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Research article

New frozen product development from strawberries (*Fragaria Ananassa* Duch.)Ansar^{a,*}, Nazaruddin^b, Atri Dewi Azis^c^a Department of Agricultural Engineering, Faculty of Food Technology and Agribusiness, University of Mataram, Indonesia^b Department of Food Science and Technology, Faculty of Food Technology and Agribusiness, University of Mataram, Indonesia^c Department of English Education, Faculty of Teacher Training and Education, University of Mataram, Indonesia

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ABSTRACT

Strawberry fruit has a short shelf life. If stored at ambient temperature only lasts 1 day, so it needs to be dried into a frozen product so that its shelf life is longer. Frozen products are favored by consumers because they still have properties like fresh fruit. This study was aimed at examining the physical and sensory characteristics of new frozen products from strawberries. The research sample was freeze-dried at 3 variations of the heating plate temperature were 40, 50, and 60 °C and 3 variations of the drying time were 24, 36, and 48 h. The research parameters observed were weight loss, water content, texture, color, aroma, and taste. The results showed that the freeze-vacuum drying process has a significant influence on the parameters of weight loss, moisture content, texture, and color of frozen strawberries, but does not influence significantly to aroma and taste. The highest weight loss and evaporation were obtained at 60 °C and 48 h of drying time. Frozen strawberries most preferred by panelists are those that are freeze dried at 50 °C and a drying time of 36 h because they have aroma and flavor that were fresh strawberries.

1. Introduction

Strawberry fruit (*Fragaria ananassa* Duch.) can be found in every country because almost all countries in the world have cultivated it (Falah et al., 2016; Macinnis et al., 2020). This fruit is loved for consumption because it has nutrients that are very beneficial for human health (Cari et al., 2016; Blanch and Castillo, 2012; Giampieri et al., 2015; Watson et al., 2020). Strawberries also contain large amounts of folate (Martins et al., 2020; Hu et al., 2020). Polyphenols and vitamins are antioxidant compounds that are found in strawberries (Giampieri et al., 2015). Polyphenols in strawberries such as anti-oxidants, anti-inflammatory, anti-microbial, anti-allergic, and anti-hypertensive are known to improve health and prevent various types of diseases (Yuan et al., 2020; Hemmati et al., 2020). Besides, the vitamin compounds present in strawberries also have a variety of health benefits including anti-cancer and anti-chronic properties (Battino et al., 2020; Jiang et al., 2017). The Physical structure and nutrient content of fresh strawberries is shown in Figure 1 (Gaetan et al., 2019).

The post-harvest strawberries have a short shelf life that can only last one day if stored at environmental temperatures (Souza et al., 2014;

Oetark and Singh, 2019). This strawberry fruit cannot be sold to consumers if the skin has blisters or bruises (Salasuriya et al., 2019). To maintain and increase the shelf life of strawberries, post-harvest processing for these fruits is necessary (An et al., 2020; Silva et al., 2020).

Postharvest processing methods for fruits that are commonly used are drying (Ansar and Azis, 2020; Hwang et al., 2020). However, the skin of strawberries is very thin, so it is easily broken if dried using conventional dryers (Tiang et al., 2020). Also, strawberries dried with conventional dryers have a non-uniform color, so they are less favored by consumers (Karoline Martensen et al., 2020). Anthocyanin contained in strawberries can also be damaged during the conventional drying process. Anthocyanin is unstable at high temperatures, so the stability of these compounds can be disrupted during the conventional drying process (Mawil et al., 2020; Dash et al., 2020).

Frozen fruit is one of the processed fruit products that are very popular with consumers today (Ribattab et al., 2019). Frozen fruit is popular because it has color, aroma, and taste still like fresh fruit (Sungom et al., 2013). Frozen products that have been widely circulating in the market today such as frozen cassava sticks made from fresh cassava are specially processed, hygienic, and without preservatives, to produce products that

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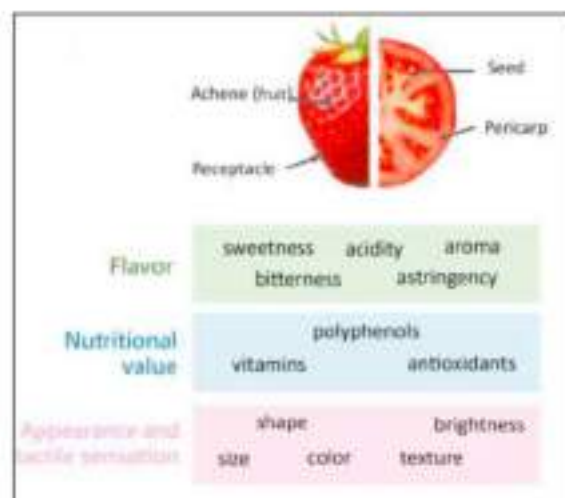


Figure 1. Physical structure and nutrient content of fresh strawberries.

are high in flavor and healthy for consumption by all ages (Galus and Kadzińska, 2015). Other frozen products are frozen grilled bananas made from fresh bananas which are split and flattened and then baked (Moringgal et al., 2019). The shelf life of this frozen product is still short because it has high water content (Thi Phuu et al., 2019).

A freeze vacuum dryer is an effective tool for producing high-quality freeze-dried products when compared to other dryers (Jiang et al., 2017; Shaozhi et al., 2017; Obeide et al., 2017). This freeze vacuum dryer has been used extensively to obtain high-quality dry products (Qiao et al., 2012; Reyes et al., 2010; Schulze et al., 2014). Frozen vacuum dryers can be applied to strawberries (Yu et al., 2006; Silva et al., 2020). Frozen products produced are in line with the desires and needs of consumers for quality processed products that are hygienic and quality (Abkhani and Danesh Garmakhtany, 2012; Sun et al., 2016).

Research on the freeze-drying process for fruits has been widely reported (Lohachoungpl et al., 2004; Giuffe et al., 2019), but no publications have been found that explain the physical and sensory characteristics of frozen strawberries produced from frozen vacuum dryers. Publications that have been revealed by previous researchers include engineering environmental storage to extend the shelf life of strawberry fruit (Fernández-Lam et al., 2015), the combined effect of gamma irradiation and MAP on the antioxidant and antimicrobial properties of strawberries (Kirkin and Gonen, 2018), evaluation of the effect of modified atmospheric packaging (MAP) on strawberry storage (Pozzo et al., 2014), coating method to maintain the organoleptic and functional properties of strawberries (Sicari et al., 2020), and effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry fruit during cold storage (Moshari-Nasirkaadi et al., 2020).

Based on some of the arguments mentioned above, the purpose of this study was to analyze the physical and sensory characteristics of new frozen products from strawberries.

2. Material and methods

2.1. Sample preparation

The research sample was strawberries with Sweet Charlie variety. It was obtained from farmers in Sembalum, East Lombok, Indonesia. Strawberries were sorted and washed with the water, then drained. Then they were stored in the refrigerator at 10 °C to wait for the next process.

2.2. Vacuum-freeze dryer

Samples were dried using the Merck Christ T2/04 series vacuum freeze dryer. The temperature of the condenser was set at -52 °C. The temperature of the heating plate was set at 3 levels were 40, 50, and 60 °C and freeze-drying times were 24, 36, and 48 h. Thermocouples are used to monitor product temperatures during drying. Each drying process was used 2 kg of strawberries. Each treatment was repeated three times.

2.3. Weight loss measurement

The weight loss of the sample was measured before and after drying. It was calculated using the following equation (Hung et al., 2011):

$$\text{Weight loss} = \frac{w_1 - w_2}{w_1} \times 100\% \quad (1)$$

where, w_1 = mass of the sample before drying (gram), w_2 = mass of the sample after drying (gram).

2.4. Moisture content

The moisture content of frozen strawberry was determined according to the standard methods of analysis (Anwar and Aziz, 2019). Approximately 5 g of the sample was weighed into a can. The sample was heated to 50 ± 1 °C until a constant weight was reached, transferred to a desiccator, and was weighed soon after it had reached the environment temperature. The water content of the sample was calculated by the equation:

$$M_c = \frac{a - b}{a} \times 100\% \quad (2)$$

where, M_c = moisture content (%), a = initial of moisture content (%), b = final of moisture content (%).

2.5. Texture measurement

The texture measurement of frozen strawberries using a texture analyzer with ball probe, series SMS P/0.25 S. Test mode: compression; pre-test speed: 1.0 mm/s; test speed: 1.0 mm/s; post-test speed: 5.0 mm/s; target mode: distance: 3 mm; trigger type: auto (force: 10 g); tare mode: auto. The force of compression is expressed in Newton (N). The greater the force needed, the higher the texture of frozen strawberries.

2.6. Color measurement

The color measurement of frozen strawberry using the Chroma meter type AT-13-04 Konica Minolta type CR-400. Color measurement using the Hunter L^* a^* b^* color value system using the following equation (Chapman et al., 2019):

$$L^* = \frac{\text{Lightness}}{255} \times 100 \quad (3)$$

$$a^* = \frac{244a}{255} - 120 \quad (4)$$

$$b^* = \frac{240b}{255} - 120 \quad (5)$$

where, L^* = 0 (black), L^* = 100 (white), a^* (-a = greenness, +a = redness), and b^* (-b = blueness, +b = yellowness).

2.7. Sensory test

There are 25 panelists to carry out the sensory test. Consist of 10 men and 15 women, aged 18–40 years old. The samples were presented by

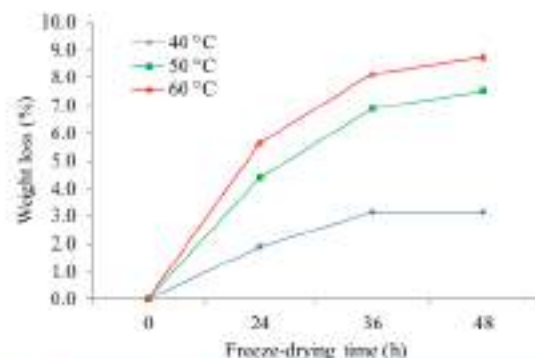


Figure 2. A profile of strawberry weight loss during freeze-vacuum drying at variations of heating plate temperature.

panelists with a random sample. Before the panelists gave an assessment, fresh strawberries were provided as a control sample. Each panelist was asked to rate using a hedonic scale ranges from 1–5, where 1 = detest, 2 = dislike, 3 = neutral, 4 = like, and 5 = extremely like. The sensory evaluation includes the intensity of aroma and taste [Van de Velden et al., 2016]. All participants in the sensory tests gave informed consent.

2.8. Statistical analysis

A two-way analysis of variance was used to determine the effect of heating plate temperature and freeze-drying time variations on the physical characteristics and sensory of frozen strawberry. If the *F*-count value is greater than *F*-crit, it means there is a significant difference in effect at the 95% significance level. The most influenced variables can be calculated using Duncan's Multiple Ranges Test [Yu et al., 2018].

3. Results and discussions

3.1. Weight loss

Profile of strawberry weight loss during freeze-vacuum drying at variations at heating plate temperature and freeze-drying time was shown in Figure 2. At the beginning of drying, weight loss decreases rapidly up to 36 h and then tends to slope until the duration drying is 48 h. After reaching the freezing point, the weight loss not yet changes. Based on Figure 2 it is also showing that the higher of heating plate temperature, the higher the percentage of strawberry weight loss.

The strawberry fruit was freeze-dried at heating plate temperature 60 °C and drying time 48 h had a weight loss of 8.75%, while the samples were dried at the heating plate temperature of 50 and 40 °C have a weight loss of 3.750 and 7.50%, respectively. These data show that the heating plate temperature has a significant effect on decreasing the weight loss of strawberries. Freeze-drying time also significantly influences the weight loss of strawberries. The longer the freeze-drying time, the higher the weight loss due to the presence of flashes and sublimation that are getting longer, so that the release of water is also higher.

The results of the analysis of variance are known that the value of *F*-count (7.96) is greater than the *F*-crit value (5.14). This means that the

treatment of variations at heating plate temperature and freeze-drying time has significant influence ($p < 0.05$) on the decrease in strawberry weight as a result of drying (Table 1). This data also shows that the weight loss of strawberries changes during freeze-drying.

The fruit weight loss was generally affected by the evaporation of moisture content during the drying process [Jades et al., 2018]. During the drying process there is a decomposition of organic compounds into inorganic compounds, namely compounds that are oxidized to CO_2 and absorb O_2 , then reduced to H_2O . The respiration process also causes changes in carbohydrate compounds and produces CO_2 [Thomas-Valdes et al., 2019]. The respiration process takes place continuously, so that the drying longer, the reduction in mass in the fruit also increases [Buvé et al., 2018].

3.2. Moisture content

The analysis results of the frozen strawberry moisture content ranged from 90–95%. Evaporation of the moisture content of strawberry during the vacuum-freeze dryer as shown in Figure 3. At the beginning of drying, the moisture content drops dramatically until the 24th hour, then they decrease at the 36th hour, and they stable at the 48th hour. This data proves that the curve of decreasing moisture rate shows a pattern that is consistent with the results of other studies [Thomas-Valdes et al., 2018].

The strawberry moisture content is still stable during the drying process at treatment variation of heating plate temperatures. The stability of this moisture content shows low metabolic activity during the drying process. Other researchers also reported that strawberries stored at freezing temperatures still occur in the process of respiration, namely the release of water (H_2O) and carbon dioxide (CO_2) [Pan et al., 2014].

Evaporation of moisture content from fruit cells occurs during the drying process because of the sublimation of water to ice crystals. The moisture content evaporates from the cell then freezes on the surface of the fruit skin. Changes in moisture content into ice crystals occur by absorbing water from cells so that the fruit cells become dry and the surface of the fruit skin wrinkles [Falah et al., 2016].

The analysis of variance results shows that *F*-count (8.58) is greater than the *F*-crit value (5.14) (Table 2). This means that variations at the

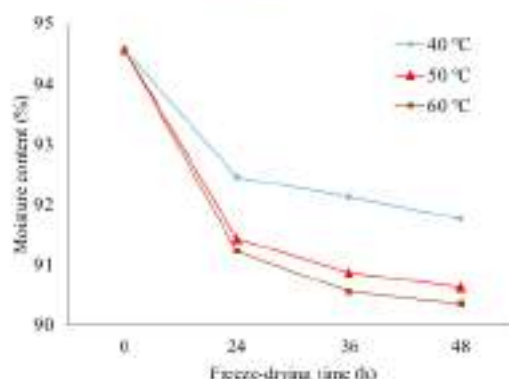


Figure 3. Evaporation of strawberry moisture content during a vacuum-freeze drying at heating plate temperature and freeze-drying time variations.

Table 1. Results of analysis of variance of the weight loss parameters of frozen strawberry at variations heating plate temperature and freeze-drying time.

Source of Variation	SS	df	MS	F	P-value	F-crit
Blocks	27.79	2	13.89	7.96	0.020	5.14
Columns	78.48	3	26.16	14.98	0.003	4.79
Rows	10.48	6	1.75			
Total	116.76	11				

Table 2. Results analysis of variances of the frozen strawberry moisture content parameters at heating plate temperature and freeze-drying time variations.

Source of Variation	SS	df	MS	F	P-value	F-crit
Born	2.40	2	1.20	8.68	0.007	5.34
Colonne	25.34	2	12.67	86.91	7.65E-05	4.79
Error	0.86	6	0.14			
Total	28.67	11				

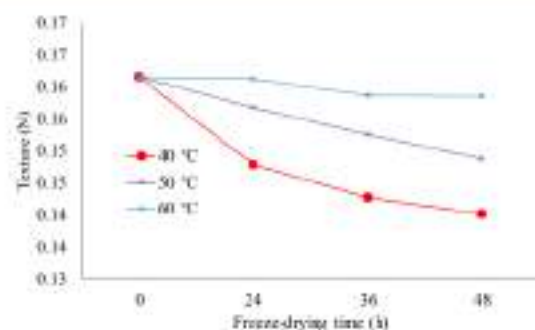


Figure 4. Graph of texture changes of frozen strawberries during vacuum freeze-dryer at heating plate temperature variations.

treatment of heating plate temperature and freeze-drying time have a significant influence ($p < 0.05$) on the frozen strawberry moisture content. This shows that there is a significant change in the strawberry moisture content during the freeze-drying process. The same has been explained by [Ganun et al. \(2019\)](#) that the strawberry moisture content decreases during freeze-drying.

3.3. Texture determination

The frozen strawberry texture was determined based on pressing strength (F-max value). The F-max value for the treatment of heating plate temperature of 40 °C and freeze-drying time of 24, 36, and 48 h of 0.15, 0.14, and 0.14 N, respectively. For the treatment of heating plate

temperature of 50 °C and freeze-drying time 24, 36, and 48 h, the F-max values are 0.16, 0.15, and 0.15 N, and a heating plate, temperature 60 °C and freeze-drying time 24, 36, and 48 h, the F-max value are 0.16, 0.16, and 0.17 N.

In general, the strawberry texture has decreased after freeze-drying ([Figure 4](#)). The mechanical strength of the fruit decreases due to the evaporation of moisture content so that the volume of strawberry fruit is also reduced. The same has been reported by [Asioili et al. \(2018\)](#) that mechanical resistance to compression, shear force, and strawberry stiffness decreases after drying.

Frozen strawberries have a soft and wrinkled texture because some moisture content has evaporated. This is in line with the report [Aliakbari and Dorati Garmakhsani \(2012\)](#) that if the moisture content in fruit cells decreases due to evaporation during drying, the skin cells become soft, limp, and dry, so the fruit looks wrinkled. The texture of strawberries changes during storage due to moisture evaporation ([Ainoli et al., 2018](#)). If the moisture content in the cell decreases, the cell becomes soft and weak ([Jorge et al., 2018](#)).

The variance of analysis results for texture parameters indicates that the F-count value (8.183) is greater than the F-crit value (5.343) ([Table 3](#)). This means that the treatment of variations in heating plate temperature and freeze-drying time has influenced significantly ($p < 0.05$) on the strawberry texture. It also shows that the texture of strawberries undergoes significant changes during the drying process.

3.4. Color analysis

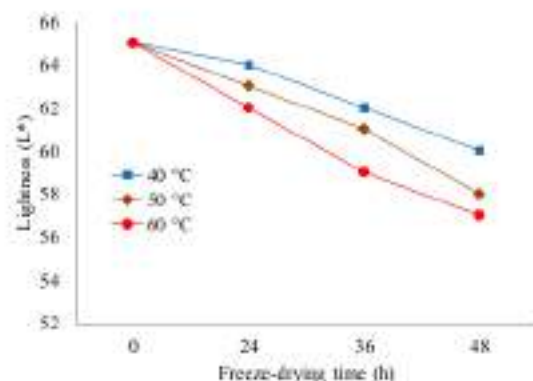
Color was the main parameter for consumers for determining the quality of processed food products. The product color can be easily seen visually by the sense of sight without using the equipment. The color

Table 3. The analysis of variance results for frozen strawberry texture parameters at heating plate temperature and freeze-drying time variations.

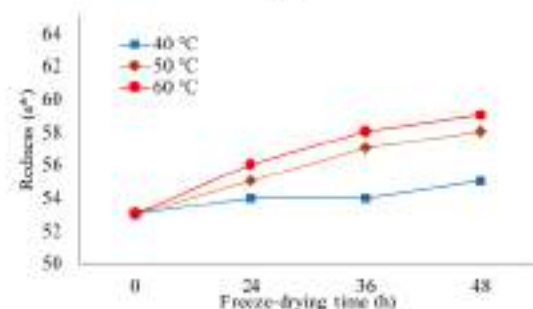
Source of Variation	SS	df	MS	F	P-value	F-crit
Born	2.80	2	1.40	8.18	0.02	5.34
Colonne	2.67	2	1.33	7.99	0.004	4.79
Error	1.03	6	0.17			
Total	6.57	11				



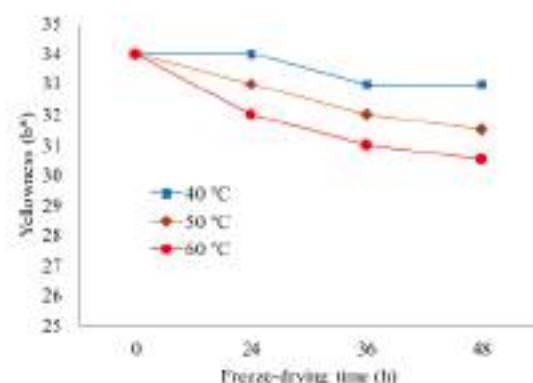
Figure 5. Strawberry fruit, (A) before freeze-drying and (B) after freeze-drying.



(A)

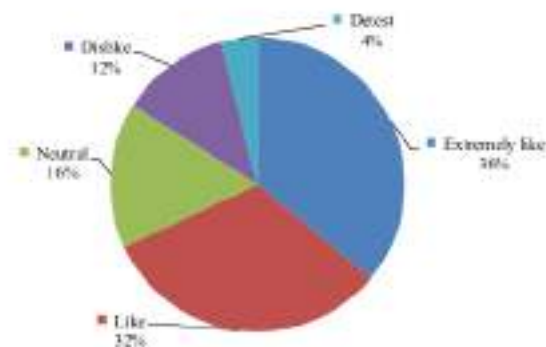


(B)

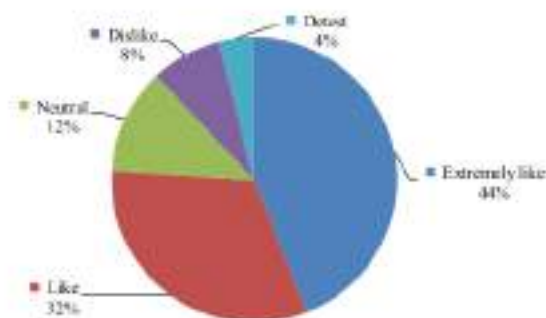


(C)

Figure 6. Graph of color change (A) lightness (L^*), (B) redness (a^*), and (C) yellowness (b^*) of frozen strawberry at heating plate temperature variation.



A



(B)

Figure 7. The results of the panelist's assessment of the aroma (A) and taste (B) of frozen strawberries.

difference between fresh and frozen strawberries from the results of this study is shown in Figure 5. Based on this figure it can be seen that the color of fresh strawberry is greenish-red, while frozen strawberry is dark red.

Graph of the color changes of frozen strawberries as shown in Figure 6. The color components of dried strawberry tend to decrease during the drying process. It can be seen that the strawberry color changes from red to dark red during the drying process.

Based on Figure 6, it can be seen that the redness color component increases during the drying process. This indicates that the color of the strawberries before being dried is greenish-red and then turns into a maroon after drying. While yellowness colors tend to decrease after drying. The discoloration of the strawberries becomes dark because of the enzymatic browning process. The enzymatic browning process occurs because of the reaction between polyphenol oxidase and oxygen enzymes with phenolic substrates on strawberry fruit (Chien et al., 2007). Some researchers also report that color is the most important criterion for consumers in determining product choices (Yue et al., 2019).

Table 4. Results of analysis of variance for frozen strawberry color parameters at variations heating plate temperature and freeze-drying time.

Source of Variation	SS	df	MS	F	P value	F-crit
Block	6.17	2	3.08	5.94	0.04	5.14
Columns	68.35	3	22.78	43.16	0.00	4.79
Rows	3.17	4	0.80			
Total	77.69	11				

The results analysis of variance obtained F-count values (5.84) greater than the F-crit value (5.14) (Table 4). This data showed variation of heating plate temperature and freeze-drying time has influenced significantly ($p < 0.05$) on the color parameters of frozen strawberries. Thus, during the freeze-drying process, there has been a change in color from bright red to dark red.

The color change that occurs in strawberries is one of the important factors in the freeze-drying process. The same analogy has been explained by Jiang et al. (2020) that the color changes of strawberries during storage at room temperature occur significantly, but the changes are not significant at cold temperatures. This color change is also influenced by changes in the physiology and chemistry of strawberries. The color change of strawberries is the process of synthesizing carotenoid pigments and flavonoids (Lesme et al., 2020).

The strawberry fruit has a red pigment that comes from the concentration of anthocyanin (Patras et al., 2009; Gussas et al., 2019). The lower the concentration of anthocyanin, the color of the fruit becomes purple, on the contrary, if the concentration of anthocyanin is very high, the color of the fruit can be blackish (Aicoli et al., 2019). For low pH, anthocyanin can have a red effect on fruit, while for neutral pH the color of the fruit becomes blue, and for high pH, the fruit color becomes pale (Orzan and Berninger, 2011). Besides, the formation of pigments in the fruit is also influenced by temperature, light, and carbohydrate content (Curi et al., 2016). The higher the place where the plant grows, the higher the anthocyanin content of the fruit (Brown et al., 2008).

3.5. Sensory tests

Sensory tests for frozen strawberries were carried out by 25 panelists. This test uses an assessment method with values from 1-5 to measure the panelist preference level for the parameter of the aroma and taste of frozen strawberries. The results of the panelist's assessment of the aroma and taste of frozen strawberries are presented in Figure 7A and B.

Based on data from the panelist's assessment of the aroma of frozen strawberries, it is known that 30% of panelists said that they extremely like, 32% said that they like, 16% said that they neutral, 12% said that they dislike, and only 4% detest (Figure 7A). This data shows that in general frozen strawberries in various variations of freeze-drying treatment are still favored by consumers because they have a fresh fruit-like aroma.

The use of low temperatures during freeze-drying does not significantly affect the aroma of frozen strawberries. This is in line with the results of research conducted by Sun et al. (2016) that the use of a vacuum freeze dryer is safer against the risk of degradation of product aroma changes. This happens because the temperature used for drying is low, Karoline Martinsen et al. (2020) have also reported that samples that are dried in freeze-drying are first frozen, and then dried using low pressure, resulting in a sublimation process in which the water content was frozen turns into steam.

Another indicator of consumer acceptance of frozen food products is taste. As reported by Yusufe et al. (2017) that taste is an indicator of organoleptic food quality which is formed as a result of stimulation of the taste buds (tongue) that make up the overall flavor of the product being assessed.

The results of the panelist's assessment of the taste of frozen strawberries found that 44% of panelists said that they extremely like, 32% said that they like, 12% said that they neutral, 8% said that they dislike, and only 4% detest (Figure 7B). Based on the data it can be said that in general, the taste of frozen strawberries is also very favored by panelists. The taste of frozen strawberry products is no different from the taste found in fresh strawberries.

A frozen food product even though it has an attractive appearance and color and is loved by consumers, but its acceptance will decrease if there has been a deviation of taste (Anwar and Aziz, 2019). Strawberry fruit has a sweet and sour taste (citrus) that is fresh and soft (Yue et al.,

2019). This compound is not easily evaporated by the influence of environmental temperature (Sotras et al., 2014).

4. Conclusion

The freeze-vacuum drying process has a significant influence on the parameters of weight loss, moisture content, texture, and color, but does not influence significantly to aroma and taste. The parameters of aroma and taste of frozen strawberries do not change significantly after was frozen and they seem fresh fruit. The decrease in weight loss ranged from 3.75-8.75%, moisture content ranged from 2.80-4.20%, textures ranged from 0.30-2.13%, and colors ranged from 3.50-7.00%. Processing strawberries into frozen products is a good prospect for the industry in the future.

Declarations

Author contribution statement

Anwar: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data.

Nazaruddin: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Azri D. Aziz: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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