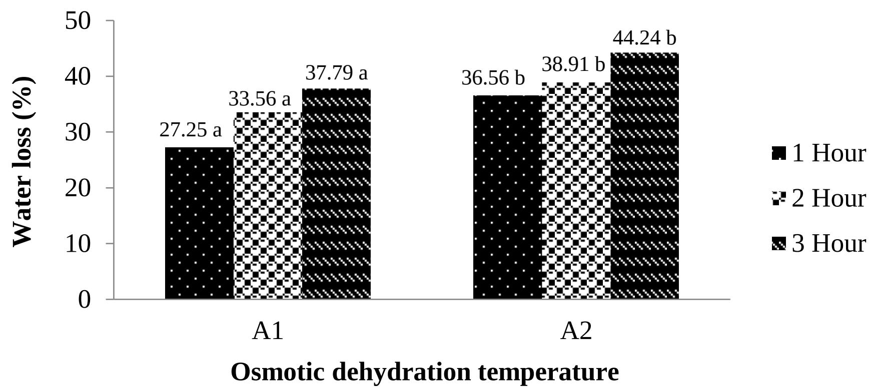

Figure 1. Water loss after osmotic 3 h.

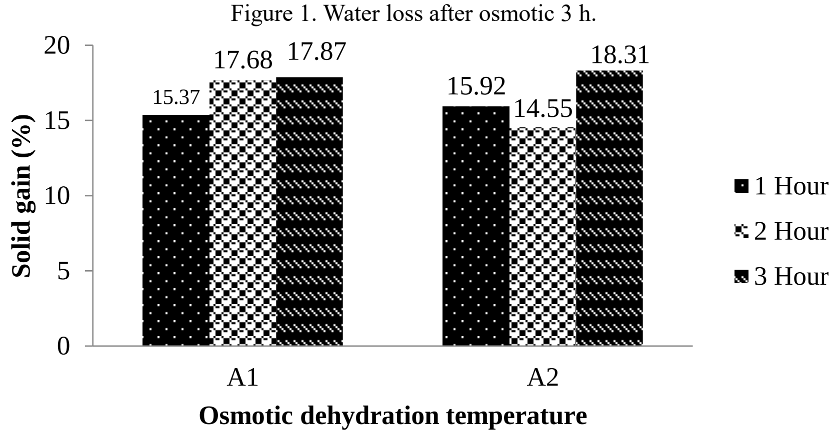

Figure 4. Solid gain after osmotic 3 hours.

2.4.5. Solid gain (%)

The increase of solids in carrots during the 3 h osmotic process is presented in Figure 4. The increase in solids during osmotic dehydration shows the amount of dissolved substances from the osmotic media that enter the carrots, because the water mass in the carrots flows out of the carrots into the osmotic media, the space filled with water in the carrots become empty(Sari et al., 2018).

The increase in solid contents at high temperatures is greater than at low temperatures, which is seen at osmotic times of 1 hour and 3 hours. Meanwhile, in the second hour of soaking, the increase in solids decreased for treatment A2. This is possibly due to the mass of water coming out of the material into the osmotic medium, bringing some of the solids out with it. Based on the statistical analysis, it shows that temperature treatment has no significant effect on the increasing of carrot solids. The increase in carrot solids with treatment A2 (soaking at 50°C) was 18.31%. The results of this study show that temperature has an effect on decreasing water content but has no effect on increasing solids.

2.5. Effect of drying method

2.5.1. Water content (%)

The water content of carrots during osmotic dehydration for 3 hours is presented in Figure 5. The water content of fresh carrots before osmotic dehydration was 90% (wb). After osmotic dehydration treatment for 3 h there was a decrease in water content in each treatment. The water content after osmosis at a temperature of 25°C was 65.72% and a temperature of 50°C was 63.29%. This is because the higher the temperature of the osmotic medium, the greater the decrease in water content. Osmotic temperature affects the final water content of carrots. A high solution temperature causes a lot of water to be lost so that the final osmotic water content becomes lower. Osmotic dehydration affects the drying time of carrots using the same drying technique. Osmotic dehydration produces semi-moist carrots with a lower water content compared to fresh carrots, but still high by instant dry carrot standards. This is based on the principle of the osmotic dehydration technique which is an initial drying technique so that further drying still needs to be carried out to reach the desired water content. The water content of carrots after further drying can be seen in Figure 6.

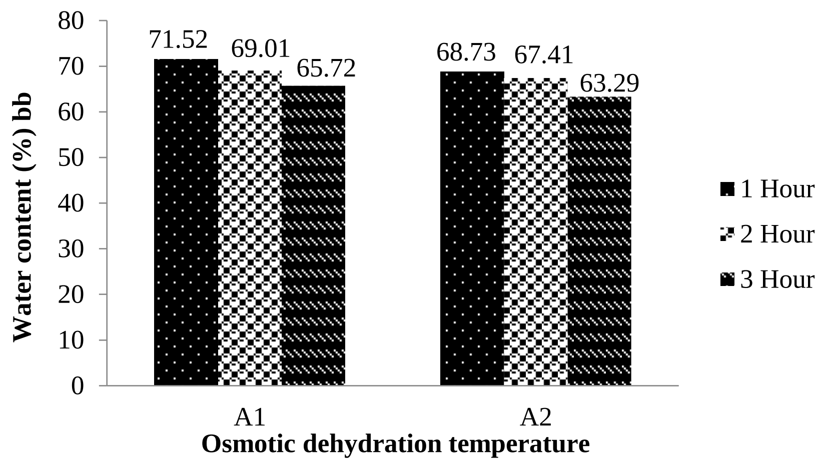

Figure 5. Water content in osmotic dehydration of carrots.

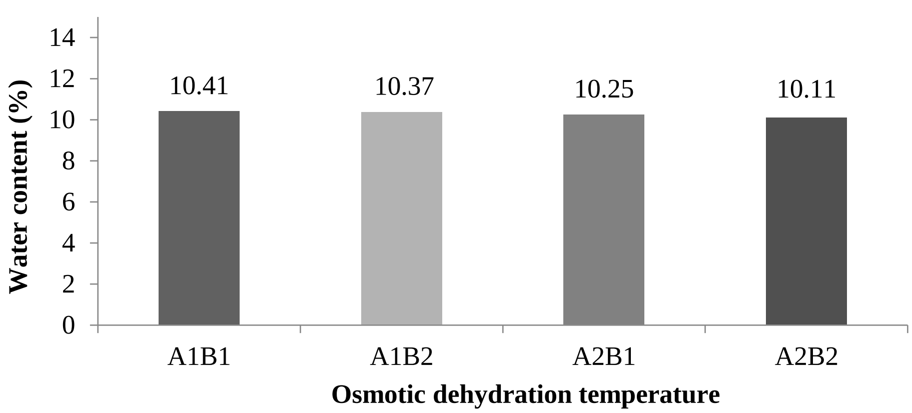

Figure 6. Water content of carrots after further drying.

The combination treatment of osmotic with an oven dryer at a temperature of 50°C requires a drying time of 24 h with an osmotic soaking temperature of 25 °C and 22 h with an osmotic soaking temperature of 50 °C. The combination of osmotic with an infrared dryer at a temperature of 50 °C takes 10 h with a soaking temperature of 25°C and 8 h with a soaking temperature of 50°C to reach the specified water content (10%). The significant reduction in drying time with the infrared drying method is due to the more porous structure of carrots, which allows water to move from the inside of the carrot tissue to the outside and helps reduce the dense layer that forms on the surface of the carrot slices during drying. This results in a high heat density and deeper penetration during infrared drying that increases the rate of moisture transfer to the surface (Vishwanathan *et al*., 2013).

Gilandeh *et al*. (2020) stated that infrared radiation and illumination penetrate into the product and produce heat that accelerate the evaporation process and moves water vapor from the center to the surface of the material. In addition, Sakare *et al*. (2020) stated that the reduction in water content of the product depends on the distance between the infrared heating source and the product, as well as the location of the product at the air inlet or outlet. The upper infrared heating element shows a greater effect on moisture removal compared to the lower infrared heating element because the base on the product forms a barrier to infrared radiation, while the upper heating element infrared rays directly hit the product.

2.6. Changes in quality during storage

2.6.1. Carotenoids

Carotenoids are the main pigments in carrots and are very susceptible to heat and oxidation. Total carotenoids during the 14 day storage process are presented in Table 1.

The data shown in Table 1 shows that the carotenoid content in samples with osmotic dehydration pretreatment followed by further drying generally decreased during the subsequent storage period compared to the initial stage (Selvakumar, 2011). Based on the results of statistical analysis, it shows that the osmotic media temperature treatment and further drying have a significant effect, while the interaction of the two factors shows that there is no significant effect on carotenoids.

Loss of carotenoid content in A2B2 treatment is due to leaching in osmotic media and degradation of carotene at high temperatures caused by the oxidation process. This is because the color intensity of the carotenoids decreases or the color becomes pale, which indicates that the carotenoids in the product are reduced due to oxidation. Additionally the slightly lower retention of carotenoids with the combined infrared drying method could be attributed to higher oxidation losses.

Cui *et al*. (2004) have studied the effect of different drying methods on the carotenoid retention of carrot slices, and reported that carotenoid retention was lower in the combination of microwave vacuum drying and hot air than in microwave vacuum. The loss of carotenoids upon exposure to air is associated with the oxidation of unsaturated carotenoid molecules, as well as the isomerization of carotenoids to light-colored cis forms.

Table 1. Carotenoid and rehydration during storage for 14 days.

Treatment	Carotenoid (mg/100 g)	Rehydration (%)
A_1B_1	32.95 a	193.78 a
A_1B_2	31.94 ab	235.80 ab
A_2B_1	30.98 b	271.14 b
A_2B_2	29.65 b	301.42 b

Note: Number descriptions with different letters show significantly different effects

2.6.2. Rehydration

Rehydration is the ability of a material to absorb water. The rehydration process is a water absorption process that occurs in dry materials by immersing the materials in water (Marabi & Saguy, 2009). Rehydration during the 14 day storage process is presented in Table 1. The highest rehydration was produced by the A2B2 treatment combination with a value of 301.42%. Based on the results of statistical analysis, it shows that the osmotic media temperature treatment and subsequent drying have a significant effect, while the interaction of the two factors shows that there is no significant effect on rehydration. Rehydration of dried carrots is caused by osmotic dehydration treatment as a pre-treatment which can maintain the stability of the cellular structure of the material so that the rehydration process takes place optimally and influence the appearance of the final product. The infrared drying method shows higher rehydration results compared to the oven drying. This is caused by uniform and fast drying by infrared can directly heat the interior layer of the material where water molecules begin to evaporate from the inside of the tissue (Vishwanathan *et al*., 2013). Rapid drying and faster diffusion of water vapor within the material can maintain the pore structure, increasing the material's ability to absorb higher amounts of water during rehydration. Baysal *et al*. (2003) stated that the rehydration capacity of infrared dried carrots is higher compared to those dried using hot air or a microwave. In general, dried carrot products in cube form in the food processing industry produce a rehydration value of 225%. High rehydration makes the product soft and easily destroyed during the process of water absorption in the material during soaking.

4. CONCLUSIONS

The results showed that the temperature of the osmotic medium had an effect on water loss, decreased water content, carotenoids and rehydration of dried carrots. The best treatment is a combination of osmotic dehydration and further drying based on the results of the analysis of all the parameters measured, the A2B2 treatment gives the best results seen from the high water loss value of 44.24%, high solids increase of 18.31%, low water content of 10.11% with a drying time of 8 hours and high rehydration, namely 301.42%. The best carotenoid value was osmotic dehydration at a temperature of 25°C, followed by oven or infrared drying with a value of 32.95 (mg/100g) – 31.94 (mg/100g).

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