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Physicochemical Characteristics of Carrot Chips (Dried Slices) with Differences in Temperature and Drying Time

Misbhatul Laily[1], Alfi Asben[1], and Khandra Fahmy[1].

[1] *Agricultural Industrial Technology Department, Faculty of Agricultural Technology, Andalas University, Padang, West Sumatra, 25613 Indonesia*

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CORRESPONDING AUTHOR

*E-mail: misbhatullaily98@gmail.com

A B S T R A C T

Carrots are one of the vegetable commodities that are rich in nutrients. This research is about drying carrots to extend the shelf life of vegetable products and maintain the nutritional content contained in carrots. Carrots are dried to produce a product like nutritious carrot chips. This research uses vacuum oven drying with different temperatures and drying times to determine the correct temperature and drying time to maintain carrot chips' nutritional content and physical appearance. The research design was a Completely Randomized Design (CRD) with two factors, namely drying temperature (50°C, 60°C, 70°C) and drying time (6 hours, 8 hours, 10 hours). Carrot chips with different temperatures and drying times significantly affected water content, total carotene, color index, and texture. Carrot chip products with vacuum oven drying at 60°C for 10 hours gave results with a water content of 4.24%, the highest total carotene value of 57.15 mg/100g, color appearance with an L* index of 35.68, a * of 20.91, b* of 17.63, texture value of 281.65 N/m2. As well as having organoleptic test results that were liked by the panelists regarding the color and texture of the carrot chips.

1. INTRODUCTION

1.1. Research Background

Indonesia is a country with fertile land. The agricultural and horticultural sectors have an important role as a source of foreign exchange for the country. Vegetables are agricultural products whose availability is always abundant throughout the year and are rich in beneficial nutrients, so they are very important for consumption by all groups. According to research by Valmorbida, 87% of children consume less than one serving of vegetables daily [1]. The Indonesian population over 10 years old still lacks consumption of vegetables and fruit [2]. Thus, vegetable consumption in Indonesia must be increased by processing nutritious vegetable products to increase interest in consuming vegetables.

West Sumatra is a province that has a high potential for vegetable production. There are various types of vegetables produced, one of which is carrots. West Sumatra Province produced carrots in total Production of 25.45 tons in 2021 [3].

1.2. Literature Review

The carrot (*Daucus carrot*, L.) is a popular vegetable because of its α- and β-carotene content. Both types of carotene are important in human nutrition as provitamin A. Carrots are also known to contain fiber, protein, carbohydrates, fat, vitamins B, and C. The level of β-carotene contained in carrots is almost twice as high as the content of β-carotene [4]. The β-carotene compound plays a role in maintaining the body's defenses and immunity, maintaining healthy skin, lungs, and intestinal organs, and helping the growth of new cells. Carrots have bioactive compounds such as carotenoids. Besides acting as provitamin A, carrot beta carotene is also protective against several diseases because it is an antioxidant. The high content of carotene antioxidants has been proven to combat the effects of pollution and passive smoking [5].

As an agricultural vegetable product, carrots require careful handling after being harvested, if left alone they will experience physiological, biological, physical and chemical changes [6]. These changes result in the characteristics of carrots in terms of color, taste, aroma and texture decreasing. The decrease in quality is caused by high water content, so these vegetables do not last long and are easily damaged or rotten. The nature of vegetables after harvest is that they are easily damaged due to the activity of various types of enzymes, so action needs to be taken immediately to maintain the economic and nutritional value of vegetables [7]. Seeing the potential of carrots as a source of provitamin A and to overcome the problem of quality degradation after harvesting, it is necessary to process carrots into a product with a long shelf life.

One of the common ways of preserving vegetables is drying [8]. Drying is widely used in the food processing industry, often being the main process and a stage in post-harvest processing. Drying can extend the shelf life of products by reducing water activity to levels low enough to inhibit the growth of microorganisms. In addition, dry products will be easier to handle in transportation and storage. The drying process will improve products' durability (self-life) without adding chemical preservatives and reducing product volume and transportation costs [9].

The temperature and drying time factors are very important because they will affect the final quality of the dried product. Drying temperatures that are too high and drying periods that are too long will cause damage and a decrease in some nutrients as well as damage to the natural color of carrot tubers. During drying, the water content in the food material will evaporate, causing an increase in the nutrient content in the mass left behind. Dried carrots will experience physical and chemical changes, because the quality of preserved food will differ from original or fresh food [10].

One drying method is with a vacuum oven. A vacuum oven is a method of drying food with nutritional content that cannot withstand high temperatures. In the vacuum drying process, the operating temperature is quite low, around 40 ºC - 70 ºC. The working mechanism of a vacuum oven is reducing air pressure in a vacuum drying device using a vacuum pump connected to a water cooler. The hot air from the system containing water vapor is removed from the oven and cooled in cooling water. Using vacuum air conditions reduces the boiling point of water vapor, so the drying process can be carried out at low temperatures. Food ingredients that cannot withstand high temperatures such as vegetable and fruit products because they can reduce their nutritional content can be dried using the vacuum oven drying method [11].

Some of the advantages of vacuum oven technology are that it does not damage the texture and appearance of materials, minimizes the waste of aroma and volatile active ingredients (easily evaporates), suppresses nutritional damage (protein denaturation), reduces the occurrence of browning due to oxidation with air, energy efficiency due to use of drying at low temperatures [11]. Materials that are dried with the help of a vacuum pump do not experience much damage to the material's color, taste and physical properties [12]. This product form is what consumers like and can be a characteristic of ready-to-eat dry products [13].

Making dried or chip carrots is one way to obtain added value from carrot vegetables. Chip carrots are dried pieces of fresh carrots. Making chips is the easiest way to get long-lasting products and reduce losses due to damage [14]. Dried processed products are usually processed by frying but have weaknesses such as high-fat content, which can increase cholesterol levels in the blood. Chip carrots could be an attractive proposition for consumers who want to increase their vegetable consumption if carrots' natural carotenoid content and other nutritious properties can be maintained during the drying process used in the production process. Based on the description above, it is necessary to research the physicochemical characteristics of chip carrots with different temperatures and drying times using a vacuum oven.

1.3. Research Objective

This research uses a vacuum oven drying method with different temperatures and drying times to determine the right temperature and drying time to maintain the nutritional and nutritional content and physical appearance of carrot chips.

2. MATERIALS AND METHODS

2.1. Preparation of sample

Carrots obtained from Singgalang, X Koto District, Tanah Datar Regency, West Sumatra Province. Then sorted by size, then cleaned and peeled. After that, the carrots are washed again and sliced into 3 mm pieces.

2.2. Blanching

Put the carrot slices in water at a temperature of 85^{o}C for 10 minutes. Blanching can improve carrots' brightness, color, nutrition and texture [15]. After the blanching process, the carrot slices are drained until dry.

2.3. Drying in a vacuum oven

Drain the blanched carrots, place them in a 200 g aluminum baking dish, then dry using a vacuum oven at a temperature of 50, 60, 70ºC and a pressure of 150 mmHg for 6, 8 and 10 hours.

2.4. Research design

This experimental research uses temperature and drying time to produce products *chip* carrot. The research was carried out by looking at the influence and interaction of temperature factors and drying time using a vacuum oven dryer. The research design was a Completely Randomized Design (CRD) with two factors: drying temperature and drying time. Varying vacuum oven temperatures were 50°C, 60°C and 70°C with 6, 8 and 10 hours drying times. Observations were made in the form of product analysis, namely chemical analysis including water content and total carotene, physical observations including color and texture, as well as organoleptic observations including color and level of hardness. The experiment used 3 levels and 3 replications to obtain 27 experimental units. The data obtained were tested using diversity analysis with a confidence level of 95% using the SPSS version 22 program. If each treatment had an effect, a further Duncan Multiple Range Test was carried out. The DMRT test is carried out to see which levels produce differences in quality.

2.5. Observation

2.5.1. Water content gravimetric method [16]

A total of 5 grams of sample is put into an aluminum cup whose total weight is known. The aluminum cup containing the sample was placed in an oven with a temperature of 110^{o}C. Every 1 hour of heating, the cup is removed from the oven, moved into a desiccator for 10-15 minutes, and weighed. Warm the sample until a fixed or constant weight is obtained. Calculate the water content of the sample using the equation below:

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% water content = ((W1+W2)-W3)/ W2 x100%

Information :

W1 = weight of empty aluminum cup (g)

W2 = sample weight (g)

W3 = weight of the cup and sample after drying (g)

2.5.2. Total carotene [17]

A total of 1 gram of sample was added with 2 mL of acetone and 2 mL of hexan, placed in a test tube, and placed in an ultrasonic bath for 15 minutes. Then, the saline was transferred to a centrifuge tube and centrifuged at 3000 rpm for 10 minutes. Then, the solvent was removed, and another 2 mL of acetone and 2 mL of hexane were added and centrifuged again until clear centrifuge results were obtained. The solvent obtained was transferred into a 20 mL measuring flask and added hexane until the reading mark was read using spectrophotometry at a wavelength of 450 nm.

$$Total\ carotene\ \left(\frac{\mu g}{g}\right) = \frac{A\ x\ V\ x\ 10^{-4}}{A_{1\ cm}^{1\%}\ x\ P}$$

Information:

A = Absorbance

V = Volume total extract (mL)

P = Sample weight (g)

2.5.3. Color [18]

Color analysis is carried out using the *color meter Hunterlab Color Flex E2*. The color test used the hunter color system L*, a*, b*. The L* value represents the reflected light that produces the achromatic colors white, gray, and black. The a* value represents a mixed red-green chromatic color, and the b* value represents a blue-yellow chromatic color mixture. The results are numerical data for each variable L*, a*, b*.

2.5.4. Texture [19]

Hardness is tested using tools*Teksture Analyzer Brook Field*. Measurement results*chip* Carrot with a depth of 10 mm and a probe diameter of 4 mm pierces the product for 10 seconds, directly correlating with the hardness of the tested sample.

2.5.5. Organoleptic analysis [20]

Carrying out a hedonic (liking) test to assess a product's color and hardness (texture) level. 25 panelists carried out the work. The color was observed directly, and the panelists observed the hardness level by crumbling it in their hands. The scale range used is 1 to 5, where the statements are really don't like (1), don't like (2), normal (3), like (4), and really like (5).

3. RESULT AND DISCUSSION

3.1. Water content

Water content is one of the chemical properties of ingredients, and water content shows the amount of water contained in food ingredients. The average water content value obtained in this study ranged from 8.98%. – 3.63 %. The analysis showed that the different drying temperature treatments, different drying times, and the interaction of the two treatments had a significant effect at the 5% level on the water content of carrot chips. Drying at 50 °C, 60 °C, and 70 °C combined with drying times of 6, 8, and 10 hours showed that the water content value had decreased.

The increasing temperature and the drying time length greatly influence the speed of water transfer. If the drying temperature increases, the rate of water evaporation of the material will increase, so the water content in the material will decrease. The drying temperature and drying period influence the process of reducing water content in carrot chips [21]. The rate of water evaporation during drying is determined by the increase in drying temperature so that the heat required during evaporation is reduced.

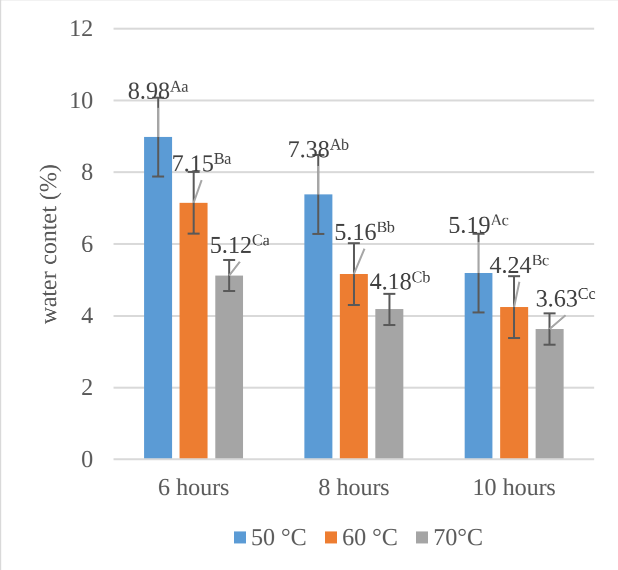

Fig 1. The Interaction Effect of Temperature and Drying Time on the Water Content of Carrot Chips

The research results show that the longer the drying process and the higher the drying air temperature, the less or lower the water content. This decrease in water content is similar to research conducted by Histifarina *et al*. [9], namely that the longer the drying time and the higher the drying temperature, the water content of the resulting dried carrots decreases. The water content of pumpkin chips (dried slices) decreases with increasing drying temperature [22]. Cassava slices experienced decreased water content and a faster drying rate as the temperature and drying process increased [23].

Vacuum oven drying reduces the moisture content of materials by evaporating them at pressures below atmospheric. The drying provided has a real influence on the water movement in the material. Low temperatures and short drying times cause the bound water contained in the material not to evaporate too much, where the water content is determined by the bound water and free water contained in the material. The higher the drying temperature causes more water molecules to evaporate from the carrot chips, resulting in a lower water content. Each increase in temperature and drying time given will have a very real influence on the movement of water in the material [24].

3.2. Total carotene

Carrots are vegetables that contain carotene which is important in human nutrition as provitamin A. Statistical testing shows that different treatments in drying temperature, different drying times, and the interaction of the two treatments have a significant effect at the 5% level on the total carotene of carrot chips. The average carotene of carrot chips due to temperature treatment and drying time was 36.00 – 57.15 mg/100g.

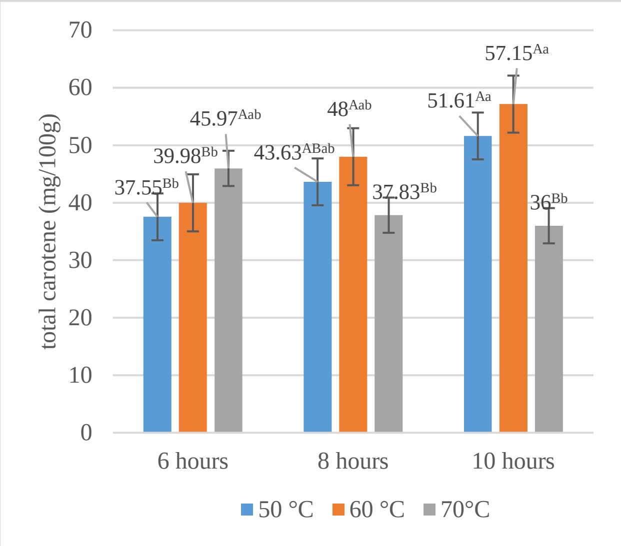

Fig 2. The Interaction Effect of Temperature and Drying Time on the Total Carotene of Carrot Chips

Based on research results, the higher the drying temperature and the longer the drying time, the total carotene tends to increase. The effect of temperature on the oxidation of carotenoids has not been damaged due to heating at a temperature of 60°C [25]; the longer the drying, the more total carotene can be maintained [26]. Total carotene tends to increase after drying. This is thought to be influenced by reduced water content, as a result of which carotene compounds are better retained, and the total carotene value is higher. Carotene does not react with water, so the carotene content becomes more after the drying process, and the color of the carrots becomes more intense reddish yellow [27].

In this study, a drying temperature of 70°C had an average total carotene that tended to decrease after 10 hours of drying. This is caused by the higher drying temperature, causing the carotene to experience less damage. The total change in carotene occurs during drying due to the cis-trans oxidation isomerization reaction to form epoxy carotenoids and apocarotenal [28]. This follows research conducted by Fauzi et al. [22] that the carotene content in pumpkin chips decreased due to the higher drying temperature. Carotenoids are natural compounds with a very high level of unsaturation, so they are easily degraded due to oxidation and heating processes.

3.3. Color

3.3.1. Lightness (L)*

The level of color brightness on carrot chips is indicated by the lightness value (L*). A higher L* value indicates a brighter color, while a lower L* value indicates a darker color. The results of the lightness statistical test show that the drying temperature and drying time factors have a real influence ($\alpha = 0.05$) on the brightness level of the carrot chip color. The interaction between temperature and drying time had no significant effect on the color brightness of carrot chips.

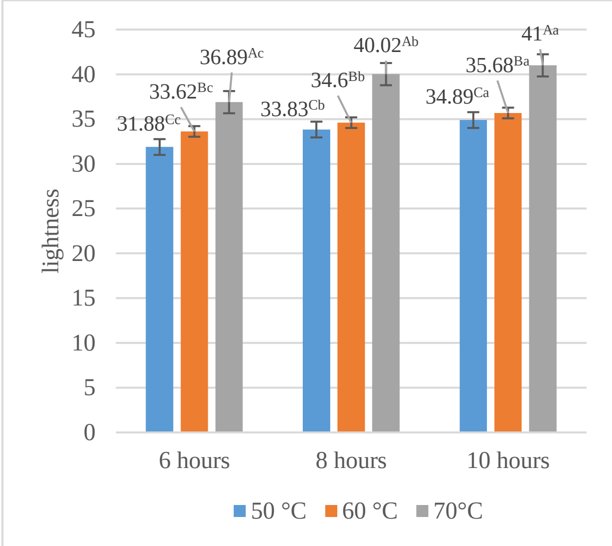

Fig 3. The Interaction Effect of Temperature and Drying Time on the Lightness (L*) of Carrot Chips

The average L* value of carrot chips obtained at different temperatures and drying times using a vacuum oven ranged from 31.88 – 41.00. Observations on the brightness level of carrot chips showed that the higher the temperature and the longer the drying time, the higher the brightness level of carrot chips. The color change of carrot chips occurs due to several chemical and physical processes that affect the color components in carrots. Several factors influence the color of carrots when dried, namely dehydration, chemical reactions, changes in cell structure, Maillard reactions, and the influence of drying conditions. The drying process causes the concentration of pigments and color components in carrots to increase, making the color brighter or more intense.

3.3.2. Redness (a)*

A* value indicates Redness or the level of reddish color in carrot chips. Statistical testing shows that the different drying temperature treatments, different drying times, and the interaction of the two treatments significantly affect the Redness of carrot chips at the 5% level.

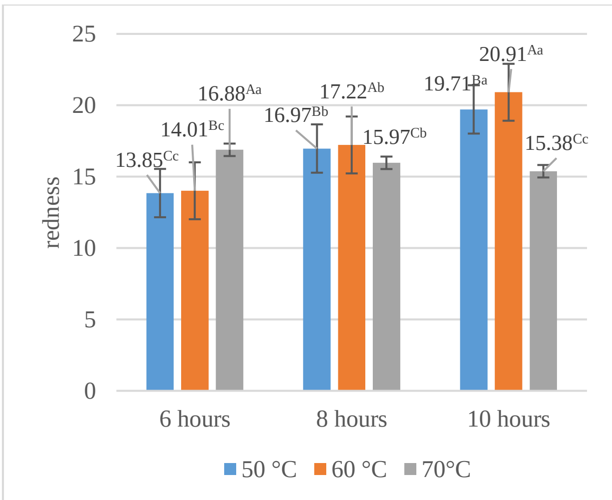

Fig 4. The Interaction Effect of Temperature and Drying Time on the Redness (a*) of Carrot Chips

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Due to temperature treatment and long drying, the index redness color of carrot chips has an average value ranging from 13.85 to 20.91. Treatment at drying temperatures of 50°C and 60°C produces a* value that is increasingly higher as the drying time increases, indicating a deeper red color. However, drying at a temperature of 70°C produces a* value that decreases with increasing drying time.

This study's Redness (a*) value aligns with total carotene. Because the red color in carrots comes from the carotenoid pigment, namely beta-carotene. Beta-carotene is a red-orange pigment that gives carrots their characteristic color and functions as provitamin A. Carotene types α- and β- are the primary carotenoid pigments that cause yellow and orange colors; at least 50% of the total carotenoid content is β-carotene [29].

The color change in carrot chips occurs due to the degradation process of carotenoid pigments, especially beta-carotene. Carotenoid damage at high temperatures occurs due to thermal degradation, so the carotenoid structure decomposes from trans to cis bonds [30]. The oxidation process damages the beta-carotene molecule's structure and causes the pigment to lose its ability to give carrots their red color. Apart from that, the reduced intensity of the red color can also be caused by the Maillard reaction, namely the reaction between sugar and amino acids in carrots.

3.3.3. Yellowness (b)*

The b* value indicates Yellowness or the level of yellowish color in carrot chips. The temperature and drying time factors significantly influenced (α = 0.05) the yellow color of the carrot chips. The 8 and 10-hour drying treatments were not significantly different in the b* value for the color of the carrot chips. Drying at 60°C and 70°C also did not significantly differ in the b* value for the color of carrot chips. The interaction between temperature and drying time had no significant effect on the b* value of the carrot chip color index. The longer the drying time, the higher the b* value.

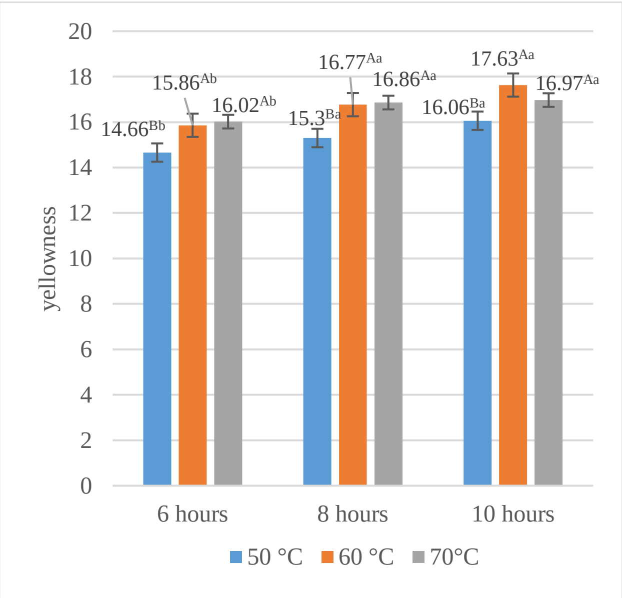

Fig 5. The Interaction Effect of Temperature and Drying Time on the Yellowness (b*) of Carrot Chips

Due to the interaction of temperature and time, the level of Yellowness in the color of carrot chips produces values with an average ranging from 14.66 to 17.63. Besides beta-carotene, carrots contain other pigments, such as alpha-carotene and lutein, which give carrots their yellow color. The combination of these various pigments can also cause a change in the overall color of dried carrots to become more reddish yellow. Long drying causes carrots to lose significant water content. This water loss can increase the concentration of remaining pigment and produce a more concentrated color, so the resulting color is more intense.

3.4. Texture

Texture is one of the important quality attributes for drying-based food products. Statistical testing showed that the different drying temperature treatments, different drying times, and the interaction of the two treatments had a significant effect at the 5% level on the texture of the carrot chips. Duncan's test results showed that the texture of carrot chips, when dried at 70°C for 10 hours, was significantly different from other treatments.

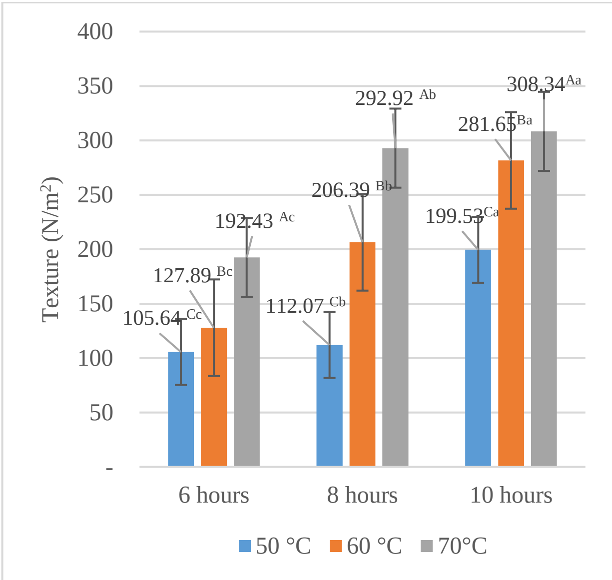

Fig 6. The Interaction Effect of Temperature and Drying Time on the Texture of Carrot Chips

Based on Figure 6, which shows the results of the Duncan test on the texture value of carrot chips, it can be concluded that the higher the temperature and the longer the drying time, the higher the texture value. Increasing texture values indicate a denser and less crunchy texture [31]. The hardness level is influenced by several factors, including the water content of the material, where at a lower water content, the hardness value turns out to be higher than dry carrots with a low water content value.

3.5. Organoleptic

Carrying out a hedonic (liking) test to assess a product's color and hardness (texture) level. The organoleptic test results can be seen in Table 1. Color is an important parameter that becomes a visual object that attracts consumers [18]. Based on Table 1, it can be seen that the color of the carrot chips shows a significant influence (P>0.05) between treatments with a score range of 2.40 – 4.20, with the panelists' liking being normal to very liking. The results of the panelists' assessment of the color of the carrot chips, the panelists tended to give the lowest score for the color of the carrot chips dried at a temperature of 50°C for 6 hours, while the highest score was for drying at a temperature of 60°C for 10 hours. This shows that the panelists prefer the carrot chips, which are dark orange.

Table 1. Average Organoleptic Test Results

Sample	Color ± DS	Hardness ± DS
50°C 6 hours	2.40 ± 0.76^{e}	3.20 ± 0.65^{e}
50°C 8 hours	3.56 ± 0.58^{bc}	3.56 ± 0.58^{c}
50°C 10 hours	4.08 ± 0.76^{a}	3.80 ± 0.65^{c}
60°C 6 hours	2.88 ± 0.78^{d}	3.60 ± 0.58^{c}
60°C 8 hours	3.80 ± 0.65^{ab}	4.24 ± 0.52^{b}
60°C 10 hours	4.20 ± 0.58^{a}	4.52 ± 0.51^{ab}
70°C 6 hours	3.60 ± 0.58^{bc}	4.24 ± 0.66^{b}
70°C 8 hours	3.28 ± 0.61^{cd}	4.48 ± 0.51^{ab}
70°C 10 hours	3.00 ± 0.87^{d}	4.64 ± 0.49^{a}

Information: DS= Deviation Standard

The level of hardness or texture is one of the important food quality attributes. Based on Table 1, it can be seen that the hardness of carrot chips shows a significant influence (P>0.05) between treatments with a score range of 3.20 to 4.64 with the panelists' liking being normal to very like. In this hardness level test, panelists break samples per treatment and assess which samples have a crunchy texture (easy to break) and a hard texture (difficult to break). Then, judge which carrot chips with hardness are preferred by the panelists. The higher the drying temperature and the longer the drying takes, the resulting carrot chips with a harder texture. Then, the texture is also in line with the water content. The lower the water content a harder texture [32].

4. CONCLUSION

Differences in temperature and drying time had a significant effect (α=5%) on water content, total carotene, color index, and texture of carrot chips. Drying at a temperature of 60 °C for 10 hours produced a product that was liked by the panelists regarding color and level of hardness, with analysis results for water content of 4.24%, the highest total carotene of 57.15 mg/100g, color appearance with lightness amounted to 35.68, Redness amounted to 20.91, yellowness 17.63, and texture of 281.65 N/m^2.

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