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New product development from of strawberries (Fragaria Ananassa Duch.)

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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 product from strawberries produced from a vacuum freeze dryer. 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 hours. The research parameters observed were weight loss, water content, texture, color, aroma, and taste. The results showed that the heating plate and drying time had a significant effect on weight loss, moisture content, texture, and color of frozen strawberries, but did not affect the aroma and taste. The highest weight loss and evaporation were obtained at 60°C and 48 hours drying time. Frozen strawberries most preferred by panelists are those that are freeze-dried at 50°C and a drying time of 36 hours because they have the aroma and flavor that still matches the fresh strawberries.
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Dr. Ansar

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Highlights

- The physical properties of frozen strawberries including the texture, moisture content, and color are explained.
- Sensory properties include aroma and taste have been summarized.
- The methods used to evaluate physical and sensory properties have been described.
- The texture of frozen strawberries was affected by the temperature and duration of the freeze-dryer.

New product development from of strawberries (*Fragaria Ananassa* Duch.)

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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 product from strawberries produced from a vacuum freeze dryer. 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 hours. The research parameters observed were weight loss, water content, texture, color, aroma, and taste. The results showed that the heating plate and drying time had a significant effect on weight loss, moisture content, texture, and color of frozen strawberries, but did not affect the aroma and taste. The highest weight loss and evaporation were obtained at 60°C and 48 hours drying time. Frozen strawberries most preferred by panelists are those that are freeze-

dried at 50°C and a drying time of 36 hours because they have the aroma and flavor that still matches the fresh strawberries.

Keywords: frozen strawberry; moisture content; texture; color; aroma; taste.

1. Introduction

Strawberry fruit (*Fragaria ananassa* Duch.) can be found in every country because almost all countries in the world have cultivated its (Falah, Husna, Dewi, & Jumeri, 2016; MacInnis, Buddle, & Forrest, 2020). This fruit is loved for consumption because it has nutrients that are very beneficial for human health (Curi, et al., 2016; Blanch & Castilo, 2012; Giampieri, et al., 2015; Watson, Noling, & Desaeger, 2020). Strawberries also contain large amounts of folate (Marian, et al., 2020; Hu, Lu, Guo, & Zhu, 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 (ZhixiangYuan, et al., 2019; Hemmati, Ahmeda, Salehabadi, Zangeneh, & Zangeneh, 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 **Fig. 1**. (Gaston, Osorio, Denoyes, & Rothan, 2019).

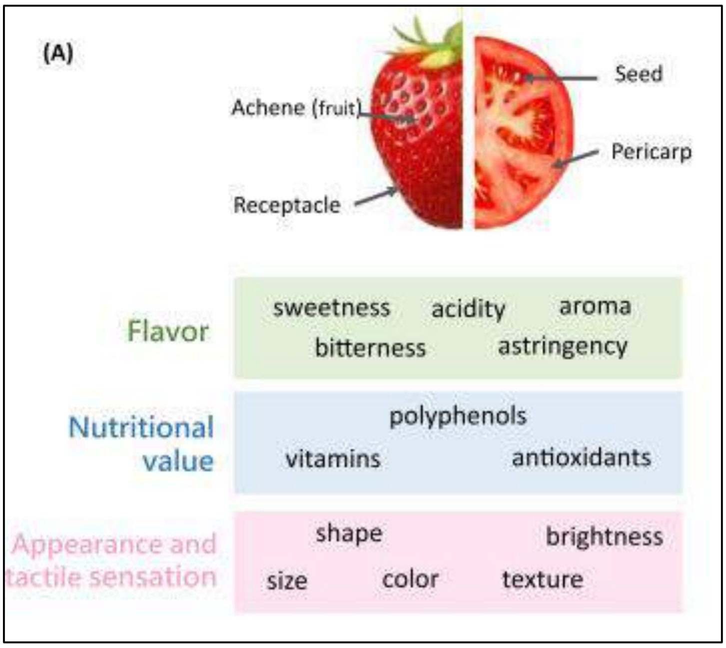


Fig. 1. Physical structure and nutrient content of fresh strawberries.

The post-harvest strawberries have a short shelf life that can only last one day if stored at environmental temperatures (Souza, Pereira, Silva, Lima, & Pio, 2014; Ozturk & Singh, 2019). This strawberry fruit cannot be sold to consumers if the skin has blisters or bruises (Balasooriya, Dasanayake, & Ajlouni, 2019). To maintain and increase the shelf life of strawberries, post-harvest processing for these fruits is necessary (An, Li, Zude-Sasse, Tchuenbou-Magaia, & Yang, 2020; Silva, Meireles, & Saldaña, 2020).

Postharvest processing methods for fruits that are commonly used are drying (Hwang, et al., 2020). However, the skin of strawberries is very thin, so it is easily broken if dried using conventional dryers (Tang, Ma, Li, & Wang, 2020). Also, strawberries dried with conventional dryers have a non-uniform color, so they are less favored by consumers (Karoline Martinsen, Aaby, & Skrede, 2020). Anthocyanins contained in strawberries can also be damaged during the conventional drying process. Anthocyanins are unstable at high temperatures, so the stability of these compounds can be disrupted during the conventional drying process (Mainil, Aziz, Harianto, & Maini, 2020; Dash, Chase, Agehara, & Zotarell, 2020).

Frozen fruit is one of the processed fruit products that are very popular with consumers today (Khattab, Guirguis, Tawfik, & Farag, 2019). Frozen fruit is popular because it has color, aroma, and taste still like fresh fruit (Bongoni, Steenbekkers, Verkerk, van Boekel, & Dekker, 2013). Frozen products that have been widely circulating on the market today such as frozen cassava sticks made from fresh cassava are specially processed, hygienic, and without preservatives, to produce products that are high in flavor and healthy for consumption by all ages (Galus & Kadzińska, 2015). Other frozen products are frozen grilled bananas made from fresh bananas which are split and flattened and then burned (Maringgal, Hashim, Mohamed Amin Tawakkal, & Muda Mohamed, 2019). The shelf life of this frozen product is still short because it has high water content (Thi Phan, Truong, Wang, & Bhandari, 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, Jielin, Guangming, & Qin, 2017; Obeidat, Sahni, Kessler, & Pikal, 2017). This freeze vacuum dryer has been used extensively to obtain high-quality dry products (Qiao, Fang, Huang, & Zhang, 2012; Reyes, et al., 2010; Schulze, Hubbermann, & Schwarz, 2014). Frozen vacuum dryers can be applied to strawberries (Xu, Zhang, Mujumdar, Duan, & Jin-cai, 2006; Silva, Meireles, & Saldaña, 2020). Frozen products produced are in line with the desires and needs of consumers for quality processed products that are hygienic and quality (Alikhani & Daraei Garmakhany, 2012; Sun, Li, Jiang, Sun, & Li, 2016).

Research on the freeze-drying process for fruits has been widely reported, 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-Lara, et al., 2015), the use of modified atmosphere packaging (Kirkin & Gunes, 2018). Banana chief drying uses a vacuum dryer (Khampakool, Soisungwan,

& Park, 2018). Implement a Solanaceae strategy for enhancing strawberry plants (Asioli, et al., 2018).

Various research results have been published, but no one has discussed the strategy of extending the shelf life of strawberries for a longer period. Therefore, this research is very important to reveal the physical and sensory characteristics of frozen strawberries that can be used as information for the strawberry fruit processing industry to produce frozen products that are favored by consumers. Thus, this study aims to analyze the physical and sensory characteristics of strawberries produced from frozen vacuum dryers.

2. Material and methods

2.1. Sample Preparation

The research sample was strawberry variety *Fragaria ananassa* Duch were obtained from farmers in Sembalun, East Lombok, Indonesia. Strawberries were sorted and washed with water, then drained. Then they are stored in the refrigerator at 15°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 hours. Thermocouples are used to monitor product temperatures during drying. Each drying process was used 2 kg of strawberries.

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):

$$Weight\ loss = \frac{w_f - w_d}{w_f}\ 100\% \qquad (1)$$

where, w_f = mass of the sample before drying (gram), w_d = 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 (Ansar; Nazaruddin; Azis, A D, 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:

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

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):

$$L^* = \frac{Lightness}{255} x100 \qquad (3)$$

$$a^* = \frac{240a}{255} - 120 \quad (4)$$

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

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

2.7. Sensory Evaluation

Sensory evaluation was used to determine consumer acceptance of frozen strawberries produced from vacuum freeze dryers related to aroma and taste. There are 25 trained panelists were used to carry out the sensory analysis. Consist of 10 men and 15 women, aged between 18-40 years. The samples were presented to each panelist with a random sample. Each panelist was asked to rate using a hedonic scale ranges from 1-5, where 1= dislike extremely, 2 = dislike moderately, 3 = dislike, 4 = like moderately, and 5 = like extremely. The sensory evaluation includes the intensity of aroma and taste (Van de Velde, Esposito, Grace, Pirovani, & Lila, 2018).

2.8. Statistical Analysis

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 F-count value is greater than F-crit, it means there is a significant difference in effect at the 95% significance level. The most influential variables can be calculated using Duncan's Multiple Ranges Test (Yu, Low, & Zhou, 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 **Fig. 2**. At the beginning of drying, weight loss decreases rapidly up to 36 hours and then tends to slope until the duration drying is 48 hours. After reaching the freezing point, the weight loss not yet change. Based on **Fig. 2** it is also shows that the higher of heating plate temperature, the higher the percentage of strawberry weight loss.

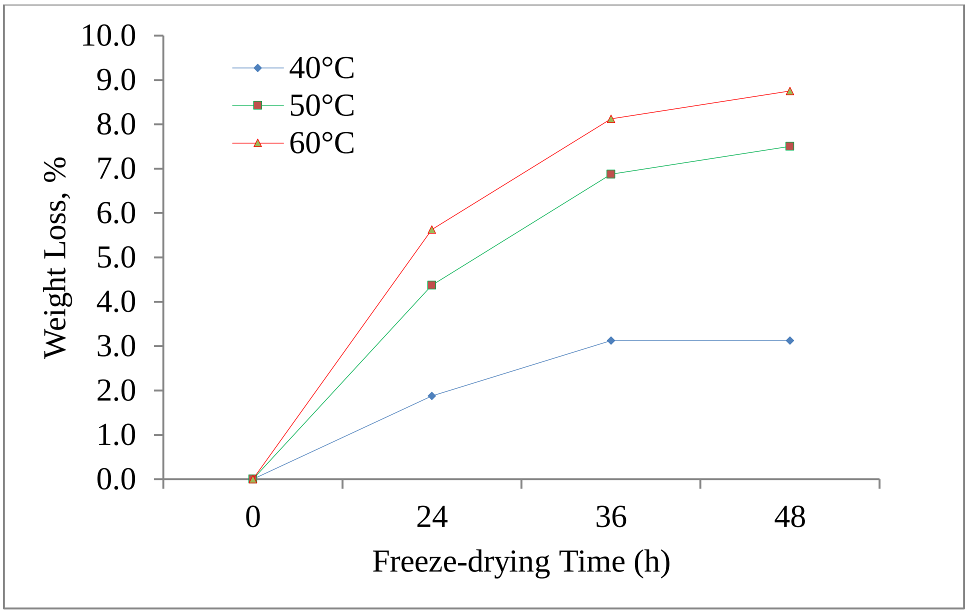


Fig. 2. A profile of strawberry weight loss during freeze-vacuum drying at variations of heating plate temperature.

The strawberry fruit was freeze-dried at heating plate temperature 60°C and drying time 48 hours 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.

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**
Rows	27.79	2	13.89	7.96	0.020	5.14
Columns	78.48	3	26.16	14.98	0.003	4.76
Error	10.48	6	1.75			
Total	116.76	11				

The fruit weight loss is generally affected by the evaporation of moisture content during the drying process (Jaster, 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-Valdés, Theoduloz, Jiménez-Aspee, & Schmeda-Hirschmann, 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

Fig. 3. At the beginning of drying, the moisture content runs very fast until the 24 hour, then runs slowly at the 36 hour to reach the equilibrium point at the 48 hour. This data proves that the curve of decreasing moisture rate shows a pattern that is consistent with the results of other studies (Thomas-Valdés, S; Theoduloz, C; Jiménez-Aspee, F; Burgos-Edwards, A; Schmeda-Hirschmann, G, 2018).

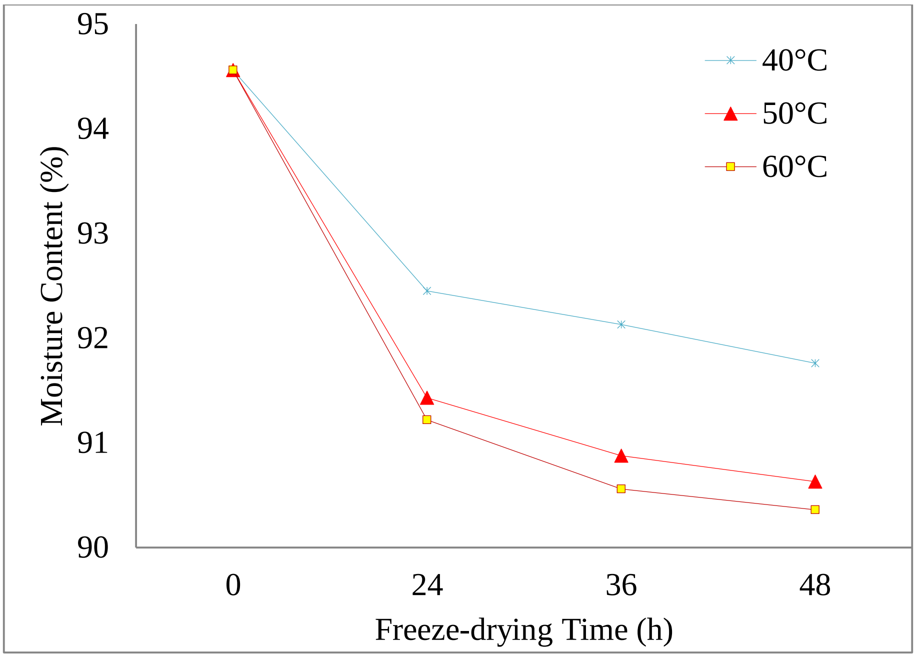


Fig. 3. Evaporation of strawberry moisture content during a vacuum-freeze drying at heating plate temperature and freeze-drying time variations.

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, Zhang, Zhu, Mao, & Tu, 2014).

Evaporation of moisture content from fruit cells occurs during the drying process as a result 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, Husna, Dewi, & Jumeri, 2016).

The analysis of variance results shows that F-count (8.68) is greater than the F-crit value (5.14) (**Table 2**). This means that variations at the 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 Gaston et al. (2019) that the strawberry moisture content decreases during freeze-drying.

Table 2. Results analysis of variance 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
Rows	2.49	2	1.25	8.68	0.017	5.14
Columns	25.34	3	8.44	58.91	7.65E-05	4.76
Error	0.86	6	0.14			
Total	28.67	11				

3.3. Texture Determination

The frozen strawberry texture was determinates 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 hours 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 hours, the F-max values are 0.16; 0.15; and 0.15 N, and at heating plate temperature 60°C and freeze-drying time 24, 36, and 48 hours, the F-max value are 0.16; 0.16; and 0.17 N.

In general, the strawberry texture has decreased after freeze-drying (**Fig. 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 Asioli, et al. (2018) that mechanical resistance to compression, shear force, and strawberry stiffness decreases after drying.

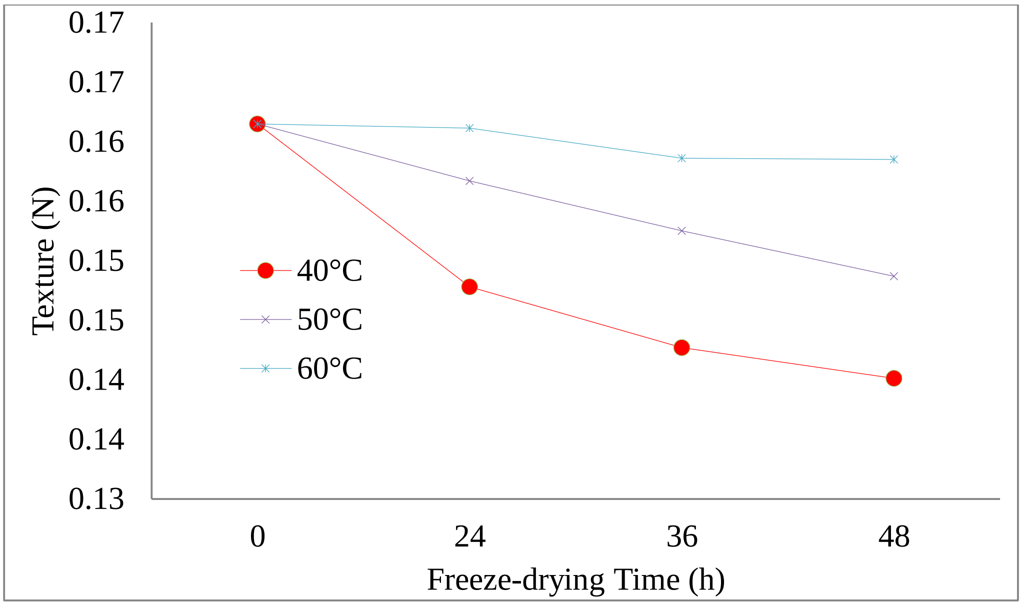


Fig. 4. Graph of texture changes of frozen strawberries during vacuum-freeze dryer at heating plate temperature variations.

Frozen strawberries have a soft and wrinkled texture because some moisture content has evaporated. This is in line with the report Alikhani and Daraei Garmakhany (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 (Asioli, 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-crib value (5,143) (**Table 3**). This means that the treatment of variations in heating plate temperature and freeze-drying time has significant influence ($p> 0.5$) on the strawberry texture. It also shows that the texture of strawberries undergoes significant changes during the drying process.

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**
Rows	2.86	2	1.43	8.18	0.02	5.14
Columns	2.67	3	0.89	5.09	0.044	4.76
Error	1.05	6	0.17			
Total	6.57	11				

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

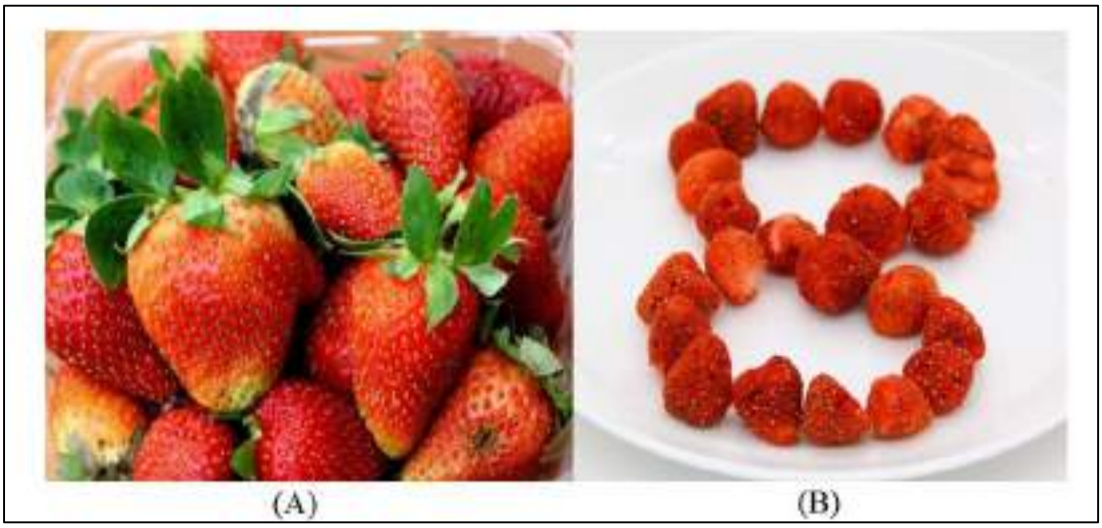
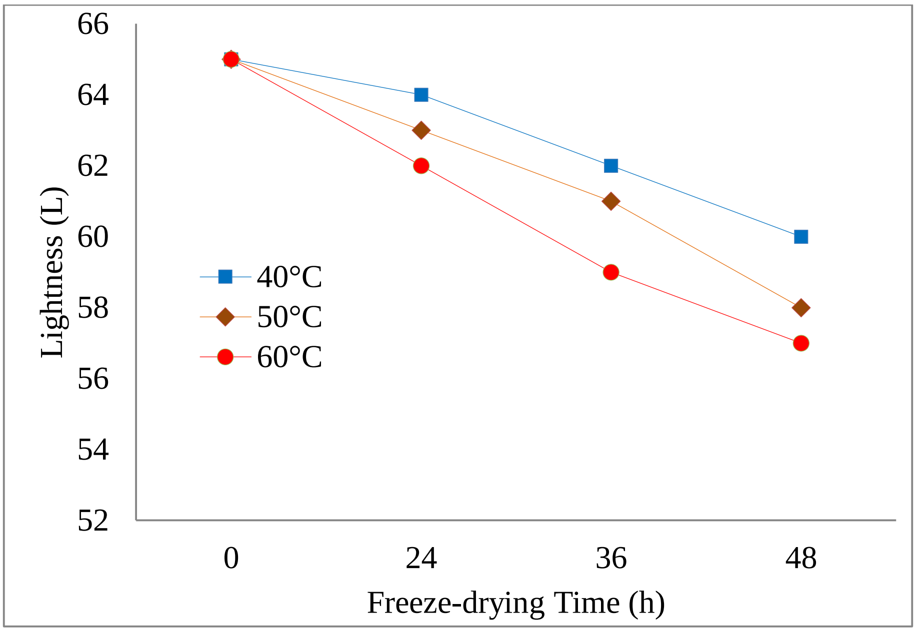
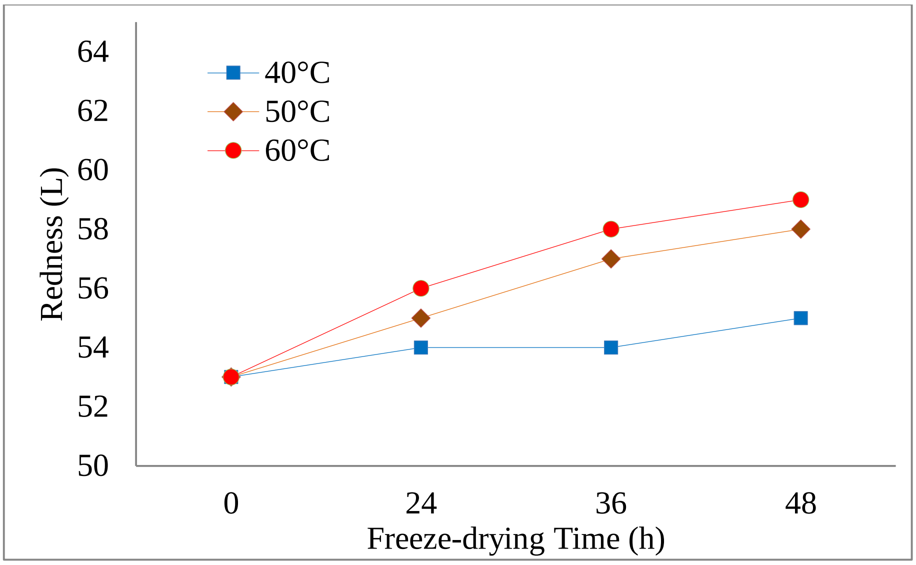


Fig. 5. Strawberry fruit, (A) before freeze-drying and (B) after freeze-drying

Graph of the color changes of frozen strawberries as shown in **Fig. 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.



(A)



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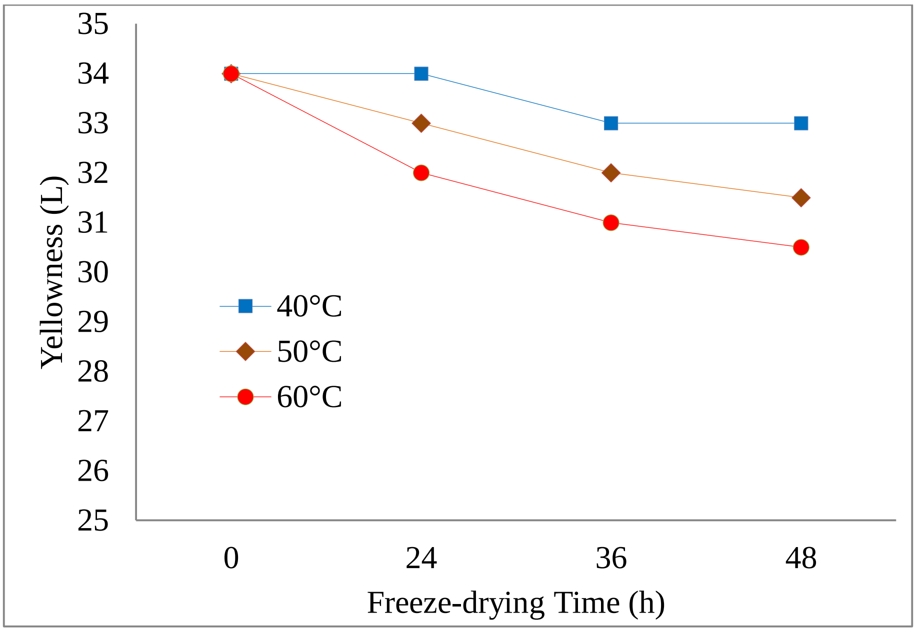


(C)

Fig. 6. Graph of color change (A) lightness, (B) redness, and (C) yellowness of frozen strawberry at heating plate temperature variation.

Based on **Fig. 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 (Chisari, Riccardo, Barbagallo, & Spagna, 2007). Some researchers also report that color is the most important criterion for consumers in determining product choices (Yue, Shang, Yang, Huang, & Wang, 2019).

The results analysis of variance obtained F-count values (5.84) greater than the F-crit value (5.14) (**Table 4**). This data means that variations of heating plate temperature and freeze-drying time have 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.

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

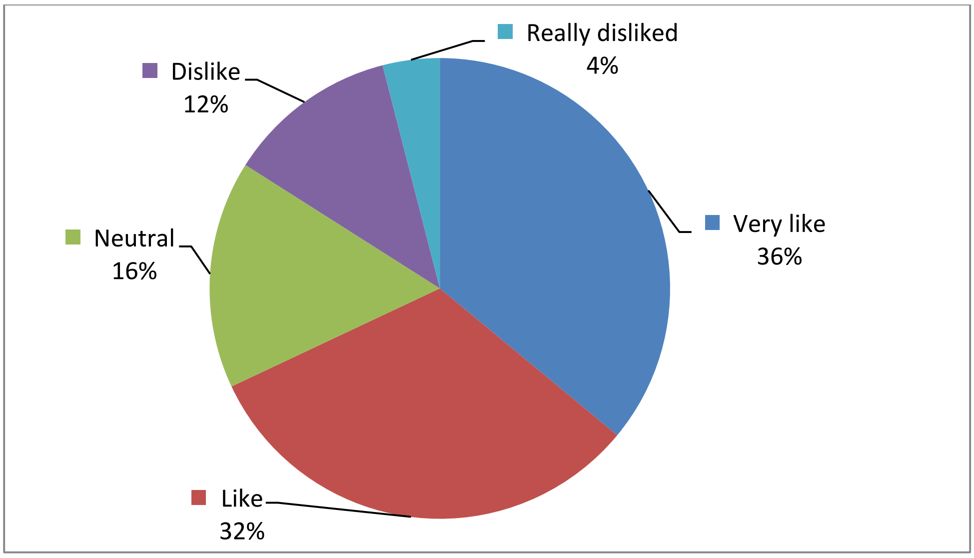
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F-crit**
Rows	6.17	2	3.08	5.84	0.04	5.14
Columns	68.33	3	22.78	43.16	0.00	4.76
Error	3.17	6	0.53			
Total	77.67	11				

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).

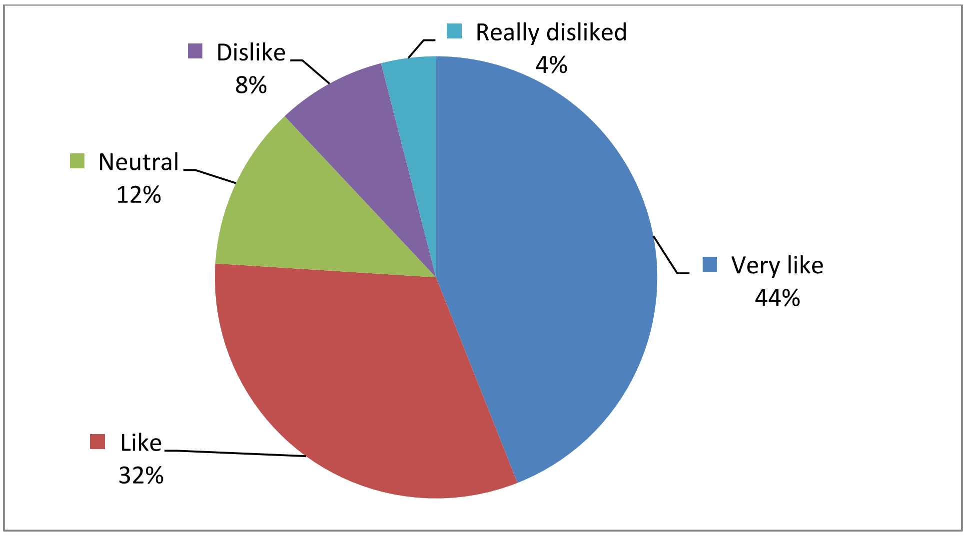
The strawberry fruit has a red pigment that comes from the concentration of anthocyanins (Patras, Brunton, Pieve, & Butler, 2009; Gaston, Osorio, Denoyes, & Rothan, 2019). The lower the concentration of anthocyanins, the color of the fruit becomes purple, on the contrary, if the concentration of anthocyanins is very high, the color of the fruit can be blackish (Asioli, et al., 2018). For low pH, anthocyanins 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 (Ozcan & Barringer, 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, Durst, Wrolstad, & De Jong, 2008).

3.5. Sensory Tests

Sensory tests for frozen strawberries were carried out by 25 trained panelists. This test uses an assessment method with a range of values from 1 to 5 to measure the panelist preference level for the parameters 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 **Fig. 7A** and **7B.**



(A)



(B)

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

Based on data from the judicial assessment of the aroma of frozen strawberries, it is known that 36% of panelists answered very like, 32% said they liked, and only 16% stated neutral, 12% disliked, and 4% said they really disliked (**Fig. 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 temperature. Karoline et al. (2020) have also reported that samples that are dried in freeze-drying are first frozen, then dried using low pressure, resulting in a sublimation process in which the water content that 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 they really liked, 32% said they liked, 12% said they were neutral, 8% said they didn't like it, and only 4% who said they really didn't like it (**Fig. 7B**). Based on this 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 (Ansar; Nazaruddin; Azis, A D, 2019). Strawberry fruit has a sweet and sour taste (citrus) that is fresh and soft (Yue, Shang, Yang, Huang, & Wang, 2019). This compound is not easily evaporated by the influence of environmental temperature (Souza, Pereira, Silva, Lima, & Pio, 2014).

4. Conclusion

The temperature of the heating plate and freeze drying time significantly influence the parameters of weight loss, water content, texture, and color, but do not significantly influence the aroma and flavor parameters of new product from a frozen strawberries. Average 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%. Based on the results of sensory tests consisting of aromas and flavors, it is known that frozen strawberries do not change significantly during the freeze drying process. This research is important as information for the strawberry processing industry to new product that are liked by consumers.

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CONFLICT OF INTEREST

The all authors not have any conflict of interest.

References

Akrom, M., Hidayanto, E., & Susilo. (2014). Study effect of gamma radiation on weight on weight shrinkage of red guava fruit during storage. *Journal of Pendidikan Fisika Indonesia, 10*, 86-91.

Alikhani, M., & Daraei Garmakhany, A. (2012). Effect of microencapsulated essential oils on storage life and quality of strawberry (Fragaria ananassa cv. Camarosa). *Quality Assurance and Safety of Crops & Foods, 4*(1), 106–112.

Amelio, M. (2019). Olive oil sensory evaluation: An alternative to the robust coefficient of variation (Cvr %) for measuring panel group performance in official tasting sessions. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.02.044.

An, X., Li, Z., Zude-Sasse, M., Tchuenbou-Magaia, F., & Yang, Y. (2020). Characterization of textural failure mechanics of strawberry fruit. *Journal of Food Engineering, 282*(110016). doi:10.1016/j.jfoodeng.2020.110016.

Ansar; Nazaruddin; Azis, A D. (2019). Effect of vacuum freeze-drying condition and maltodextrin on the physical and sensory characteristics of passion fruit (Passiflora edulis sims) extract. *IOP Conference Series: Earth and Environmental Science* (pp. 1-12). Makassar: IOP Publishing. doi:10.1088/1755-1315/355/1/012067.

Asioli, D., Rocha, C., Wongprawmas, R., Popa, M., Gogus, F., & Almli, V. L. (2018). Microwave-dried or air-dried? Consumers' stated preferences and attitudes for organic dried strawberries. A multi-country investigation in Europe. *Food Research International, 76*, 645–653. doi:10.1016/j.foodres.2018.11.037.

Balasooriya, H., Dasanayake, K., & Ajlouni, S. (2019). Bioaccessibility of micronutrients in fresh and frozen strawberry fruits grown under elevated carbon dioxide and temperature. *Food Chemistry*, 1-9. doi:10.1016/j.foodchem.2019.125662

Battino, M., Giampieri, F., Cianciosi, D., Ansary, J., Chen, X., Zhang, D., . . . Forbes-Hernández, T. (2020). The roles of strawberry and honey phytochemicals on human health: a possible clue on the molecular mechanisms involved in the prevention of oxidative stress and inflammation. *Phytomedicine, 153170*. doi:10.1016/j.phymed.2020.153170.

Blanch , G. P., & Castilo, M. L. (2012). Changes in strawberry volatile constituents after pre-harvest treatment with natural hormonal compounds. *Flavour and Fragrence Journal, 27*(1), 180-187.

Bongoni, R., Steenbekkers, L. A., Verkerk, R., van Boekel, M. S., & Dekker, M. (2013). Studying consumer behaviour related to the quality of food: A case on vegetable preparation affecting sensory and health attributes. *Trends in Food Science & Technology, 33*(2), 139-145. doi:10.1016/j.tifs.2013.08.004.

Brown, C. R., Durst, R. W., Wrolstad, R., & De Jong, W. (2008). Variability of phytonutrient content of potato in relation to growing location and cooking method. *Potato Reearch, 51*(4), 259-270.

Buvé, C., Neckebroeck, B., Haenen, A., Kebede, B., Hendrickx, M., Grauwet, T., & Van Loey, A. (2018). Combining untargeted, targeted and sensory data to investigate the impact of storage on food volatiles: A case study on strawberry juice. *Food Research International, 113*, 382–391. doi:10.1016/j.foodres.2018.07.022.

Chapman, J., Elbourne, A., Truong, V. K., Newman, L., Gangadoo, S., Rajapaksha Pathirannahalage, P., & Cozzolino, D. (2019). Sensomics - from conventional to functional NIR spectroscopy-shining light over the aroma and taste of foods. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.07.013.

Chisari, M., Riccardo, N., Barbagallo, & Spagna, G. (2007). Characterization of polyphenol oxidase and peroxides and influence on browning of cold stored strawberry fruit. *Journal of Agriculture and Food Chemistry, 55*(1), 3469-3476.

Curi, P. N., Tavares, B. S., Almeida, A. B., Pio, R., Peche, P. M., & Souza, V. R. (2016). Influence of subtropical region strawberry cultivars on jelly characteristics. *Journal of Food Science, 81*(6), 15-20.

Dash, P. K., Chase, C. A., Agehara, S., & Zotarell, L. (2020). Heat stress mitigation effects of kaolin and s-abscisic acid during the establishment of strawberry plug transplants. *Scientia Horticulturae, 267*(109276). doi:10.1016/j.scienta.2020.109276.

Esa, A., Neela, S., & Addisalem, H. (2015). Effect of storage methods and ripening stages on postharvest quality of tomato (Lycopersicum esculentum L.) Cv. Chali. *Annals of Food Sci. and Tech., 16*(1), 127-137.

Falah, M. A., Husna, H., Dewi, A. R., & Jumeri. (2016). Quality evaluation of fresh strawberry (Fragaria sp. cv. Earlybrite) during storage in a tropical environment. *AIP Conference Proceedings*, 1-6.

Fernández-Lara, R., Gordillo, B., Rodríguez-Pulido, F. J., Lourdes González-Miret, M., del Villar-Martínez, A. A., Dávila-Ortiz, G., & Heredia, F. G. (2015). Assessment of the differences in the phenolic composition and color characteristics of new strawberry (Fragaria x ananassa Duch.) cultivars by HPLC–MS and Imaging Tristimulus

Colorimetry. *Food Research International, 76*, 645–653. doi:10.1016/j.foodres.2015.07.038.

Galus, S., & Kadzińska, J. (2015). Food applications of emulsion-based edible films and coatings. *Trends in Food Science & Technology, 45*(2), 273-283. doi:10.1016/j.tifs.2015.07.011.

Gaston, A., Osorio, S., Denoyes, B., & Rothan, C. (2019). Applying the Solanaceae Strategies to Strawberry Crop Improvement. *Trends in Plant Science*. doi:10.1016/j.tplants.2019.10.003.

Giampieri, F., Alvarez Suarez, J., & Battino, M. (2014). Strawberry and human health: Effects beyond antioxidant activity. *Journal of Agricultural and Food Chemistry, 62*(18), 3867-3876. doi:10.1021/jf405455n

Giampieri, F., Forbes-Hernandez, T. Y., Gasparrini, M., Alvarez-Suarez, J. M., Afrin, S., Bompadre, S., . . . Battino, M. (2015). Strawberry as a health promoter: an evidence based review. *Food & Function, 6*(5), 1386-1398. doi:10.1039/c5fo00147a.

Hanif, Z. (2015). Quality improvement of fresh strawberry fruit through harvest and postharvest handling. *Journal of Balitjestro, 15*(1), 1-6.

Hematyar, N., Masilko, J., Mraz, J., & Sampels, S. (2018). Nutritional quality, oxidation, and sensory parameters in fillets of common carp (Cyprinus carpio L.) influenced by frozen storage (-20 8C). *J Food Process Preserv*, e13589.

Hemmati, S., Ahmeda, A., Salehabadi, Y., Zangeneh, A., & Zangeneh, M. M. (2020). Synthesis, characterization, and evaluation of cytotoxicity, antioxidant, antifungal, antibacterial, and cutaneous wound healing effects of copper nanoparticles using the aqueous extract of Strawberry fruit and L-Ascorbic acid. *Polyhedron, 114425*. doi:10.1016/j.poly.2020.114425.

Hu, X., Lu, L., Guo, Z., & Zhu, Z. (2020). Volatile compounds, affecting factors and evaluation methods for rice aroma: A review. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2020.01.003.

Hung, D. V., Tong, S., Tanaka, F., Yasunaga, D. H., Hamanaka, D., & Hiruma, N. (2011). Controlling the weight loss of fresh produce during postharvest storage under a nano-size mist environment. *J. Food Eng, 106*, 325-330.

Hwang, E. J., Jeong, S. Y., Kim, M. J., Jeong, J. S., Lee, K. H., Jeong, N. R., & Kim, I. (2020). Year-round trap capture of the spotted-wing drosophila, Drosophila suzukii (Diptera: Drosophilidae), in Korean strawberry greenhouses. *Journal of Asia-Pacific Entomology, 23*(1), 204–213. doi:10.1016/j.aspen.2020.01.004.

Jaster, H., Arend, G. D., Rezzadori, K., Chaves, V. C., Reginatto, F. H., & Petrus, J. C. (2018). Enhancement of antioxidant activity and physicochemical properties of yogurt enriched with concentrated strawberry pulp obtained by block freeze concentrated strawberry pulp obtained by block freeze concentration. *Food Research International, 104*, 119-125. doi:10.1016/j.foodres.2017.10.006.

Jedlinska , A., Samborska, K., Janiszewska-Turak, E., Witrowa-Rajchert, D., Seuvre, A. M., & Voilley, A. (2018). Physicochemical properties of vanilla and raspberry aromas microencapsulated in the industrial conditions by spray drying. *J Food Process Eng*, e12872.

Jiang, N., Liu, C., Li, D., Zhang, Z., Liu, C., Wang, D., . . . Zhang, M. (2017). Evaluation of freeze drying combined with microwave vacuum drying for functional okra snacks: Antioxidant properties, sensory quality, and energy consumption. *LWT-Food Science and Technology, 82*, 216-226. doi:10.1016/j.lwt.2017.04.015.

Jiang, Y., Yu, L., Hu, Y., Zhu, Z., Zhuang, C., Zhao, Y., & Zhong, Y. (2020). The preservation performance of chitosan coating with different molecular weight on strawberry using electrostatic spraying technique. *International Journal of Biological Macromolecules*. doi:10.1016/j.ijbiomac.2020.02.169.

Jorge, A., Sauer Leal, E., Sequinel, R., Sequinel, T., Kubaski, E. T., & Tebcherani, S. M. (2018). Changes in the composition of tomato powder (Lycopersicon esculentum Mill) resulting from different drying methods. *J Food Process Preserv*, e13595.

Karoline Martinsen, B., Aaby, K., & Skrede, G. (2020). Effect of temperature on stability of anthocyanins, ascorbic acid and color in strawberry and raspberry jams. *Food Chemistry, 126297*. doi:10.1016/j.foodchem.2020.126297.

Khampakool, A., Soisungwan, S., & Park, S. H. (2018). Potential application of infrared assisted freeze drying (IRAFD) for banana snacks: Drying kinetics, energy consumption, and texture. *LWT-Food Science and Technology*. doi:10.1016/j.lwt.2018.09.081.

Khattab, A. R., Guirguis, H. A., Tawfik, S. M., & Farag, M. A. (2019). Cheese ripening: A review on modern technologies towards flavor enhancement, process acceleration and improved quality assessment. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.03.009.

Kirkin, C., & Gunes, G. (2018). Modified atmosphere packaging and gamma-irradiation of some herbs and spices: Effects on antioxidant and antimicrobial properties. *J Food Process Preserv*, 1-13.

Lesme, H., Courcoux,, P., Alleaume, C., Famelart, M. H., Bouhallab, C., Prost, C., & Rannou, C. (2020). Contribution of temporal dominance of sensations performed by modality (M-TDS) to the sensory perception of texture and flavor in semi-solid products: a case study on fat-free strawberry yogurts. *Food Quality and Preference, 80*, 1-13. doi:10.1016/j.foodqual.2019.103789.

MacInnis, G., Buddle, C. M., & Forrest, J. K. (2020). Small wild bee abundance declines with distance into strawberry crops regardless of field margin habitat. *Basic and Applied Ecology*. doi:10.1016/j.baae.2020.02.007.

Mainil, A. K., Aziz, A., Harianto, J., & Maini, R. I. (2020). Comparative assessment of closed loop heat pump dryer and direct solar dryer system for banana drying. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 66*(2), 136-144.

Marian, M., Ohno, T., Suzuki, H., Kitamura, H., Kuroda, K., & Shimizu, M. (2020). A novel strain of endophytic Streptomyces for the biocontrol of strawberry anthracnose caused by Glomerella cingulate. *Microbiological Research, 126428*. doi:10.1016/j.micres.2020.126428.

Maringgal, B., Hashim, N., Mohamed Amin Tawakkal, I. S., & Muda Mohamed, M. T. (2019). Recent advance in edible coating and its effect on fresh/fresh-cut fruits quality. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.12.024.

Nguyen, V. B., Nguyen, D. H., & Nguyen, H. V. (2020). Combination effects of calcium chloride and nano-chitosan on the postharvest quality of strawberry (Fragaria x ananassa Duch.). *Postharvest Biology and Technology, 162*(111103). doi:10.1016/j.postharvbio.2019.111103.

Obeidat, W. M., Sahni, E., Kessler, W., & Pikal, M. (2017). Development of a Mini-Freeze Dryer for Material-Sparing Laboratory Processing with Representative Product Temperature History. *AAPS PharmSciTech, 19*(12), 599-609. doi:10.1208/s12249-017-0871-5.

Ozcan, G., & Barringer, S. (2011). Effect of enzymes on strawberry volatiles during storage, at different ripeness level, in different cultivars, and during eating. *Journal of Food Science, 76*(2), 324-334.

Ozturk, O. K., & Singh, T. P. (2019). Selected physical and viscoelastic properties of strawberries as a function of heated-air drying conditions. *Drying Technology*, 1-11. doi:10.1080/07373937.2018.1543701

Pan, L., Zhang, W., Zhu, N., Mao, S., & Tu, K. (2014). Early detection and classification of pathogenic fungal disease in post-harvest strawberry fruit by electronic nose and gas chromatography–mass spectrometry. *Food Research International, 62,* 162–168. doi:10.1016/j.foodres.2014.02.020.

Patras, A., Brunton, N. P., Pieve, S. D., & Butler, F. (2009). Impact of high pressure processing on total antioxidant activity, phenolic, ascorbic acid, anthocyanin content and colour of strawberry and blackberry purees. *Innov Food Sci Emerg Technol, 10*(1), 308–313.

Qiao, F., Fang, C., Huang, L., & Zhang, S. (2012). The Effect of Different Heating Patterns on Vacuum Freeze-Drying of Litchi Pulp. *Journal of Food Process Engineering, 36*(4), 407-411. doi:10.1111/j.1745-4530.2012.00680.x.

Reyes, V., Bubnovich, R., Bustos, M., Vásquez, R., Vega, R., & Scheuermann , E. (2010). Comparative study of different process conditions of freeze drying of ‘Murtilla’ berry. *Drying Technology: An International Journal, 28:12, 1416-1425, 28*(12), 1416-1425. doi:10.1080/07373937.2010.482687.

Schulze, B., Hubbermann, E. M., & Schwarz, K. (2014). Stability of quercetin derivatives in vacuum impregnated apple slices after drying (microwave vacuum drying, air drying, freeze drying) and storage. *LWT-Food Science and Technology, 57*(1), 426-433. doi:10.1016/j.lwt.2013.11.021.

Shaozhi, Z., Jielin, L., Guangming, C., & Qin, W. (2017). Thermodynamic analysis of a freeze-dryer utilizing hygroscopic solution. *Drying Technology*. doi:10.1080/07373937.2017.1308952.

Shiraz, S., Djebbi-Simmons, D., Alhejaili, M., Danos, K., Janes, M., Fontenot, K., & Xu, W. (2020). Evaluation of the microbial safety and quality of Louisiana strawberries after flooding. *Food Control, 110*(106970). doi:10.1016/j.foodcont.2019.106970.

Silva, E. K., Meireles, M. A., & Saldaña, M. A. (2020). Supercritical carbon dioxide technology: A promising technique for the non-thermal processing of freshly fruit and vegetable juices. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2020.01.025.

Singh, S. P., & Pal, R. K. (2009). Ionizing radiation treatment to improve postharvest life and maintain quality of fresh guava fruit. *Radiation Phy. Chem.*, *78*(1), 135-140.

Singh, Z., & Khan, A. S. (2010). Physiology of plum fruit ripening. *Stewart Postharvest Rev., 2*(1), 3-12.

Souza, V. R., Pereira, P. A., Silva, T. L., Lima, L. C., & Pio, R. (2014). Determination of the bioactive compounds, antioxidant activity and chemical composition of Brazilian blackberry, red raspberry, strawberry, blueberry, and sweet cherry fruits. *Food Chem, 56*(1), 362-368.

Sun, K., Li, R., Jiang, W., Sun, Y., & Li, H. (2016). Comparison of three-dimensional printing and vacuum freeze-dried techniques for fabricating composite scaffolds. *Biochemical and Biophysical Research Communications, 477*(4), 1085-1091. doi:10.1016/j.bbrc.2016.07.050.

Tang, Y., Ma, X., Li, M., & Wang, Y. (2020). The effect of temperature and light on strawberry production in a solar greenhouse. *Solar Energy, 195*, 318-328. doi:10.1016/j.solener.2019.11.070.

Thi Phan, K. K., Truong, T., Wang, Y., & Bhandari, B. (2019). Nanobubbles: Fundamental characteristics and applications in food processing. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.11.019.

Thomas-Valdés, S., Theoduloz, C., Jiménez-Aspee, F., & Schmeda-Hirschmann, G. (2019). Effect of simulated gastrointestinal digestion on polyphenols and bioactivity of the native Chilean red strawberry (Fragaria chiloensis ssp. chiloensis f. patagonica). *Food Research International, 123*, 106-114. doi:10.1016/j.foodres.2019.04.039.

Thomas-Valdés, S; Theoduloz, C; Jiménez-Aspee, F; Burgos-Edwards, A; Schmeda-Hirschmann, G. (2018). Changes in polyphenol composition and bioactivity of the native Chilean white strawberry (Fragaria chiloensis spp. chiloensis f. chiloensis) after in vitro gastrointestinal digestion. *Food Research International, 105*, 10-18. doi:10.1016/j.foodres.2017.10.074.

Van de Velde, F., Esposito, D., Grace, M. H., Pirovani, M. E., & Lila, M. A. (2018). Anti-inflammatory and wound healing properties of polyphenolic extracts from strawberry and blackberry fruits. *Food Research International, 121*, 453-462. doi:10.1016/j.foodres.2018.11.059.

Watson, T. T., Noling, J. W., & Desaeger, J. A. (2020). Fluopyram as a rescue nematicide for managing sting nematode (Belonolaimus longicaudatus) on commercial strawberry in Florida. *Crop Protection, 132*, 105108. doi:10.1016/j.cropro.2020.105108.

Xu, Y., Zhang, M., Mujumdar, A. S., Duan, X., & Jin-cai, S. (2006). A two-stage vacuum freeze and convective air drying method for strawberries. *Drying Technology: An International Journal, 24*(8), 1019-1023. doi:10.1080/07373930600776209.

Yu, P., Low, M. Y., & Zhou, W. (2018). Design of experiments and regression modelling in food flavour and sensory analysis: A review. *Trends in Food Science & Technology, 71*, 202-215. doi:10.1016/j.tifs.2017.11.013.

Yue, X. Q., Shang, Z. Y., Yang, J. Y., Huang, L., & Wang, Y. Q. (2019). A smart data-driven rapid method to recognize the strawberry maturity. *Information Processing in Agriculture*. doi:10.1016/j.inpa.2019.10.005.

Yusufe, M., Mohammed, A., & Satheesh, N. (2017). Effect of duration and drying temperature on characteristics of dried tomato (Lycopersicon esculentum L.) cochoro variety. *Journal of Food Technology, 21*(1), 41-50.

ZhixiangYuan, Shi, Y., Cai, F., Zhao, J., Xiong, Q., Wang, Y., & Zheng, Y. (2019). Isolation and Identification of Polysaccharides from Pythium arrhenomanes and Application to Strawberry Fruit (Fragaria ananassa eservation. *Food Chemistry, 125604*. doi:10.1016/j.foodchem.2019.125604.

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☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Editor and Reviewer comments:

Reviewer #1: Methods:Methods are described with sufficient details

Results:Results are well included but has to be better discussed

Interpretation:Interpretation of data has to be extended

Other comments:The study's design, data presentation, and citations comply with standard COPE ethical guidelines and has proper approval and consent been acquired as outlined in Heliyon Editorial Policies

Reviewer #2: General comment:
The paper is interesting and in general well organized, there are some missing informations so it's necessary to improve the paper before its acceptance.

Introduction:
The authors adfirm that to increase the shelf life of strawberries post harvest processing is necessary..This is correct but it 's better to improve with post harvest technology management such as processing…
Line-83Please improve with more references Such as Peano et al., 2014…Journal of Food, Agriculture and Environment, Volume 12, Issue 2, 2014, Pages 93-100
DLine 86-91: please delete this sentence.Various ….conumers.

Methodology:
Fragaria ananssa is no the variety.
Please explicit the variety
Line 97 :15°C is no a refrigerator temperature!
Line 103 : please explain how many replicate for analysis.
Give more informations about the panel test
Why the control (fresh fruits) only for some analysis?
Fig.6 Please check the redness (L?) and Yellowness (L?)on y axis
Sensory test: pleas erevise this part It's no clear at wich Plate temperature was performed, then could be interesting also to evaluate the fresh fruits as control.

Results:

Considering The missing information about the sensory test that authors must to improve it' no possible to sfirm343-3444 (but don't significantly influence the aroma and flavor parametres…..

Discussion:
Please improve the conclusion suggesting the possible use of these processed strawberry

Bibliography/References:
Others: Please check the use of English see line 136-137….
Decision: Major revisons

Reviewer #3: This paper deals with new product development from of strawberries (Fragaria Ananassa Duch.) which will be of interest to the readers of Heliyon. However, in my opinion, this manuscript suffers from a lot of flaws and lack of sufficient insights to inspire the readers as required for publication quality. Therefore, I recommend rejection of this manuscript.

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Reviewer #1: Page 1, are the names of authors correctly written?

Author response #1: Yes, names of authors is correct.

Reviewer #2: Page 1, line 18: here and in the whole manuscript, when you indicate the temperature, separate the value from the symbol: 60 °C.

Author response #2: I have correct it.

Reviewer #3: Page 4, line 78, you have stated that …. "Research on the freeze-drying process for fruits has been widely reported"…. but no reference you have included, here you have to support your statement with some reference regarding to frozen small fruits. I suggest, at least [x1-x2]:

[x1] The influence of film and storage on the phenolic and antioxidant properties of red raspberries (*Rubus idaeus* L.) cv. Erika. Giuffrè A.M., Louadj L., Rizzo P., De Salvo E., Sicari V. Antioxidants 8 (8), 254 (2019). doi:10.3390/antiox8080254

[x2] The change of total anthocyanins in blueberries and their antioxidant effect after drying and freezing. Virachnee Lohachoompol, George Srzednicki, John Craske J Biomed Biotechnol. 2004 Dec 1; 2004(5): 248–252. doi: 10.1155/S1110724304406123

Author response #3: I have correct it.

Reviewer #4: Page 4, line 83, specify that other post-harvest methods were studied. In two lines, find, read and discuss [x3-x4]:

[x3] Evaluation of *Aloe arborescens* gel as new coating to maintain the organoleptic and functional properties of strawberries (Fragaria x ananassa cv. Cadonga) fruits. Sicari V., Loizzo M.R., Pellicanò T.M., Giuffrè A.M., Poiana M. International Food Science and Technology, 55 (2) 861-870 (2020). doi:10.1111/ijfs.14349

[x3] Effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry (Fragaria×ananassa Duch. cv. Sabrina) fruit during cold storage. Moshari-Nasirkandi, A., Alirezalu, A., Hachesu, M.A. Biocatalysis and Agricultural Biotechnology, 25 (2020), Article number 101613.

Author response #4: I have correct it.

Reviewer #5: Page 5, lines 95-96, verify the English form of this sentence and re-write it; what is the name of the variety? and in the whole manuscript: strawberries of your manuscript were obtained from a cultivar or from a variety? Cultivar and variety are not synonyms.

Author response #5: The research sample was strawberry variety sweet charlie were obtained from farmers in Sembalun, East Lombok, Indonesia.

Reviewer #6: Page 5, line 97: in the refrigerator at 15 °C? Please, verify; they were stored…;

Author response #6: The sample were stored in the refrigerator at 10 °C to wait for the next process.

Reviewer #7: Page 6, line 112, here and in the whole manuscript, verify how to insert a reference in relation to the guidelines of Heliyon;

Author response #7: I have correct it.

Reviewer #8: Page 6 you did not use italics for Lab, whereas you have written Lab in italics on page 7, please, be consistent in the whole manuscript;

Author response #8: I have correct it.

Reviewer #9: Lines 136-137, verify the English form;

Author response #9: I have correct it.

Reviewer #10: Pages 9-10, lines 185-86, verify the English form;

Author response #10: I have correct it.

Reviewer #11: Page 11, lines 209-210, verify the English form and re-arrange this sentence;

Author response #11: I have correct it.

Reviewer #12: Lines 223-225, 232-233, verify the English form;

Author response #12: I have correct it.

Reviewer #13: Line 238: F-crib value?

Author response #13: F-crib value is the comparison value obtained from the Anova table

Reviewer #14: Line 239: p>0.5?

Author response #14: I have correct it become p<0.05.

Reviewer #15: Lines 278-279, verify the English form and the meaning of this sentence;

Author response #15: It means that variations of heating plate temperature and freeze-drying time have significantly on color parameters of frozen strawberries

Reviewer #16: Lines 285-286, verify the form of this sentence

Author response #16: I have correct it.

Reviewer #17: Lines 291-293, re-write this sentence, it is not comprehensible

Author response #17: I have correct it.

Reviewer #18: Line 326, verify the English form; In the captions of figures, please write Figure 1. and not Fig.1. (use some recent published paper as a sample).

Author response #18: I have correct it.

Reviewer #19: References section, sometime you have abbreviated the journal title and sometime not, please, be consistent.

Author response #19: I have correct it.

Reviewer #20: References section, lines 384, 469 and so on: how many periods before Forbes and Zhang?

Author response #20: I have correct it.

Reviewer #21: Line 390, Flavour and Fragrance Journal.

Author response #21: I have correct it.

Reviewer #22: Line 417, the scientific names of plants in italics, use the International rules.

Author response #22: I have correct it.

Reviewer #23: Introduction: The authors adfirm that to increase the shelf life of strawberries post harvest processing is necessary..This is correct but it 's better to improve with post harvest technology management such as processing...

Author response #23: I have correct it.

Reviewer #24: Line-83 Please improve with more references Such as Peano et al., 2014… Journal of Food, Agriculture and Environment, Volume 12, Issue 2, 2014, Pages 93-100

Author response #24: I have correct it.

Reviewer #25: Line 86-91: please delete this sentence. Various ….consumers.

Author response #25: I have correct it.

Reviewer #26: Methodology: Fragaria ananssa is no the variety. Please explicit the variety

Author response #26: I have correct it.

Reviewer #27: Line 97 :15°C is no a refrigerator temperature!

Author response #27: Yes, I have correct become: the sample were stored in the refrigerator at

10 °C to wait for the next process.

Reviewer #28: Line 103 : please explain how many replicate for analysis.

Author response #28: Each treatment was repeated three times.

Reviewer #29: Give more informations about the panel test. Why the control (fresh fruits) only for some analysis?

Author response #29: I have correct it.

Reviewer #30: Fig.6 Please check the redness (L?) and Yellowness (L?) on y axis

Author response #30: I have correct it.

Reviewer #31: Sensory test: please revise this part It's no clear at wich Plate temperature was performed, then could be interesting also to evaluate the fresh fruits as control.

Author response #31: I have correct it.

Reviewer #32: Results: Considering The missing information about the sensory test that authors must to improve it' no possible to sfirm 343-344 (but don't significantly influence the aroma and flavor parametres…..

Author response #32: This statement is based on the results of the panelists' assessment.

Reviewer #33: Discussion: Please improve the conclusion suggesting the possible use of these processed strawberry.

Author response #33: Processing strawberries into frozen products is a good prospect for the industry in the future.

Reviewer #34: Bibliography/References: Others: Please check the use of English see line 136-137.

Author response #34: I have correct it.

New product development from of strawberries (*Fragaria Ananassa* Duch.)

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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 product from strawberries produced from a vacuum freeze dryer. 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 hours. 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 paramaters 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 hours drying time. Frozen strawberries most

preferred by panelists are those that are freeze-dried at 50 °C and a drying time of 36 hours because they have aroma and flavor that seem fresh strawberries.

Keywords: frozen strawberry; moisture content; texture; color; aroma; taste.

1. Introduction

Strawberry fruit (*Fragaria ananassa* Duch.) can be found in every country because almost all countries in the world have cultivated its (Falah, Husna, Dewi, & Jumeri, 2016; MacInnis, Buddle, & Forrest, 2020). This fruit is loved for consumption because it has nutrients that are very beneficial for human health (Curi, et al., 2016; Blanch & Castilo, 2012; Giampieri, et al., 2015; Watson, Noling, & Desaeger, 2020). Strawberries also contain large amounts of folate (Marian, et al., 2020; Hu, Lu, Guo, & Zhu, 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 (ZhixiangYuan, et al., 2019; Hemmati, Ahmeda, Salehabadi, Zangeneh, & Zangeneh, 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. (Gaston, Osorio, Denoyes, & Rothan, 2019).

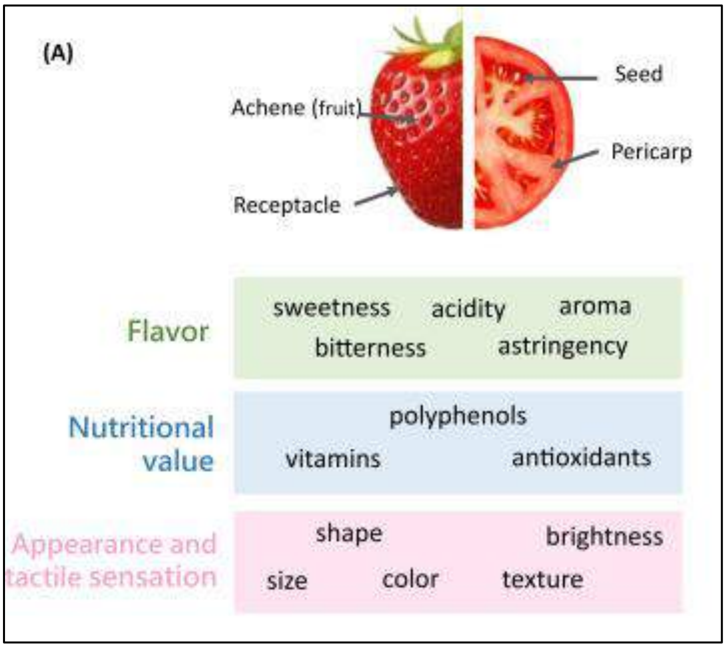


Figure 1. Physical structure and nutrient content of fresh strawberries.

The post-harvest strawberries have a short shelf life that can only last one day if stored at environmental temperatures (Souza, Pereira, Silva, Lima, & Pio, 2014; Ozturk & Singh, 2019). This strawberry fruit cannot be sold to consumers if the skin has blisters or bruises (Balasooriya, Dasanayake, & Ajlouni, 2019). To maintain and increase the shelf life of strawberries, post-harvest processing for these fruits is necessary (An, Li, Zude-Sasse, Tchuenbou-Magaia, & Yang, 2020; Silva, Meireles, & Saldaña, 2020).

Postharvest processing methods for fruits that are commonly used are drying (Ansar; Nazaruddin; Azis, A D, 2020; Hwang, et al., 2020). However, the skin of strawberries is very thin, so it is easily broken if dried using conventional dryers (Tang, Ma, Li, & Wang, 2020). Also, strawberries dried with conventional dryers have a non-uniform color, so they are less favored by consumers (Karoline Martinsen, Aaby, & Skrede, 2020). Anthocyanins contained in strawberries can also be damaged during the conventional drying process. Anthocyanins are unstable at high temperatures, so the stability of these compounds can be disrupted during the conventional drying process (Mainil, Aziz, Harianto, & Maini, 2020; Dash, Chase, Agehara, & Zotarell, 2020).

Frozen fruit is one of the processed fruit products that are very popular with consumers today (Khattab, Guirguis, Tawfik, & Farag, 2019). Frozen fruit is popular because it has color, aroma, and taste still like fresh fruit (Bongoni, Steenbekkers, Verkerk, van Boekel, & Dekker, 2013). Frozen products that have been widely circulating on the market today such as frozen cassava sticks made from fresh cassava are specially processed, hygienic, and without preservatives, to produce products that are high in flavor and healthy for consumption by all ages (Galus & Kadzińska, 2015). Other frozen products are frozen grilled bananas made from fresh bananas which are split and flattened and then burned (Maringgal, Hashim, Mohamed Amin Tawakkal, & Muda Mohamed, 2019). The shelf life of this frozen product is still short because it has high water content (Thi Phan, Truong, Wang, & Bhandari, 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, Jielin, Guangming, & Qin, 2017; Obeidat, Sahni, Kessler, & Pikal, 2017). This freeze vacuum dryer has been used extensively to obtain high-quality dry products (Qiao, Fang, Huang, & Zhang, 2012; Reyes, et al., 2010; Schulze, Hubbermann, & Schwarz, 2014). Frozen vacuum dryers can be applied to strawberries (Xu, Zhang, Mujumdar, Duan, & Jin-cai, 2006; Silva, Meireles, & Saldaña, 2020). Frozen products produced are in line with the desires and needs of consumers for quality processed products that are hygienic and quality (Alikhani & Daraei Garmakhany, 2012; Sun, Li, Jiang, Sun, & Li, 2016).

Research on the freeze-drying process for fruits has been widely reported (Lohachoompol, Srzednicki, & Craske, 2004; Giuffre, Louadj, Rizzo, De Salvo, & Sicari, 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-Lara, et al., 2015), the use of modified atmosphere packaging (Kirkin & Gunes, 2018). Banana chief drying uses a vacuum dryer (Khampakool, Soisungwan, & Park, 2018). Implement a solanaceae strategy for enhancing strawberry plants (Asioli, et al., 2018). Evaluation of the effect of modified atmospheric packaging (MAP) on strawberry storage (Peano, Girgenti, & Giuggioli, 2014). Coating method to maintain the organoleptic and functional properties of strawberries (Sicari, Loizzo, Pellicano, Giuffre, & Poiana, 2020). Effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry fruit during cold storage (Moshari-Nasirkandi, Alirezalu, & Hachesu, 2020).

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

2. Material and methods

2.1. Sample Preparation

The research sample was strawberry variety sweet charlie were obtained from farmers in Sembalun, East Lombok, Indonesia. Strawberries were sorted and washed with 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 hours. 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):

$$Weight\ loss = \frac{w_f - w_d}{w_f}\ 100\% \qquad (1)$$

where, w_f = mass of the sample before drying (gram), w_d = 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 (Ansar; Nazaruddin; Azis, A D, 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:

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

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):

$$L^* = \frac{\text{Lightness}}{255} x100 \quad (3)$$

$$a^* = \frac{240a}{255} - 120 \quad (4)$$

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

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

2.7. Sensory Test

Sensory test was used to determine consumer's acceptance of frozen strawberries were produced from vacuum freeze dryers that relate to aroma and taste. There are 25 panelists to carry out the sensory test. Consist of 10 men and 15 women, who aged 18-40 years old. The samples were presented by panelists with 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= dislike extremely, 2 = dislike moderately, 3 = dislike, 4 = like moderately, and 5 = like extremely. The sensory evaluation includes the intensity of aroma and taste (Van de Velde, Esposito, Grace, Pirovani, & Lila, 2018).

2.8. Statistical Analysis

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 F-count value is greater than F-crit, it means there is a significant difference in effect at the 95% significance level. The most influential variables can be calculated using Duncan's Multiple Ranges Test (Yu, Low, & Zhou, 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 hours and then tends to slope until the duration drying is 48 hours. After reaching the freezing point, the weight loss not yet change. Based on Figure 2 it is also shows that the higher of heating plate temperature, the higher the percentage of strawberry weight loss.

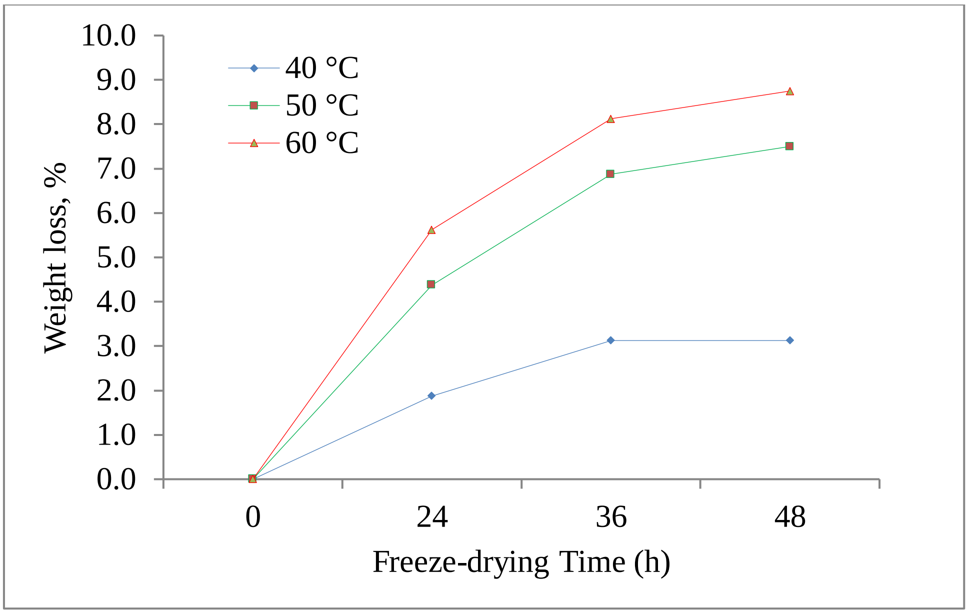


Figure 2. A profile of strawberry weight loss during freeze-vacuum drying at variations of heating plate temperature.

The strawberry fruit was freeze-dried at heating plate temperature 60 °C and drying time 48 hours 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.

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**
Rows	27.79	2	13.89	7.96	0.020	5.14
Columns	78.48	3	26.16	14.98	0.003	4.76
Error	10.48	6	1.75			
Total	116.76	11				

The fruit weight loss is generally affected by the evaporation of moisture content during the drying process (Jaster, 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-Valdés, Theoduloz, Jiménez-Aspee, & Schmeda-Hirschmann, 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 drop dramatically until 24th hour, then they decrease at 36th hour and they stable at 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-Valdés, S; Theoduloz, C; Jiménez-Aspee, F; Burgos-Edwards, A; Schmeda-Hirschmann, G, 2018).

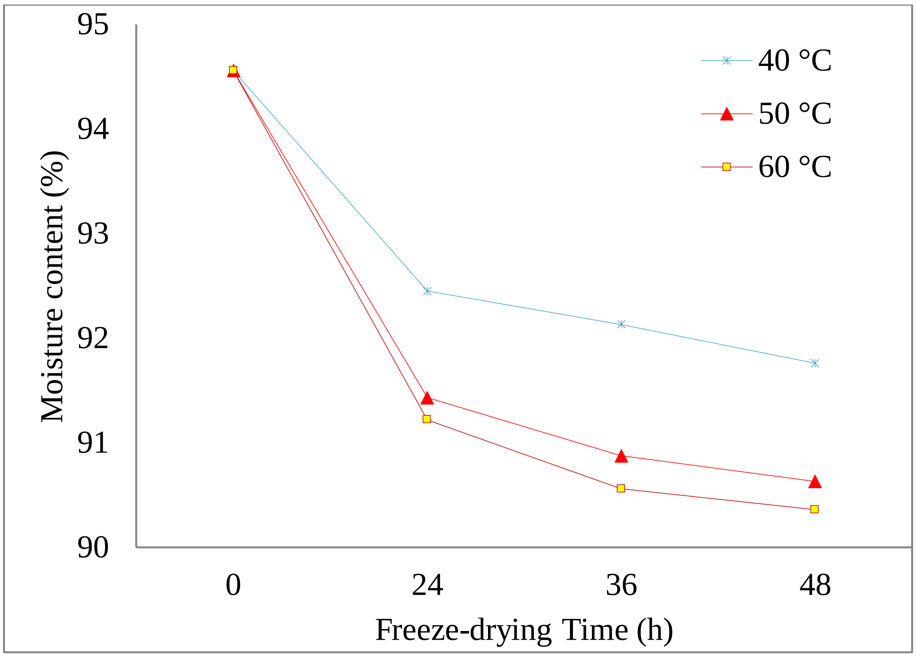


Figure 3. Evaporation of strawberry moisture content during a vacuum-freeze drying at heating plate temperature and freeze-drying time variations.

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, Zhang, Zhu, Mao, & Tu, 2014).

Evaporation of moisture content from fruit cells occurs during the drying process as a result 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, Husna, Dewi, & Jumeri, 2016).

The analysis of variance results shows that F-count (8.68) is greater than the F-crit value (5.14) (Table 2). This means that variations at the 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 Gaston et al. (2019) that the strawberry moisture content decreases during freeze-drying.

Table 2. Results analysis of variance 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**
Rows	2.49	2	1.25	8.68	0.017	5.14
Columns	25.34	3	8.44	58.91	7.65E-05	4.76
Error	0.86	6	0.14			
Total	28.67	11				

3.3. Texture Determination

The frozen strawberry texture was determinates 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 hours 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 hours, the F-max values are 0.16; 0.15; and 0.15 N, and at heating plate temperature 60 °C and freeze-drying time 24, 36, and 48 hours, 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 Asioli, et al. (2018) that mechanical resistance to compression, shear force, and strawberry stiffness decreases after drying.

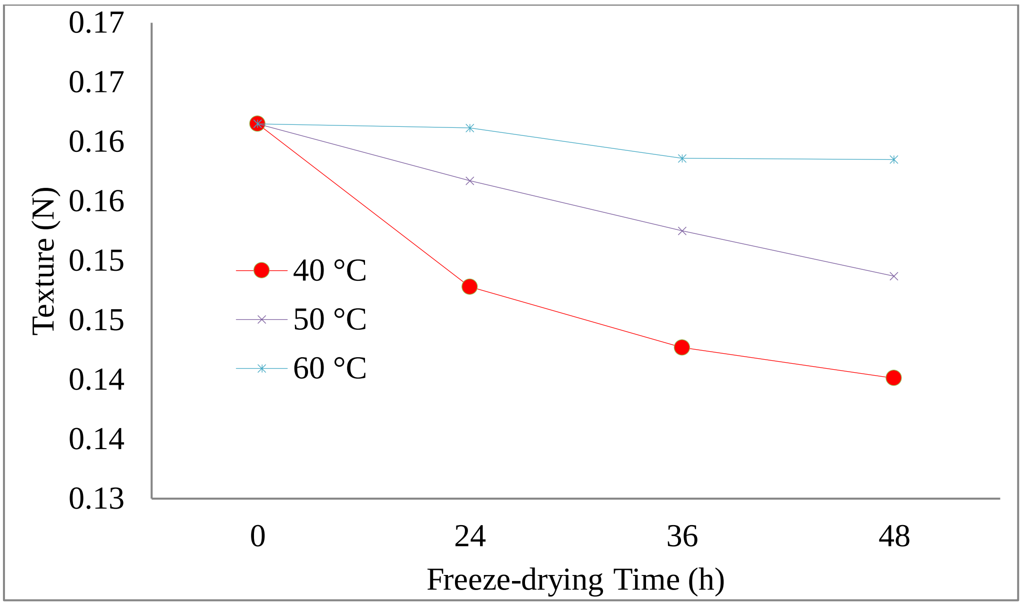


Figure 4. Graph of texture changes of frozen strawberries during vacuum-freeze dryer at heating plate temperature variations.

Frozen strawberries have a soft and wrinkled texture because some moisture content has evaporated. This is in line with the report Alikhani and Daraei Garmakhany (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 (Asioli, 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 (5,143) (Table 3). This means that the treatment of variations in heating plate temperature and freeze-drying time has significant influence ($p<0.05$) on the strawberry texture. It also shows that the texture of strawberries undergoes significant changes during the drying process.

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
Rows	2.86	2	1.43	8.18	0.02	5.14
Columns	2.67	3	0.89	5.09	0.044	4.76
Error	1.05	6	0.17			
Total	6.57	11				

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

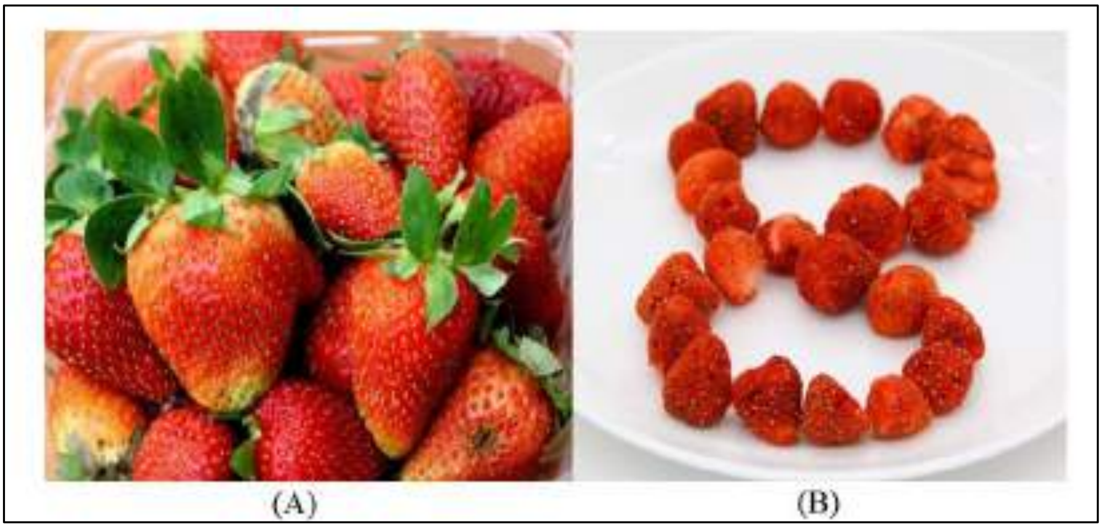
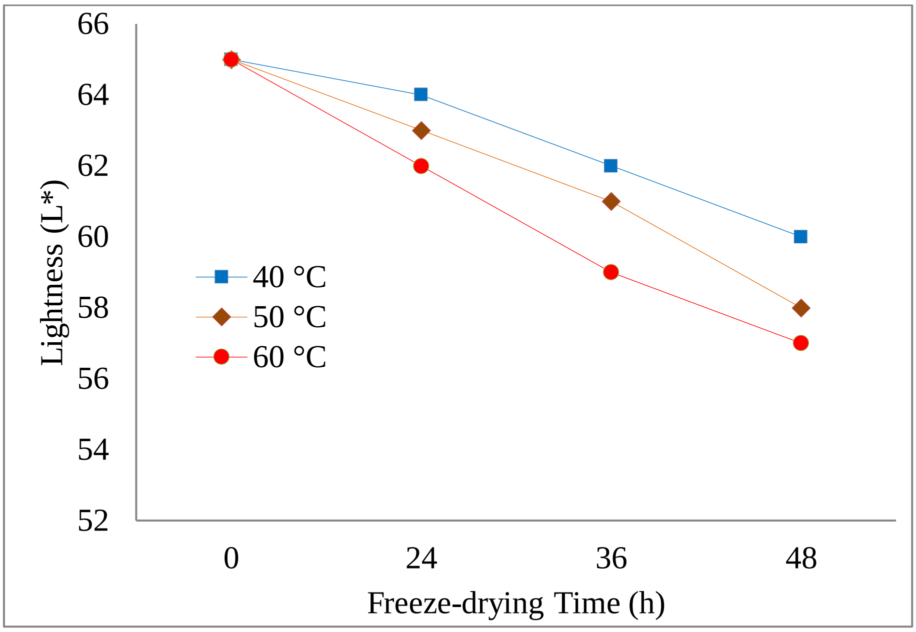
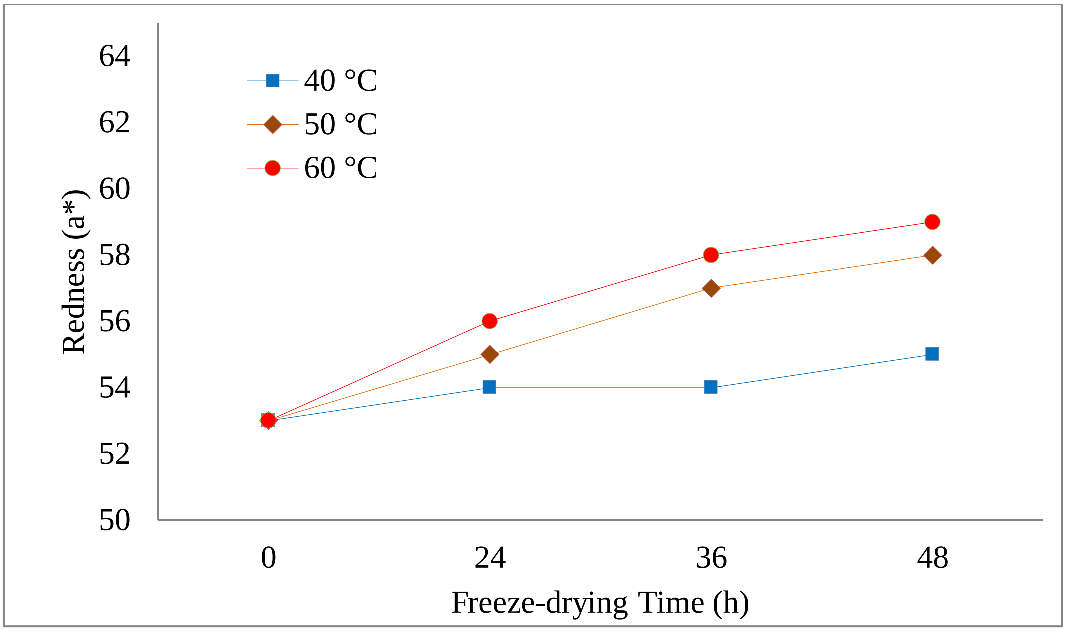


Figure 5. Strawberry fruit, (A) before freeze-drying and (B) after freeze-drying

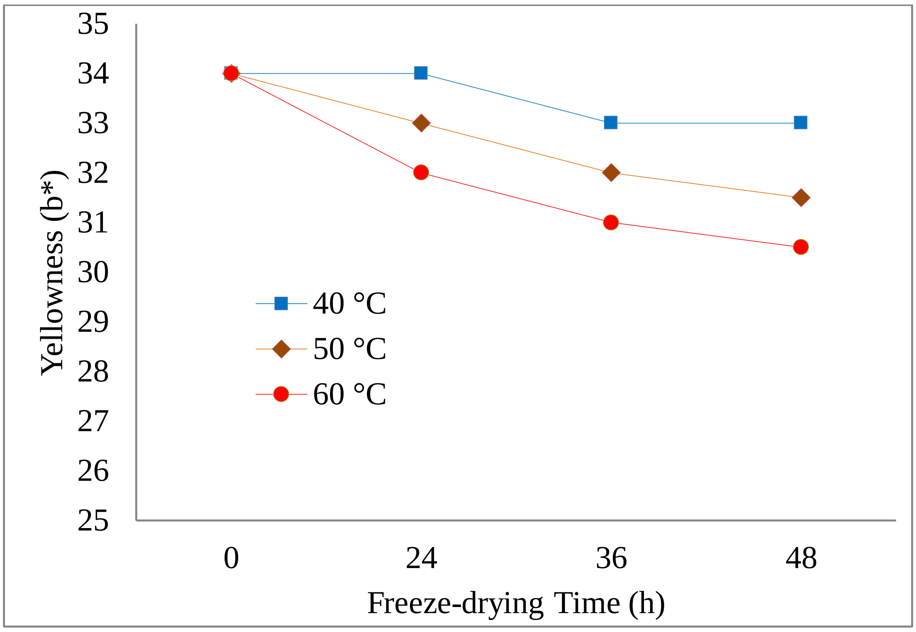
Graph of the color changes of frozen strawberries as shown in Figure 6. The color components of dried strawberry tend to decrease during the drying process. It can be seen that the strawberry color changes from red to dark red during the drying process.



(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.

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 (Chisari, Riccardo, Barbagallo, & Spagna, 2007). Some researchers also report that color is the most important criterion for consumers in determining product choices (Yue, Shang, Yang, Huang, & Wang, 2019).

The results analysis of variance obtained F-count values (5.84) greater than the F-crit value (5.14) (Table 4). This data means that variations of heating plate temperature and freeze-drying time have 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.

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

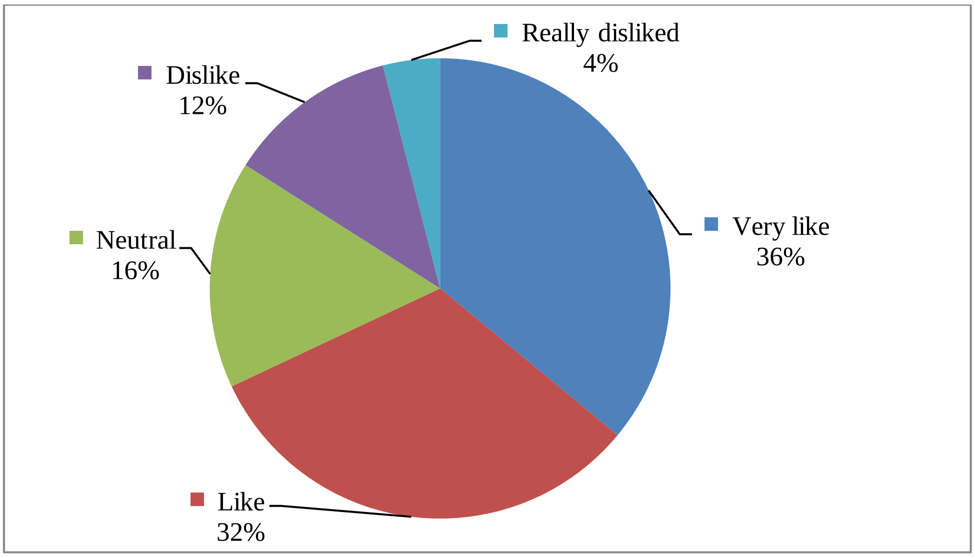
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F-crit**
Rows	6.17	2	3.08	5.84	0.04	5.14
Columns	68.33	3	22.78	43.16	0.00	4.76
Error	3.17	6	0.53			
Total	77.67	11				

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).

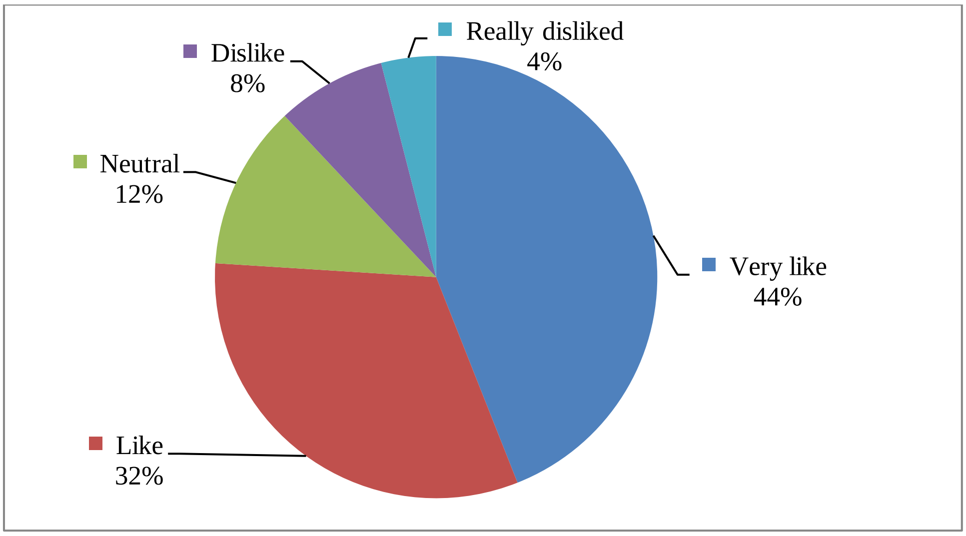
The strawberry fruit has a red pigment that comes from the concentration of anthocyanins (Patras, Brunton, Pieve, & Butler, 2009; Gaston, Osorio, Denoyes, & Rothan, 2019). The lower the concentration of anthocyanins, the color of the fruit becomes purple, on the contrary, if the concentration of anthocyanins is very high, the color of the fruit can be blackish (Asioli, et al., 2018). For low pH, anthocyanins 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 (Ozcan & Barringer, 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, Durst, Wrolstad, & De Jong, 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 parameters 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 7B.



(A)



(B)

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

Based on data from the judicial assessment of the aroma of frozen strawberries, it is known that 36% of panelists answered very like, 32% said they liked, and only 16% stated neutral, 12% disliked, and 4% said they really disliked (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 temperature. Karoline et al. (2020) have also reported that samples that are dried in freeze-drying are first frozen, then dried using low pressure, resulting in a sublimation process in which the water content that 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 they really liked, 32% said they liked, 12% said they were neutral, 8% said they didn't like it, and only 4% who said they really didn't like it (Figure 7B). Based on this 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 (Ansar; Nazaruddin; Azis, A D, 2019). Strawberry fruit has a sweet and sour taste (citrus) that is fresh and soft (Yue, Shang, Yang, Huang, & Wang, 2019). This compound is not easily evaporated by the influence of environmental temperature (Souza, Pereira, Silva, Lima, & Pio, 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 does not change significantly after was frozen and they seem fresh fruit. 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.

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CONFLICT OF INTEREST

The all authors not have any conflict of interest.

References

Alikhani, M., & Daraei Garmakhany, A. (2012). Effect of microencapsulated essential oils on storage life and quality of strawberry (Fragaria ananassa cv. Camarosa). *Quality Assurance and Safety of Crops & Foods, 4*(1), 106–112.

Amelio, M. (2019). Olive oil sensory evaluation: An alternative to the robust coefficient of variation (Cvr %) for measuring panel group performance in official tasting sessions. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.02.044.

An, X., Li, Z., Zude-Sasse, M., Tchuenbou-Magaia, F., & Yang, Y. (2020). Characterization of textural failure mechanics of strawberry fruit. *Journal of Food Engineering, 282*(110016). doi:10.1016/j.jfoodeng.2020.110016.

Ansar; Nazaruddin; Azis, A D. (2019). Effect of vacuum freeze-drying condition and maltodextrin on the physical and sensory characteristics of passion fruit (Passiflora edulis sims) extract. *IOP Conference Series: Earth and Environmental Science* (pp. 1-12). Makassar: IOP Publishing. doi:10.1088/1755-1315/355/1/012067.

Ansar; Nazaruddin; Azis, A D. (2020). Caking mechanisms of passion fruit powder during storage. *International Journal of Innovation, Creatifity, and Change, 13*(2), 618-628.

Asioli, D., Rocha, C., Wongprawmas, R., Popa, M., Gogus, F., & Almli, V. L. (2018). Microwave-dried or air-dried? Consumers' stated preferences and attitudes for organic dried strawberries. A multi-country investigation in Europe. *Food Research International, 76*, 645–653. doi:10.1016/j.foodres.2018.11.037.

Balasooriya, H., Dasanayake, K., & Ajlouni, S. (2019). Bioaccessibility of micronutrients in fresh and frozen strawberry fruits grown under elevated carbon dioxide and temperature. *Food Chemistry*, 1-9. doi:10.1016/j.foodchem.2019.125662

Battino, M., Giampieri, F., Cianciosi, D., Ansary, J., Chen, X., Zhang, D., Gil, E., Forbes-Hernández, T. (2020). The roles of strawberry and honey phytochemicals on human health: a possible clue on the molecular mechanisms involved in the prevention of oxidative stress and inflammation. *Phytomedicine, 153170*. doi:10.1016/j.phymed.2020.153170.

Blanch , G. P., & Castilo, M. L. (2012). Changes in strawberry volatile constituents after pre-harvest treatment with natural hormonal compounds. *Flavour and Fragrance Journal, 27*(1), 180-187.

Bongoni, R., Steenbekkers, L. A., Verkerk, R., van Boekel, M. S., & Dekker, M. (2013). Studying consumer behaviour related to the quality of food: A case on vegetable preparation affecting sensory and health attributes. *Trends in Food Science & Technology, 33*(2), 139-145. doi:10.1016/j.tifs.2013.08.004.

Brown, C. R., Durst, R. W., Wrolstad, R., & De Jong, W. (2008). Variability of phytonutrient content of potato in relation to growing location and cooking method. *Potato Reearch, 51*(4), 259-270.

Buvé, C., Neckebroeck, B., Haenen, A., Kebede, B., Hendrickx, M., Grauwet, T., & Van Loey, A. (2018). Combining untargeted, targeted and sensory data to investigate the impact of storage on food volatiles: A case study on strawberry juice. *Food Research International, 113*, 382–391. doi:10.1016/j.foodres.2018.07.022.

Chapman, J., Elbourne, A., Truong, V. K., Newman, L., Gangadoo, S., Rajapaksha Pathirannahalage, P., & Cozzolino, D. (2019). Sensomics - from conventional to functional NIR spectroscopy-shining light over the aroma and taste of foods. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.07.013.

Chisari, M., Riccardo, N., Barbagallo, & Spagna, G. (2007). Characterization of polyphenol oxidase and peroxides and influence on browning of cold stored strawberry fruit. *Journal of Agriculture and Food Chemistry, 55*(1), 3469-3476.

Curi, P. N., Tavares, B. S., Almeida, A. B., Pio, R., Peche, P. M., & Souza, V. R. (2016). Influence of subtropical region strawberry cultivars on jelly characteristics. *Journal of Food Science, 81*(6), 15-20.

Dash, P. K., Chase, C. A., Agehara, S., & Zotarell, L. (2020). Heat stress mitigation effects of kaolin and s-abscisic acid during the establishment of strawberry plug transplants. *Scientia Horticulturae, 267*(109276). doi:10.1016/j.scienta.2020.109276.

Falah, M. A., Husna, H., Dewi, A. R., & Jumeri. (2016). Quality evaluation of fresh strawberry (Fragaria sp. cv. Earlybrite) during storage in a tropical environment. *AIP Conference Proceedings,* 1-6.

Fernández-Lara, R., Gordillo, B., Rodríguez-Pulido, F. J., Lourdes González-Miret, M., del Villar-Martínez, A. A., Dávila-Ortiz, G., & Heredia, F. G. (2015). Assessment of the differences in the phenolic composition and color characteristics of new strawberry (Fragaria x ananassa Duch.) cultivars by HPLC–MS and Imaging Tristimulus Colorimetry. *Food Research International, 76,* 645–653. doi:10.1016/j.foodres.2015.07.038.

Galus, S., & Kadzińska, J. (2015). Food applications of emulsion-based edible films and coatings. *Trends in Food Science & Technology, 45*(2), 273-283. doi:10.1016/j.tifs.2015.07.011.

Gaston, A., Osorio, S., Denoyes, B., & Rothan, C. (2019). Applying the Solanaceae Strategies to Strawberry Crop Improvement. *Trends in Plant Science*. doi:10.1016/j.tplants.2019.10.003.

Giampieri, F., Alvarez Suarez, J., & Battino, M. (2014). Strawberry and human health: Effects beyond antioxidant activity. *Journal of Agricultural and Food Chemistry, 62*(18), 3867-3876. doi:10.1021/jf405455n

Giampieri, F., Forbes-Hernandez, T. Y., Gasparrini, M., Alvarez-Suarez, J. M., Afrin, S., Bompadre, S., Quiles, J.L., Mezzetti, B., Battino, M. (2015). Strawberry as a health promoter: an evidence based review. *Food & Function, 6*(5), 1386-1398. doi:10.1039/c5fo00147a.

Giuffre, A. M., Louadj, L., Rizzo, P., De Salvo, E., & Sicari, V. (2019). The influence of film and storage on the phenolic and antioxidant properties of red raspberries (Rubus idaeus L.) cv. Erika. *Antioxidants, 8*(8), 254. doi:10.3390/antiox8080254.

Hanif, Z. (2015). Quality improvement of fresh strawberry fruit through harvest and postharvest handling. *Journal of Balitjestro, 15*(1), 1-6.

Hematyar, N., Masilko, J., Mraz, J., & Sampels, S. (2018). Nutritional quality, oxidation, and sensory parameters in fillets of common carp (Cyprinus carpio L.) influenced by frozen storage (-20 8C). *Journal of Food Processing and Preservation*, e13589.

Hemmati, S., Ahmeda, A., Salehabadi, Y., Zangeneh, A., & Zangeneh, M. M. (2020). Synthesis, characterization, and evaluation of cytotoxicity, antioxidant, antifungal, antibacterial, and cutaneous wound healing effects of copper nanoparticles using the aqueous extract of Strawberry fruit and L-Ascorbic acid. *Polyhedron, 114425*. doi:10.1016/j.poly.2020.114425.

Hu, X., Lu, L., Guo, Z., & Zhu, Z. (2020). Volatile compounds, affecting factors and evaluation methods for rice aroma: A review. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2020.01.003.

Hung, D. V., Tong, S., Tanaka, F., Yasunaga, D. H., Hamanaka, D., & Hiruma, N. (2011). Controlling the weight loss of fresh produce during postharvest storage under a nano-size mist environment. *Journal of Food Engineering*, *106*, 325-330.

Hwang, E. J., Jeong, S. Y., Kim, M. J., Jeong, J. S., Lee, K. H., Jeong, N. R., & Kim, I. (2020). Year-round trap capture of the spotted-wing drosophila, Drosophila suzukii (Diptera: Drosophilidae), in Korean strawberry greenhouses. *Journal of Asia-Pacific Entomology, 23*(1), 204–213. doi:10.1016/j.aspen.2020.01.004.

Jaster, H., Arend, G. D., Rezzadori, K., Chaves, V. C., Reginatto, F. H., & Petrus, J. C. (2018). Enhancement of antioxidant activity and physicochemical properties of yogurt enriched with concentrated strawberry pulp obtained by block freeze concentrated strawberry pulp obtained by block freeze concentration. *Food Research International*, *104*, 119-125. doi:10.1016/j.foodres.2017.10.006.

Jedlinska , A., Samborska, K., Janiszewska-Turak, E., Witrowa-Rajchert, D., Seuvre, A. M., & Voilley, A. (2018). Physicochemical properties of vanilla and raspberry aromas microencapsulated in the industrial conditions by spray drying. *Journal of Food Process Engineering*, e12872.

Jiang, N., Liu, C., Li, D., Zhang, Z., Liu, C., Wang, D., Niu, L., Zhang, M. (2017). Evaluation of freeze drying combined with microwave vacuum drying for functional okra snacks: Antioxidant properties, sensory quality, and energy consumption. *LWT-Food Science and Technology*, *82*, 216-226. doi:10.1016/j.lwt.2017.04.015.

Jiang, Y., Yu, L., Hu, Y., Zhu, Z., Zhuang, C., Zhao, Y., & Zhong, Y. (2020). The preservation performance of chitosan coating with different molecular weight on strawberry using electrostatic spraying technique. *International Journal of Biological Macromolecules*. doi:10.1016/j.ijbiomac.2020.02.169.

Jorge, A., Sauer Leal, E., Sequinel, R., Sequinel, T., Kubaski, E. T., & Tebcherani, S. M. (2018). Changes in the composition of tomato powder (Lycopersicon esculentum Mill) resulting from different drying methods. *Journal of Food Processing and Preservation*, e13595.

Karoline Martinsen, B., Aaby, K., & Skrede, G. (2020). Effect of temperature on stability of anthocyanins, ascorbic acid and color in strawberry and raspberry jams. *Food Chemistry, 126297*. doi:10.1016/j.foodchem.2020.126297.

Khampakool, A., So Asioli isungwan, S., & Park, S. H. (2018). Potential application of infrared assisted freeze drying (IRAFD) for banana snacks: Drying kinetics, energy consumption, and texture. *LWT-Food Science and Technology*. doi:10.1016/j.lwt.2018.09.081.

Khattab, A. R., Guirguis, H. A., Tawfik, S. M., & Farag, M. A. (2019). Cheese ripening: A review on modern technologies towards flavor enhancement, process acceleration and improved quality assessment. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.03.009.

Kirkin, C., & Gunes, G. (2018). Modified atmosphere packaging and gamma-irradiation of some herbs and spices: Effects on antioxidant and antimicrobial properties. *Journal of Food Processing and Preservation*, 1-13.

Lohachoompol, V., Srzednicki, G., & Craske, J. (2004). The change of total anthocyanins in blueberries and their antioxidant effect after drying and freezing. *Journal of Biomedicine Biotechnology, 5,* 248–252. doi:10.1155/S1110724304406123.

Lesme, H., Courcoux,, P., Alleaume, C., Famelart, M. H., Bouhallab, C., Prost, C., & Rannou, C. (2020). Contribution of temporal dominance of sensations performed by modality (M-TDS) to the sensory perception of texture and flavor in semi-solid products: a case study on fat-free strawberry yogurts. *Food Quality and Preference*, *80*, 1-13. doi:10.1016/j.foodqual.2019.103789.

MacInnis, G., Buddle, C. M., & Forrest, J. K. (2020). Small wild bee abundance declines with distance into strawberry crops regardless of field margin habitat. *Basic and Applied Ecology*. doi:10.1016/j.baae.2020.02.007.

Mainil, A. K., Aziz, A., Harianto, J., & Maini, R. I. (2020). Comparative assessment of closed loop heat pump dryer and direct solar dryer system for banana drying. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 66*(2), 136-144.

Marian, M., Ohno, T., Suzuki, H., Kitamura, H., Kuroda, K., & Shimizu, M. (2020). A novel strain of endophytic Streptomyces for the biocontrol of strawberry anthracnose caused by Glomerella cingulate. *Microbiological Research, 126428*. doi:10.1016/j.micres.2020.126428.

Maringgal, B., Hashim, N., Mohamed Amin Tawakkal, I. S., & Muda Mohamed, M. T. (2019). Recent advance in edible coating and its effect on fresh/fresh-cut fruits quality. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.12.024.

Moshari-Nasirkandi, A., Alirezalu, A., & Hachesu, M. A. (2020). Effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry (Fragaria×ananassa Duch. cv. Sabrina) fruit during cold storage. *Biocatalysis and Agricultural Biotechnology, 25*(101613).

Nguyen, V. B., Nguyen, D. H., & Nguyen, H. V. (2020). Combination effects of calcium chloride and nano-chitosan on the postharvest quality of strawberry (Fragaria x ananassa Duch.). *Postharvest Biology and Technology, 162*(111103). doi:10.1016/j.postharvbio.2019.111103.

Obeidat, W. M., Sahni, E., Kessler, W., & Pikal, M. (2017). Development of a Mini-Freeze Dryer for Material-Sparing Laboratory Processing with Representative Product Temperature History. *AAPS PharmSciTech, 19*(12), 599-609. doi:10.1208/s12249-017-0871-5.

Ozcan, G., & Barringer, S. (2011). Effect of enzymes on strawberry volatiles during storage, at different ripeness level, in different cultivars, and during eating. *Journal of Food Science, 76*(2), 324-334.

Ozturk, O. K., & Singh, T. P. (2019). Selected physical and viscoelastic properties of strawberries as a function of heated-air drying conditions. *Drying Technology*, 1-11. doi:10.1080/07373937.2018.1543701

Pan, L., Zhang, W., Zhu, N., Mao, S., & Tu, K. (2014). Early detection and classification of pathogenic fungal disease in post-harvest strawberry fruit by electronic nose and gas chromatography–mass spectrometry. *Food Research International*, *62*, 162–168. doi:10.1016/j.foodres.2014.02.020.

Patras, A., Brunton, N. P., Pieve, S. D., & Butler, F. (2009). Impact of high pressure processing on total antioxidant activity, phenolic, ascorbic acid, anthocyanin content and colour of strawberry and blackberry purees. *Innovative Food Science & Emerging Technologies, 10*(1), 308–313.

Peano, C., Girgenti, V., & Giuggioli, N. R. (2014). Change in quality and volatile constituents of strawberries (cv. Evie2) under MAP storage. *Journal of Food, Agriculture & Environment*, *12*(2), 93-100.

Qiao, F., Fang, C., Huang, L., & Zhang, S. (2012). The Effect of Different Heating Patterns on Vacuum Freeze-Drying of Litchi Pulp. *Journal of Food Process Engineering, 36*(4), 407-411. doi:10.1111/j.1745-4530.2012.00680.x.

Reyes, V., Bubnovich, R., Bustos, M., Vásquez, R., Vega, R., & Scheuermann , E. (2010). Comparative study of different process conditions of freeze drying of 'Murtilla' berry. *Drying Technology: An International Journal*, *28:12, 1416-1425, 28*(12), 1416-1425. doi:10.1080/07373937.2010.482687.

Schulze, B., Hubbermann, E. M., & Schwarz, K. (2014). Stability of quercetin derivatives in vacuum impregnated apple slices after drying (microwave vacuum drying, air drying, freeze drying) and storage. *LWT-Food Science and Technology, 57*(1), 426-433. doi:10.1016/j.lwt.2013.11.021.

Shaozhi, Z., Jielin, L., Guangming, C., & Qin, W. (2017). Thermodynamic analysis of a freeze-dryer utilizing hygroscopic solution. *Drying Technology*. doi:10.1080/07373937.2017.1308952.

Shiraz, S., Djebbi-Simmons, D., Alhejaili, M., Danos, K., Janes, M., Fontenot, K., & Xu, W. (2020). Evaluation of the microbial safety and quality of Louisiana strawberries after flooding. *Food Control*, *110*(106970). doi:10.1016/j.foodcont.2019.106970.

Sicari, V., Loizzo, M. R., Pellicano, T. M., Giuffre, A. M., & Poiana, M. (2020). Evaluation of aloe arborescens gel as new coating to maintain the organoleptic and functional properties of strawberries (Fragaria x ananassa cv. Cadonga) fruits. *International Food Science and Technology*, *55*(2), 861-870. doi:10.1111/ijfs.14349.

Silva, E. K., Meireles, M. A., & Saldaña, M. A. (2020). Supercritical carbon dioxide technology: A promising technique for the non-thermal processing of freshly fruit and vegetable juices. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2020.01.025.

Singh, S. P., & Pal, R. K. (2009). Ionizing radiation treatment to improve postharvest life and maintain quality of fresh guava fruit. *Radiation Physics and Chemistry.*, *78*(1), 135-140.

Singh, Z., & Khan, A. S. (2010). Physiology of plum fruit ripening. *Stewart Postharvest Review*, *2*(1), 3-12.

Souza, V. R., Pereira, P. A., Silva, T. L., Lima, L. C., & Pio, R. (2014). Determination of the bioactive compounds, antioxidant activity and chemical composition of Brazilian blackberry, red raspberry, strawberry, blueberry, and sweet cherry fruits. *Food Chemistry*, *56*(1), 362-368.

Sun, K., Li, R., Jiang, W., Sun, Y., & Li, H. (2016). Comparison of three-dimensional printing and vacuum freeze-dried techniques for fabricating composite scaffolds. *Biochemical and Biophysical Research Communications*, *477*(4), 1085-1091. doi:10.1016/j.bbrc.2016.07.050.

Tang, Y., Ma, X., Li, M., & Wang, Y. (2020). The effect of temperature and light on strawberry production in a solar greenhouse. *Solar Energy, 195*, 318-328. doi:10.1016/j.solener.2019.11.070.

Thi Phan, K. K., Truong, T., Wang, Y., & Bhandari, B. (2019). Nanobubbles: Fundamental characteristics and applications in food processing. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.11.019.

Thomas-Valdés, S., Theoduloz, C., Jiménez-Aspee, F., & Schmeda-Hirschmann, G. (2019). Effect of simulated gastrointestinal digestion on polyphenols and bioactivity of the native Chilean red strawberry (Fragaria chiloensis ssp. chiloensis f. patagonica). *Food Research International, 123*, 106-114. doi:10.1016/j.foodres.2019.04.039.

Thomas-Valdés, S; Theoduloz, C; Jiménez-Aspee, F; Burgos-Edwards, A; Schmeda-Hirschmann, G. (2018). Changes in polyphenol composition and bioactivity of the native Chilean white strawberry (Fragaria chiloensis spp. chiloensis f. chiloensis) after in vitro gastrointestinal digestion. *Food Research International, 105*, 10-18. doi:10.1016/j.foodres.2017.10.074.

Van de Velde, F., Esposito, D., Grace, M. H., Pirovani, M. E., & Lila, M. A. (2018). Anti-inflammatory and wound healing properties of polyphenolic extracts from strawberry and blackberry fruits. *Food Research International, 121*, 453-462. doi:10.1016/j.foodres.2018.11.059.

Watson, T. T., Noling, J. W., & Desaeger, J. A. (2020). Fluopyram as a rescue nematicide for managing sting nematode (Belonolaimus longicaudatus) on commercial strawberry in Florida. *Crop Protection, 132*, 105108. doi:10.1016/j.cropro.2020.105108.

Xu, Y., Zhang, M., Mujumdar, A. S., Duan, X., & Jin-cai, S. (2006). A two-stage vacuum freeze and convective air drying method for strawberries. *Drying Technology: An International Journal*, *24*(8), 1019-1023. doi:10.1080/07373930600776209.

Yu, P., Low, M. Y., & Zhou, W. (2018). Design of experiments and regression modelling in food flavour and sensory analysis: A review. *Trends in Food Science & Technology, 71*, 202-215. doi:10.1016/j.tifs.2017.11.013.

Yue, X. Q., Shang, Z. Y., Yang, J. Y., Huang, L., & Wang, Y. Q. (2019). A smart data-driven rapid method to recognize the strawberry maturity. *Information Processing in Agriculture*. doi:10.1016/j.inpa.2019.10.005.

Yusufe, M., Mohammed, A., & Satheesh, N. (2017). Effect of duration and drying temperature on characteristics of dried tomato (Lycopersicon esculentum L.) cochoro variety. *Journal of Food Technology*, *21*(1), 41-50.

ZhixiangYuan, Shi, Y., Cai, F., Zhao, J., Xiong, Q., Wang, Y., & Zheng, Y. (2019). Isolation and Identification of Polysaccharides from Pythium arrhenomanes and Application to Strawberry Fruit (Fragaria ananassa eservation. *Food Chemistry, 125604*. doi:10.1016/j.foodchem.2019.125604.

Manuscript Number **HELIYON-D-20-04139**, titled**: New product development from of strawberries (Fragaria Ananassa Duch.)**
Review 1 – 18 June 2020

Dear Editor of Heliyon,

the argument needs some improvement with regards the references. The English form has to be carefully reviewed, I have indicated some sentences to be verified but the authors have to review the whole manuscript. Many inaccuracies in the text. With regard to the references in the text and in the references section I suggest the authors to use some recent published paper as a sample. The references section has to be reviewed line by line.

1) Page 1: are the names of authors correctly written?

2) Page 1, line 18: here and in the whole manuscript, when you indicate the temperature, separate the value from the symbol: 60 °C;

3) Page 4, line 78, you have stated that …. "Research on the freeze-drying process for fruits has been widely reported"…. but no reference you have included, here you have to support your statement with some reference regarding to frozen small fruits. I suggest, at least **[x1-x2]**:

   [x1] The influence of film and storage on the phenolic and antioxidant properties of red raspberries (*Rubus idaeus* L.) cv. Erika.
   Giuffrè A.M., Louadj L., Rizzo P., De Salvo E., Sicari V.
   Antioxidants 8 (8), 254 (2019).
   doi:10.3390/antiox8080254

   [x2] The Change of Total Anthocyanins in Blueberries and Their Antioxidant Effect After Drying and Freezing
   Virachnee Lohachoompol, George Srzednicki, John Craske
   J Biomed Biotechnol. 2004 Dec 1; 2004(5): 248–252.
   doi: 10.1155/S1110724304406123

4) Page 4, line 83, specify that other post-harvest methods were studied. In two lines, find, read and discuss **[x3-x4]**:

   [x3] Evaluation of *Aloe arborescens* gel as new coating to maintain the organoleptic and functional properties of strawberries (Fragaria x ananassa cv. Cadonga) fruits.
   Sicari V., Loizzo M.R., Pellicanò T.M., Giuffrè A.M., Poiana M.
   International Food Science and Technology, 55 (2) 861-870 (2020).
   doi:10.1111/ijfs.14349

   [x3] Effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry (Fragaria×ananassa Duch. cv. Sabrina) fruit during cold storage.

Moshari-Nasirkandi, A., Alirezalu, A., Hachesu, M.A.
Biocatalysis and Agricultural Biotechnology, 25 (2020), Article number 101613

5) Page 5, lines 95-96, verify the English form of this sentence and re-write it;
6) Page 5, lines 95-96, what is the name of the variety?
7) Page 5, lines 95-96, and in the whole manuscript: strawberries of your manuscript were obtained from a cultivar or from a variety? Cultivar and variety are not synonyms;
8) Page 5, line 97: in the refrigerator at 15 °C? Please, verify;
9) Page 5, line 97: ….they were stored…;
10) Page 6, line 112, here and in the whole manuscript, verify how to insert a reference in relation to the guidelines of Heliyon;
11) Page 6 you did not use italics for Lab, whereas you have written Lab in italics on page 7, please, be consistent in the whole manuscript;
12) Lines 136-137, verify the English form;
13) Pages 9-10, lines 185-86, verify the English form;
14) Page 11, lines 209-210, verify the English form and re-arrange this sentence;
15) Lines 223-225, verify the English form;
16) Lines 232-233, verify the English form;
17) Line 238: F-crib value?
18) Line 239: $p>0.5$?
19) Lines 278-279, verify the English form and the meaning of this sentence;
20) Lines 285-286, verify the form of this sentence;
21) Lines 291-293, re-write this sentence, it is not comprehensible;
22) Line 326, verify the English form;
23) In the captions of figures, please write Figure 1. and not Fig.1. (use some recent published paper as a sample);
24) References section, sometime you have abbreviated the journal title and sometime not, please, be consistent;
25) References section, lines 384, 469 and so on: how many periods before Forbes and Zhang?
26) Line 390, Flavour and Fragrance Journal;
27) Line 417, the scientific names of plants in italics, use the International rules.

1. Methods are described with sufficient details;
2. Results are well included but has to be better discussed;
3. Interpretation of data has to be extended;
4. The study's design, data presentation, and citations comply with standard COPE ethical guidelines and has proper approval and consent been acquired as outlined in Heliyon Editorial Policies

Best regards.

Reviewer #1: Page 5, lines 85-91, re-arrange this section, verify the English form. Each sentence has to be included in a general context, whereas, as you have written each sentence is separated by the context.

Author response #1: I have revised it becomes: Publications that have been revealed by previous researchers, include engineering environmental storage to extend the shelf life of strawberry fruit (Fernández-Lara, et al., 2015), the combined effect of gamma irradiation and MAP on the antioxidant and antimicrobial properties of strawberries (Kirkin & Gunes, 2018), evaluation of the effect of modified atmospheric packaging (MAP) on strawberry storage (Peano, Girgenti, & Giuggioli, 2014), coating method to maintain the organoleptic and functional properties of strawberries (Sicari, Loizzo, Pellicano, Giuffre, & Poiana, 2020), effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry fruit during cold storage (Moshari-Nasirkandi, Alirezalu, & Hachesu, 2020).

Reviewer #2: Lines 98-99, the English form is wrong, you have not corrected. The subject is singular and the verb is plural, re-arrange this sentence. Line 98, the name of the variety in Capital letter: Sweet Charlie.

Author response #2: I have revised it becomes: The research sample was strawberry of variety Sweet Charlie. It was obtained from farmers in Sembalun, East Lombok, Indonesia.

Reviewer #3: Line 115, I repeat, verify how to insert a reference using the guidelines of Helyion.

Author response #3: I have revised it becomes: (Ansar, Nazaruddin, & Azis, 2019)

Reviewer #4: Line 138-139, verify the English form, this sentence has no sense;

Author response #4: I deleted it.

Reviewer #5: Line 240: F-crib or F-crit? Verify with table 3.

Author response #5: I have revised it becomes: F-crit.

Reviewer #6: lines 279-280, verify the English form:

Author response #6: I have revised it becomes: This data showed variations of heating plate temperature and freeze-drying time has influenced significantly ($p<0.05$) on the color parameters of frozen strawberries.

Reviewer #7: References section, the scientific names of plants in italics, use the International rules and compare with the original title of your references. Verify each reference, there is a lot of inaccuracies, for example on the line 441 (-20 8C)?

Author response # 7: I deleted it because this reference is not in the citation.

New product development from of strawberries (*Fragaria Ananassa* Duch.)

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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 product from strawberries produced from a vacuum freeze dryer. 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 hours. 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 paramaters 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 hours drying time. Frozen strawberries most

preferred by panelists are those that are freeze-dried at 50 °C and a drying time of 36 hours because they have aroma and flavor that seem fresh strawberries.

Keywords: frozen strawberry; moisture content; texture; color; aroma; taste.

1. Introduction

Strawberry fruit (*Fragaria ananassa* Duch.) can be found in every country because almost all countries in the world have cultivated its (Falah, Husna, Dewi, & Jumeri, 2016; MacInnis, Buddle, & Forrest, 2020). This fruit is loved for consumption because it has nutrients that are very beneficial for human health (Curi et al., 2016; Blanch & Castilo, 2012; Giampieri et al., 2015; Watson, Noling, & Desaeger, 2020). Strawberries also contain large amounts of folate (Marian et al., 2020; Hu, Lu, Guo, & Zhu, 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, Ahmeda, Salehabadi, Zangeneh, & Zangeneh, 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. (Gaston, Osorio, Denoyes, & Rothan, 2019).

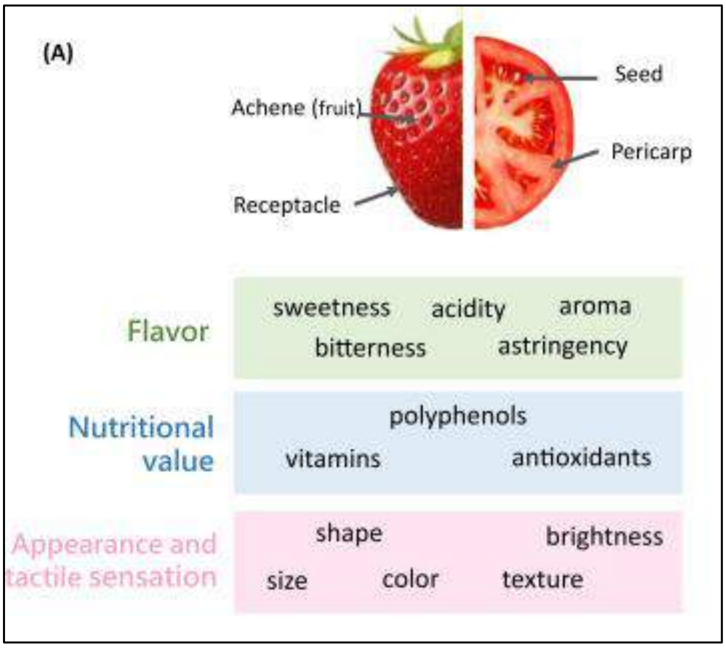


Figure 1. Physical structure and nutrient content of fresh strawberries.

The post-harvest strawberries have a short shelf life that can only last one day if stored at environmental temperatures (Souza, Pereira, Silva, Lima, & Pio, 2014; Ozturk & Singh, 2019). This strawberry fruit cannot be sold to consumers if the skin has blisters or bruises (Balasooriya, Dasanayake, & Ajlouni, 2019). To maintain and increase the shelf life of strawberries, post-harvest processing for these fruits is necessary (An, Li, Zude-Sasse, Tchuenbou-Magaia, & Yang, 2020; Silva, Meireles, & Saldaña, 2020).

Postharvest processing methods for fruits that are commonly used are drying (Ansar, Nazaruddin, & Azis, 2020; Hwang et al., 2020). However, the skin of strawberries is very thin, so it is easily broken if dried using conventional dryers (Tang, Ma, Li, & Wang, 2020). Also, strawberries dried with conventional dryers have a non-uniform color, so they are less favored by consumers (Karoline Martinsen, Aaby, & Skrede, 2020). Anthocyanins contained in strawberries can also be damaged during the conventional drying process. Anthocyanins are unstable at high temperatures, so the stability of these compounds can be disrupted during the conventional drying process (Mainil, Aziz, Harianto, & Maini, 2020; Dash, Chase, Agehara, & Zotarell, 2020).

Frozen fruit is one of the processed fruit products that are very popular with consumers today (Khattab, Guirguis, Tawfik, & Farag, 2019). Frozen fruit is popular because it has color, aroma, and taste still like fresh fruit (Bongoni, Steenbekkers, Verkerk, van Boekel, & Dekker, 2013). Frozen products that have been widely circulating on the market today such as frozen cassava sticks made from fresh cassava are specially processed, hygienic, and without preservatives, to produce products that are high in flavor and healthy for consumption by all ages (Galus & Kadzińska, 2015). Other frozen products are frozen grilled bananas made from fresh bananas which are split and flattened and then burned (Maringgal, Hashim, Mohamed Amin Tawakkal, & Muda Mohamed, 2019). The shelf life of this frozen product is still short because it has high water content (Thi Phan, Truong, Wang, & Bhandari, 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, Jielin, Guangming, & Qin, 2017; Obeidat, Sahni, Kessler, & Pikal, 2017). This freeze vacuum dryer has been used extensively to obtain high-quality dry products (Qiao, Fang, Huang, & Zhang, 2012; Reyes, et al., 2010; Schulze, Hubbermann, & Schwarz, 2014). Frozen vacuum dryers can be applied to strawberries (Xu, Zhang, Mujumdar, Duan, & Jin-cai, 2006; Silva, Meireles, & Saldaña, 2020). Frozen products produced are in line with the desires and needs of consumers for quality processed products that are hygienic and quality (Alikhani & Daraei Garmakhany, 2012; Sun, Li, Jiang, Sun, & Li, 2016).

Research on the freeze-drying process for fruits has been widely reported (Lohachoompol, Srzednicki, & Craske, 2004; Giuffre, Louadj, Rizzo, De Salvo, & Sicari, 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-Lara, et al., 2015), the combined effect of gamma irradiation and MAP on the antioxidant and antimicrobial properties of strawberries (Kirkin & Gunes, 2018), evaluation of the effect of modified atmospheric packaging (MAP) on strawberry storage (Peano, Girgenti, & Giuggioli, 2014), coating method to maintain the organoleptic and functional properties of strawberries (Sicari, Loizzo, Pellicano, Giuffre, & Poiana, 2020), and effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry fruit during cold storage (Moshari-Nasirkandi, Alirezalu, & Hachesu, 2020).

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

2. Material and methods

2.1. Sample Preparation

The research sample was strawberries with Sweet Charlie variety. It was obtained from farmers in Sembalun, 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 hours. 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):

$$Weight\ loss = \frac{w_f - w_d}{w_f}\ 100\% \qquad (1)$$

where, w_f = mass of the sample before drying (gram), w_d = 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 (Ansar, Nazaruddin, & Azis, 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:

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

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):

$$L^* = \frac{\text{Lightness}}{255} x100 \qquad (3)$$

$$a^* = \frac{240a}{255} - 120 \qquad (4)$$

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

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, who aged 18-40 years old. The samples were presented by panelists with 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= dislike extremely, 2 = dislike moderately, 3 = dislike, 4 = like moderately, and 5 = like extremely. The sensory evaluation includes the intensity of aroma and taste (Van de Velde, Esposito, Grace, Pirovani, & Lila, 2018).

2.8. Statistical Analysis

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 F-count value is greater than F-crit, it means there is a significant difference in effect at the 95% significance level. The most influential variables can be calculated using Duncan's Multiple Ranges Test (Yu, Low, & Zhou, 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 hours and then tends to slope until the duration drying is 48 hours. After reaching the freezing point, the weight loss not yet change. Based on Figure 2 it is also shows that the higher of heating plate temperature, the higher the percentage of strawberry weight loss.

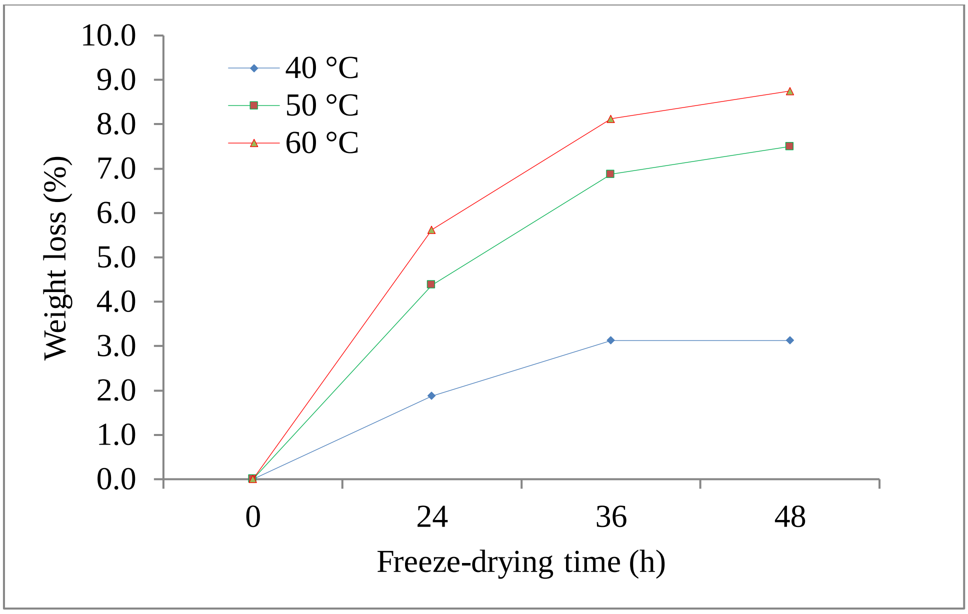


Figure 2. A profile of strawberry weight loss during freeze-vacuum drying at variations of heating plate temperature.

The strawberry fruit was freeze-dried at heating plate temperature 60 °C and drying time 48 hours 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.

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**
Rows	27.79	2	13.89	7.96	0.020	5.14
Columns	78.48	3	26.16	14.98	0.003	4.76
Error	10.48	6	1.75			
Total	116.76	11				

The fruit weight loss is generally affected by the evaporation of moisture content during the drying process (Jaster, 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-Valdés, Theoduloz, Jiménez-Aspee, & Schmeda-Hirschmann, 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 drop dramatically until 24th hour, then they decrease at 36th hour and they stable at 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-Valdés, S; Theoduloz, C; Jiménez-Aspee, F; Burgos-Edwards, A; Schmeda-Hirschmann, G, 2018).

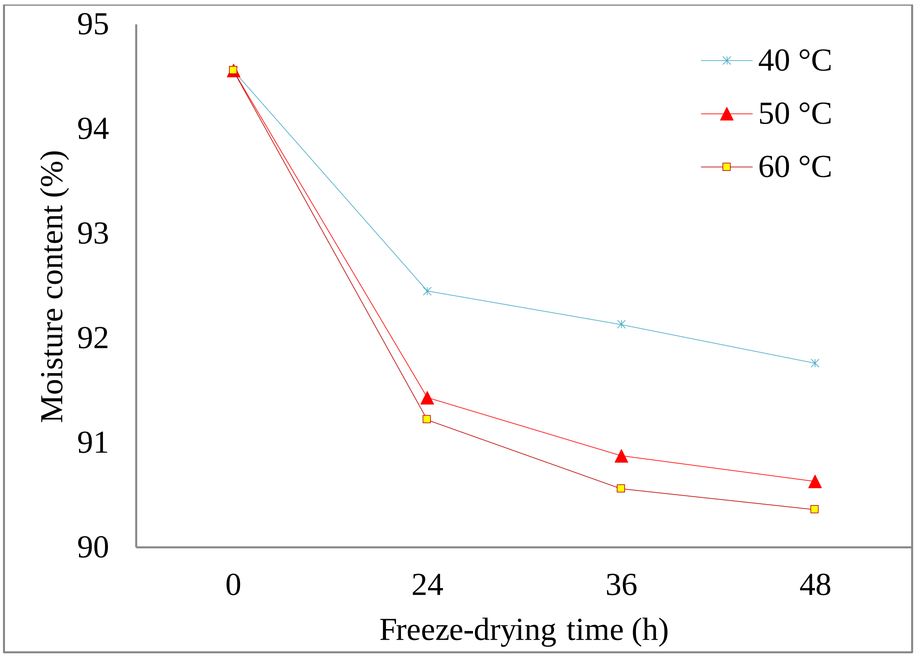


Figure 3. Evaporation of strawberry moisture content during a vacuum-freeze drying at heating plate temperature and freeze-drying time variations.

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, Zhang, Zhu, Mao, & Tu, 2014).

Evaporation of moisture content from fruit cells occurs during the drying process as a result 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, Husna, Dewi, & Jumeri, 2016).

The analysis of variance results shows that F-count (8.68) is greater than the F-crit value (5.14) (Table 2). This means that variations at the 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 Gaston et al. (2019) that the strawberry moisture content decreases during freeze-drying.

Table 2. Results analysis of variance 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**
Rows	2.49	2	1.25	8.68	0.017	5.14
Columns	25.34	3	8.44	58.91	7.65E-05	4.76
Error	0.86	6	0.14			
Total	28.67	11				

3.3. Texture Determination

The frozen strawberry texture was determinates 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 hours 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 hours, the F-max values are 0.16; 0.15; and 0.15 N, and at heating plate temperature 60 °C and freeze-drying time 24; 36; and 48 hours, 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 Asioli, et al. (2018) that mechanical resistance to compression, shear force, and strawberry stiffness decreases after drying.

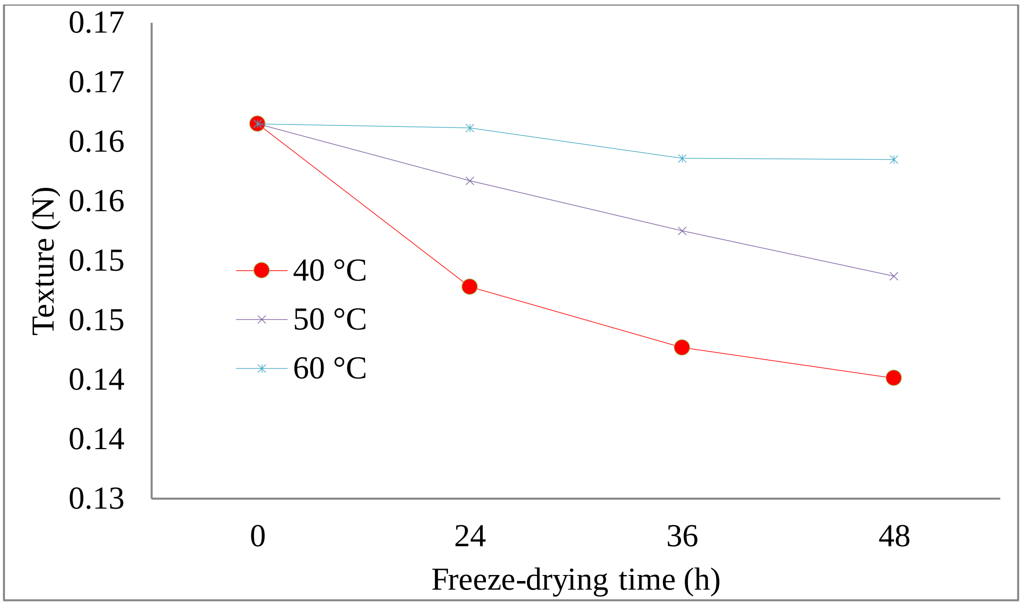


Figure 4. Graph of texture changes of frozen strawberries during vacuum-freeze dryer at heating plate temperature variations.

Frozen strawberries have a soft and wrinkled texture because some moisture content has evaporated. This is in line with the report Alikhani and Daraei Garmakhany (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 (Asioli, 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 (5,143) (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.

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**
Rows	2.86	2	1.43	8.18	0.02	5.14
Columns	2.67	3	0.89	5.09	0.044	4.76
Error	1.05	6	0.17			
Total	6.57	11				

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

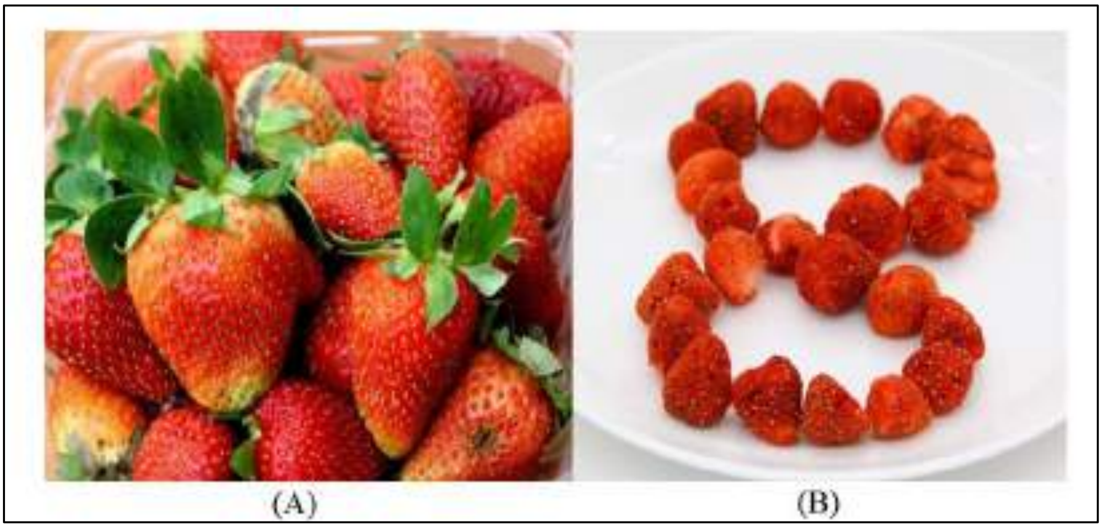
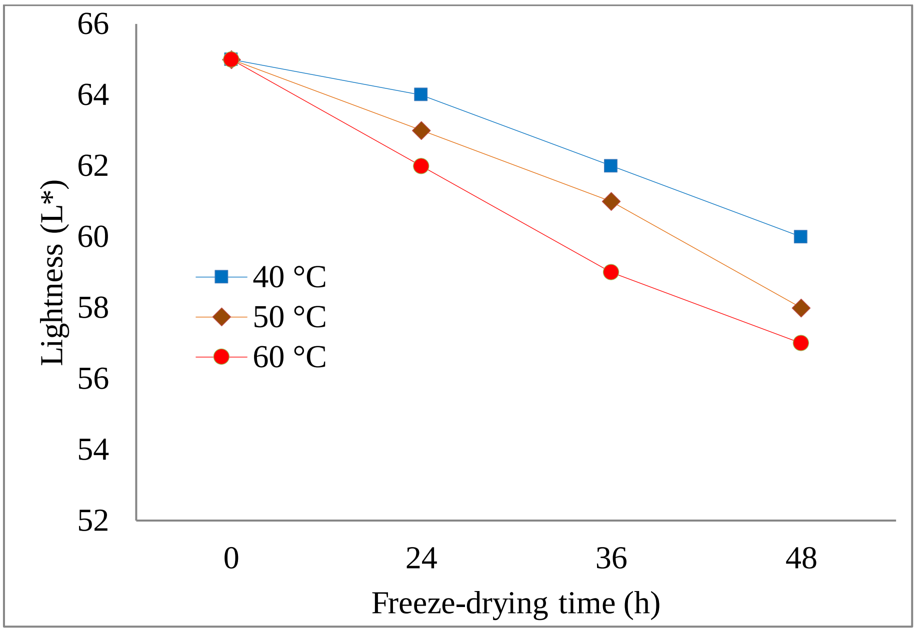
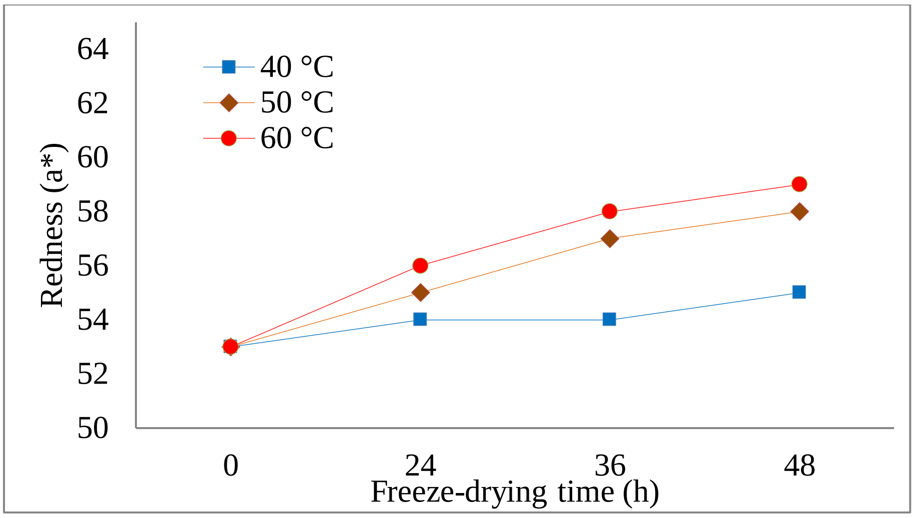


Figure 5. Strawberry fruit, (A) before freeze-drying and (B) after freeze-drying

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.



(A)



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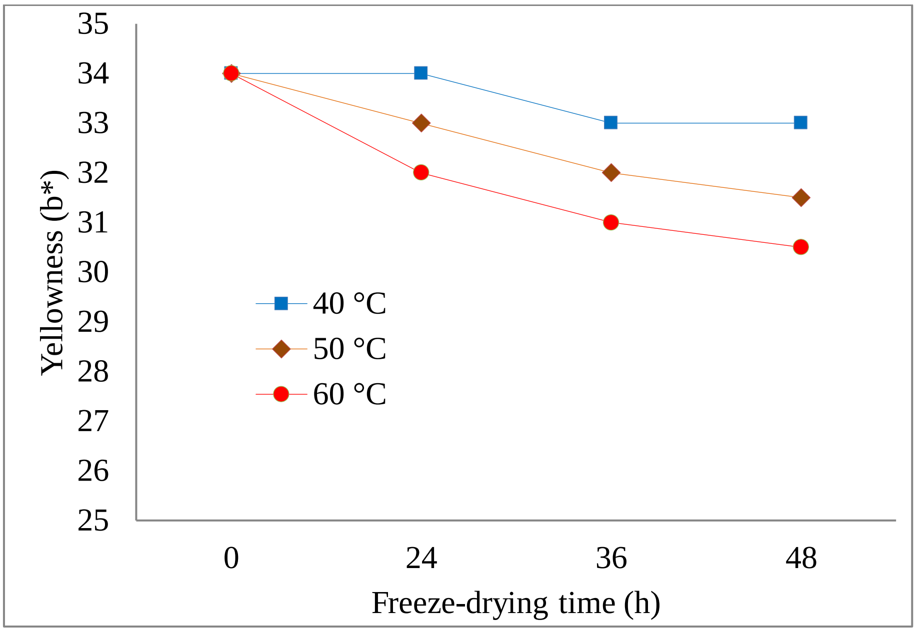


(C)

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

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 (Chisari, Riccardo, Barbagallo, & Spagna, 2007). Some researchers also report that color is the most important criterion for consumers in determining product choices (Yue, Shang, Yang, Huang, & Wang, 2019).

The results analysis of variance obtained F-count values (5.84) greater than the F-crit value (5.14) (Table 4). This data showed variations 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.

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

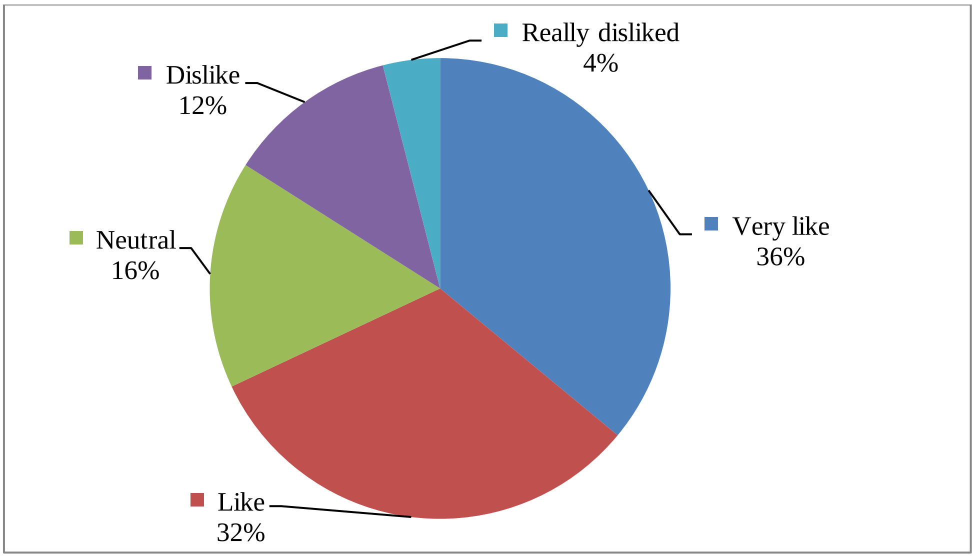
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F-crit**
Rows	6.17	2	3.08	5.84	0.04	5.14
Columns	68.33	3	22.78	43.16	0.00	4.76
Error	3.17	6	0.53			
Total	77.67	11				

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).

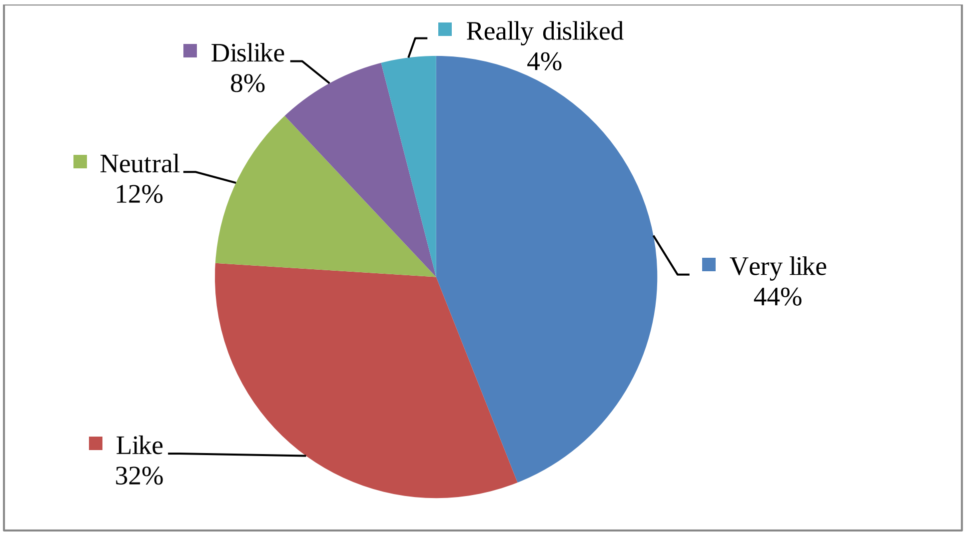
The strawberry fruit has a red pigment that comes from the concentration of anthocyanins (Patras, Brunton, Pieve, & Butler, 2009; Gaston, Osorio, Denoyes, & Rothan, 2019). The lower the concentration of anthocyanins, the color of the fruit becomes purple, on the contrary, if the concentration of anthocyanins is very high, the color of the fruit can be blackish (Asioli, et al., 2018). For low pH, anthocyanins 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 (Ozcan & Barringer, 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, Durst, Wrolstad, & De Jong, 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 parameters 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 7B.



(A)



(B)

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

Based on data from the judicial assessment of the aroma of frozen strawberries, it is known that 36% of panelists answered very like, 32% said they liked, and only 16% stated neutral, 12% disliked, and 4% said they really disliked (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 temperature. Karoline et al. (2020) have also reported that samples that are dried in freeze-drying are first frozen, then dried using low pressure, resulting in a sublimation process in which the water content that 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 they really liked, 32% said they liked, 12% said they were neutral, 8% said they didn't like it, and only 4% who said they really didn't like it (Figure 7B). Based on this 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 (Ansar, Nazaruddin, & Azis, 2019). Strawberry fruit has a sweet and sour taste (citrus) that is fresh and soft (Yue, Shang, Yang, Huang, & Wang, 2019). This compound is not easily evaporated by the influence of environmental temperature (Souza, Pereira, Silva, Lima, & Pio, 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 does not change significantly after was frozen and they seem fresh fruit. 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.

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CONFLICT OF INTEREST

The all authors not have any conflict of interest.

References

Alikhani, M., & Daraei Garmakhany, A. (2012). Effect of microencapsulated essential oils on storage life and quality of strawberry (Fragaria ananassa cv. Camarosa). *Quality Assurance and Safety of Crops & Foods, 4*(1), 106–112.

Amelio, M. (2019). Olive oil sensory evaluation: An alternative to the robust coefficient of variation (Cvr %) for measuring panel group performance in official tasting sessions. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.02.044.

An, X., Li, Z., Zude-Sasse, M., Tchuenbou-Magaia, F., & Yang, Y. (2020). Characterization of textural failure mechanics of strawberry fruit. *Journal of Food Engineering, 282*(110016). doi:10.1016/j.jfoodeng.2020.110016.

Ansar, Nazaruddin, & Azis, A. D. (2019). Effect of vacuum freeze-drying condition and maltodextrin on the physical and sensory characteristics of passion fruit (Passiflora edulis sims) extract. *IOP Conference Series: Earth and Environmental Science* (pp. 1-12). Makassar: IOP Publishing. doi:10.1088/1755-1315/355/1/012067.

Ansar, Nazaruddin, & Azis, A. D. (2020). Caking mechanisms of passion fruit powder during storage. *International Journal of Innovation, Creatifity, and Change, 13*(2), 618-628.

Asioli, D., Rocha, C., Wongprawmas, R., Popa, M., Gogus, F., & Almli, V. L. (2018). Microwave-dried or air-dried? Consumers' stated preferences and attitudes for organic dried strawberries. A multi-country investigation in Europe. *Food Research International, 76*, 645–653. doi:10.1016/j.foodres.2018.11.037.

Balasooriya, H., Dasanayake, K., & Ajlouni, S. (2019). Bioaccessibility of micronutrients in fresh and frozen strawberry fruits grown under elevated carbon dioxide and temperature. *Food Chemistry,* 1-9. doi:10.1016/j.foodchem.2019.125662

Battino, M., Giampieri, F., Cianciosi, D., Ansary, J., Chen, X., Zhang, D., Gil, E., Forbes-Hernández, T. (2020). The roles of strawberry and honey phytochemicals on human health: a possible clue on the molecular mechanisms involved in the prevention of oxidative stress and inflammation. *Phytomedicine, 153170*. doi:10.1016/j.phymed.2020.153170.

Blanch , G. P., & Castilo, M. L. (2012). Changes in strawberry volatile constituents after pre-harvest treatment with natural hormonal compounds. *Flavour and Fragrance Journal, 27*(1), 180-187.

Bongoni, R., Steenbekkers, L. A., Verkerk, R., van Boekel, M. S., & Dekker, M. (2013). Studying consumer behaviour related to the quality of food: A case on vegetable preparation affecting sensory and health attributes. *Trends in Food Science & Technology, 33*(2), 139-145. doi:10.1016/j.tifs.2013.08.004.

Brown, C. R., Durst, R. W., Wrolstad, R., & De Jong, W. (2008). Variability of phytonutrient content of potato in relation to growing location and cooking method. *Potato Reearch, 51*(4), 259-270.

Buvé, C., Neckebroeck, B., Haenen, A., Kebede, B., Hendrickx, M., Grauwet, T., & Van Loey, A. (2018). Combining untargeted, targeted and sensory data to investigate the impact of storage on food volatiles: A case study on strawberry juice. *Food Research International, 113*, 382–391. doi:10.1016/j.foodres.2018.07.022.

Chapman, J., Elbourne, A., Truong, V. K., Newman, L., Gangadoo, S., Rajapaksha Pathirannahalage, P., & Cozzolino, D. (2019). Sensomics - from conventional to functional NIR spectroscopy-shining light over the aroma and taste of foods. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.07.013.

Chisari, M., Riccardo, N., Barbagallo, & Spagna, G. (2007). Characterization of polyphenol oxidase and peroxides and influence on browning of cold stored strawberry fruit. *Journal of Agriculture and Food Chemistry, 55*(1), 3469-3476.

Curi, P. N., Tavares, B. S., Almeida, A. B., Pio, R., Peche, P. M., & Souza, V. R. (2016). Influence of subtropical region strawberry cultivars on jelly characteristics. *Journal of Food Science, 81*(6), 15-20.

Dash, P. K., Chase, C. A., Agehara, S., & Zotarell, L. (2020). Heat stress mitigation effects of kaolin and s-abscisic acid during the establishment of strawberry plug transplants. *Scientia Horticulturae, 267*(109276). doi:10.1016/j.scienta.2020.109276.

Falah, M. A., Husna, H., Dewi, A. R., & Jumeri. (2016). Quality evaluation of fresh strawberry (Fragaria sp. cv. Earlybrite) during storage in a tropical environment. *AIP Conference Proceedings*, 1-6.

Fernández-Lara, R., Gordillo, B., Rodríguez-Pulido, F. J., Lourdes González-Miret, M., del Villar-Martínez, A. A., Dávila-Ortiz, G., & Heredia, F. G. (2015). Assessment of the differences in the phenolic composition and color characteristics of new strawberry (Fragaria x ananassa Duch.) cultivars by HPLC–MS and Imaging Tristimulus Colorimetry. *Food Research International, 76*, 645–653. doi:10.1016/j.foodres.2015.07.038.

Galus, S., & Kadzińska, J. (2015). Food applications of emulsion-based edible films and coatings. *Trends in Food Science & Technology, 45*(2), 273-283. doi:10.1016/j.tifs.2015.07.011.

Gaston, A., Osorio, S., Denoyes, B., & Rothan, C. (2019). Applying the Solanaceae Strategies to Strawberry Crop Improvement. *Trends in Plant Science*. doi:10.1016/j.tplants.2019.10.003.

Giampieri, F., Alvarez Suarez, J., & Battino, M. (2014). Strawberry and human health: Effects beyond antioxidant activity. *Journal of Agricultural and Food Chemistry, 62*(18), 3867-3876. doi:10.1021/jf405455n

Giampieri, F., Forbes-Hernandez, T. Y., Gasparrini, M., Alvarez-Suarez, J. M., Afrin, S., Bompadre, S., Quiles, J.L., Mezzetti, B., Battino, M. (2015). Strawberry as a health promoter: an evidence based review. *Food & Function, 6*(5), 1386-1398. doi:10.1039/c5fo00147a.

Giuffre, A. M., Louadj, L., Rizzo, P., De Salvo, E., & Sicari, V. (2019). The influence of film and storage on the phenolic and antioxidant properties of red raspberries (Rubus idaeus L.) cv. Erika. *Antioxidants, 8*(8), 254. doi:10.3390/antiox8080254.

Hanif, Z. (2015). Quality improvement of fresh strawberry fruit through harvest and postharvest handling. *Journal of Balitjestro, 15*(1), 1-6.

Hemmati, S., Ahmeda, A., Salehabadi, Y., Zangeneh, A., & Zangeneh, M. M. (2020). Synthesis, characterization, and evaluation of cytotoxicity, antioxidant, antifungal, antibacterial, and cutaneous wound healing effects of copper nanoparticles using the aqueous extract of Strawberry fruit and L-Ascorbic acid. *Polyhedron, 114425*. doi:10.1016/j.poly.2020.114425.

Hu, X., Lu, L., Guo, Z., & Zhu, Z. (2020). Volatile compounds, affecting factors and evaluation methods for rice aroma: A review. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2020.01.003.

Hung, D. V., Tong, S., Tanaka, F., Yasunaga, D. H., Hamanaka, D., & Hiruma, N. (2011). Controlling the weight loss of fresh produce during postharvest storage under a nano-size mist environment. *Journal of Food Engineering, 106*, 325-330.

Hwang, E. J., Jeong, S. Y., Kim, M. J., Jeong, J. S., Lee, K. H., Jeong, N. R., & Kim, I. (2020). Year-round trap capture of the spotted-wing drosophila, Drosophila suzukii (Diptera: Drosophilidae), in Korean strawberry greenhouses. *Journal of Asia-Pacific Entomology, 23*(1), 204–213. doi:10.1016/j.aspen.2020.01.004.

Jaster, H., Arend, G. D., Rezzadori, K., Chaves, V. C., Reginatto, F. H., & Petrus, J. C. (2018). Enhancement of antioxidant activity and physicochemical properties of yogurt enriched with concentrated strawberry pulp obtained by block freeze concentrated strawberry pulp obtained by block freeze concentration. *Food Research International, 104*, 119-125. doi:10.1016/j.foodres.2017.10.006.

Jedlinska , A., Samborska, K., Janiszewska-Turak, E., Witrowa-Rajchert, D., Seuvre, A. M., & Voilley, A. (2018). Physicochemical properties of vanilla and raspberry aromas microencapsulated in the industrial conditions by spray drying. *Journal of Food Process Engineering*, e12872.

Jiang, N., Liu, C., Li, D., Zhang, Z., Liu, C., Wang, D., Niu, L., Zhang, M. (2017). Evaluation of freeze drying combined with microwave vacuum drying for functional okra snacks: Antioxidant properties, sensory quality, and energy consumption. *LWT-Food Science and Technology, 82*, 216-226. doi:10.1016/j.lwt.2017.04.015.

Jiang, Y., Yu, L., Hu, Y., Zhu, Z., Zhuang, C., Zhao, Y., & Zhong, Y. (2020). The preservation performance of chitosan coating with different molecular weight on strawberry using electrostatic spraying technique. *International Journal of Biological Macromolecules*. doi:10.1016/j.ijbiomac.2020.02.169.

Jorge, A., Sauer Leal, E., Sequinel, R., Sequinel, T., Kubaski, E. T., & Tebcherani, S. M. (2018). Changes in the composition of tomato powder (Lycopersicon esculentum Mill) resulting from different drying methods. *Journal of Food Processing and Preservation*, e13595.

Karoline Martinsen, B., Aaby, K., & Skrede, G. (2020). Effect of temperature on stability of anthocyanins, ascorbic acid and color in strawberry and raspberry jams. *Food Chemistry, 126297*. doi:10.1016/j.foodchem.2020.126297.

Khattab, A. R., Guirguis, H. A., Tawfik, S. M., & Farag, M. A. (2019). Cheese ripening: A review on modern technologies towards flavor enhancement, process acceleration and improved quality assessment. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.03.009.

Kirkin, C., & Gunes, G. (2018). Modified atmosphere packaging and gamma-irradiation of some herbs and spices: Effects on antioxidant and antimicrobial properties. *Journal of Food Processing and Preservation*, 1-13.

Lohachoompol, V., Srzednicki, G., & Craske, J. (2004). The change of total anthocyanins in blueberries and their antioxidant effect after drying and freezing. *Journal of Biomedicine Biotechnology, 5*, 248–252. doi:10.1155/S1110724304406123.

Lesme, H., Courcoux,, P., Alleaume, C., Famelart, M. H., Bouhallab, C., Prost, C., & Rannou, C. (2020). Contribution of temporal dominance of sensations performed by modality (M-TDS) to the sensory perception of texture and flavor in semi-solid products: a case study on fat-free strawberry yogurts. *Food Quality and Preference, 80*, 1-13. doi:10.1016/j.foodqual.2019.103789.

MacInnis, G., Buddle, C. M., & Forrest, J. K. (2020). Small wild bee abundance declines with distance into strawberry crops regardless of field margin habitat. *Basic and Applied Ecology*. doi:10.1016/j.baae.2020.02.007.

Mainil, A. K., Aziz, A., Harianto, J., & Maini, R. I. (2020). Comparative assessment of closed loop heat pump dryer and direct solar dryer system for banana drying. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 66*(2), 136-144.

Marian, M., Ohno, T., Suzuki, H., Kitamura, H., Kuroda, K., & Shimizu, M. (2020). A novel strain of endophytic Streptomyces for the biocontrol of strawberry anthracnose caused by Glomerella cingulate. *Microbiological Research, 126428*. doi:10.1016/j.micres.2020.126428.

Maringgal, B., Hashim, N., Mohamed Amin Tawakkal, I. S., & Muda Mohamed, M. T. (2019). Recent advance in edible coating and its effect on fresh/fresh-cut fruits quality. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.12.024.

Moshari-Nasirkandi, A., Alirezalu, A., & Hachesu, M. A. (2020). Effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry (Fragaria×ananassa Duch. cv. Sabrina) fruit during cold storage. *Biocatalysis and Agricultural Biotechnology, 25*(101613).

Nguyen, V. B., Nguyen, D. H., & Nguyen, H. V. (2020). Combination effects of calcium chloride and nano-chitosan on the postharvest quality of strawberry (Fragaria x ananassa Duch.). *Postharvest Biology and Technology, 162*(111103). doi:10.1016/j.postharvbio.2019.111103.

Obeidat, W. M., Sahni, E., Kessler, W., & Pikal, M. (2017). Development of a Mini-Freeze Dryer for Material-Sparing Laboratory Processing with Representative Product Temperature History. *AAPS PharmSciTech, 19*(12), 599-609. doi:10.1208/s12249-017-0871-5.

Ozcan, G., & Barringer, S. (2011). Effect of enzymes on strawberry volatiles during storage, at different ripeness level, in different cultivars, and during eating. *Journal of Food Science*, *76*(2), 324-334.

Ozturk, O. K., & Singh, T. P. (2019). Selected physical and viscoelastic properties of strawberries as a function of heated-air drying conditions. *Drying Technology*, 1-11. doi:10.1080/07373937.2018.1543701

Pan, L., Zhang, W., Zhu, N., Mao, S., & Tu, K. (2014). Early detection and classification of pathogenic fungal disease in post-harvest strawberry fruit by electronic nose and gas chromatography–mass spectrometry. *Food Research International*, *62*, 162–168. doi:10.1016/j.foodres.2014.02.020.

Patras, A., Brunton, N. P., Pieve, S. D., & Butler, F. (2009). Impact of high pressure processing on total antioxidant activity, phenolic, ascorbic acid, anthocyanin content and colour of strawberry and blackberry purees. *Innovative Food Science & Emerging Technologies, 10*(1), 308–313.

Peano, C., Girgenti, V., & Giuggioli, N. R. (2014). Change in quality and volatile constituents of strawberries (cv. Evie2) under MAP storage. *Journal of Food, Agriculture & Environment, 12*(2), 93-100.

Qiao, F., Fang, C., Huang, L., & Zhang, S. (2012). The Effect of Different Heating Patterns on Vacuum Freeze-Drying of Litchi Pulp. *Journal of Food Process Engineering, 36*(4), 407-411. doi:10.1111/j.1745-4530.2012.00680.x.

Reyes, V., Bubnovich, R., Bustos, M., Vásquez, R., Vega, R., & Scheuermann , E. (2010). Comparative study of different process conditions of freeze drying of 'Murtilla' berry. *Drying Technology: An International Journal, 28:12, 1416-1425, 28*(12), 1416-1425. doi:10.1080/07373937.2010.482687.

Schulze, B., Hubbermann, E. M., & Schwarz, K. (2014). Stability of quercetin derivatives in vacuum impregnated apple slices after drying (microwave vacuum drying, air drying, freeze drying) and storage. *LWT-Food Science and Technology, 57*(1), 426-433. doi:10.1016/j.lwt.2013.11.021.

Shaozhi, Z., Jielin, L., Guangming, C., & Qin, W. (2017). Thermodynamic analysis of a freeze-dryer utilizing hygroscopic solution. *Drying Technology*. doi:10.1080/07373937.2017.1308952.

Shiraz, S., Djebbi-Simmons, D., Alhejaili, M., Danos, K., Janes, M., Fontenot, K., & Xu, W. (2020). Evaluation of the microbial safety and quality of Louisiana strawberries after flooding. *Food Control, 110*(106970). doi:10.1016/j.foodcont.2019.106970.

Sicari, V., Loizzo, M. R., Pellicano, T. M., Giuffre, A. M., & Poiana, M. (2020). Evaluation of aloe arborescens gel as new coating to maintain the organoleptic and functional properties of strawberries (Fragaria x ananassa cv. Cadonga) fruits. *International Food Science and Technology*, *55*(2), 861-870. doi:10.1111/ijfs.14349.

Silva, E. K., Meireles, M. A., & Saldaña, M. A. (2020). Supercritical carbon dioxide technology: A promising technique for the non-thermal processing of freshly fruit and vegetable juices. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2020.01.025.

Singh, S. P., & Pal, R. K. (2009). Ionizing radiation treatment to improve postharvest life and maintain quality of fresh guava fruit. *Radiation Physics and Chemistry.*, *78*(1), 135-140.

Singh, Z., & Khan, A. S. (2010). Physiology of plum fruit ripening. *Stewart Postharvest Review*, *2*(1), 3-12.

Souza, V. R., Pereira, P. A., Silva, T. L., Lima, L. C., & Pio, R. (2014). Determination of the bioactive compounds, antioxidant activity and chemical composition of Brazilian blackberry, red raspberry, strawberry, blueberry, and sweet cherry fruits. *Food Chemistry*, *56*(1), 362-368.

Sun, K., Li, R., Jiang, W., Sun, Y., & Li, H. (2016). Comparison of three-dimensional printing and vacuum freeze-dried techniques for fabricating composite scaffolds. *Biochemical and Biophysical Research Communications*, *477*(4), 1085-1091. doi:10.1016/j.bbrc.2016.07.050.

Tang, Y., Ma, X., Li, M., & Wang, Y. (2020). The effect of temperature and light on strawberry production in a solar greenhouse. *Solar Energy*, *195*, 318-328. doi:10.1016/j.solener.2019.11.070.

Thi Phan, K. K., Truong, T., Wang, Y., & Bhandari, B. (2019). Nanobubbles: Fundamental characteristics and applications in food processing. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.11.019.

Thomas-Valdés, S., Theoduloz, C., Jiménez-Aspee, F., & Schmeda-Hirschmann, G. (2019). Effect of simulated gastrointestinal digestion on polyphenols and bioactivity of the native Chilean red strawberry (Fragaria chiloensis ssp. chiloensis f. patagonica). *Food Research International*, *123*, 106-114. doi:10.1016/j.foodres.2019.04.039.

Thomas-Valdés, S; Theoduloz, C; Jiménez-Aspee, F; Burgos-Edwards, A; Schmeda-Hirschmann, G. (2018). Changes in polyphenol composition and bioactivity of the native Chilean white strawberry (Fragaria chiloensis spp. chiloensis f. chiloensis) after in vitro gastrointestinal digestion. *Food Research International*, *105*, 10-18. doi:10.1016/j.foodres.2017.10.074.

Van de Velde, F., Esposito, D., Grace, M. H., Pirovani, M. E., & Lila, M. A. (2018). Anti-inflammatory and wound healing properties of polyphenolic extracts from strawberry and blackberry fruits. *Food Research International*, *121*, 453-462. doi:10.1016/j.foodres.2018.11.059.

Watson, T. T., Noling, J. W., & Desaeger, J. A. (2020). Fluopyram as a rescue nematicide for managing sting nematode (Belonolaimus longicaudatus) on commercial strawberry in Florida. *Crop Protection*, *132*, 105108. doi:10.1016/j.cropro.2020.105108.

Xu, Y., Zhang, M., Mujumdar, A. S., Duan, X., & Jin-cai, S. (2006). A two-stage vacuum freeze and convective air drying method for strawberries. *Drying Technology: An International Journal*, *24*(8), 1019-1023. doi:10.1080/07373930600776209.

Yu, P., Low, M. Y., & Zhou, W. (2018). Design of experiments and regression modelling in food flavour and sensory analysis: A review. *Trends in Food Science & Technology*, *71*, 202-215. doi:10.1016/j.tifs.2017.11.013.

Yuan, Z., Shi, Y., Cai, F., Zhao, J., Xiong, Q., Wang, Y., & Zheng, Y. (2019). Isolation and identification of polysaccharides from pythium arrhenomanes and application to strawberry fruit (*Fragaria ananassa* Duch.) preservation. *Food Chemistry*, *309*, 125604. doi:10.1016/j.foodchem.2019.125604.

Yue, X. Q., Shang, Z. Y., Yang, J. Y., Huang, L., & Wang, Y. Q. (2019). A smart data-drivenrapid method to recognize the strawberry maturity. *Information Processing in Agriculture*. doi:10.1016/j.inpa.2019.10.005.

Yusufe, M., Mohammed, A., & Satheesh, N. (2017). Effect of duration and drying temperature on characteristics of dried tomato (Lycopersicon esculentum L.) cochoro variety. *Journal of Food Technology*, *21*(1), 41-50.

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Reviewer #1: Methods:Methods are described with sufficient details

Results:Results are well included but has to be better discussed

Interpretation:Interpretation of data has to be extended

Other comments:The study's design, data presentation, and citations comply with standard COPE ethical guidelines and has proper approval and consent been acquired as outlined in Heliyon Editorial Policies

Reviewer #2: General comment:
The paper is interesting and in general well organized, there are some missing informations so it's necessary to improve the paper before its acceptance.

Introduction:
The authors adfirm that to increase the shelf life of strawberries post harvest processing is necessary..This is correct but it 's better to improve with post harvest technology management such as processing…
Line-83Please improve with more references Such as Peano et al., 2014…Journal of Food, Agriculture and Environment, Volume 12, Issue 2, 2014, Pages 93-100
DLine 86-91: please delete this sentence.Various ….conumers.

Methodology:
Fragaria ananssa is no the variety.
Please explicit the variety
Line 97 :15°C is no a refrigerator temperature!
Line 103 : please explain how many replicate for analysis.
Give more informations about the panel test
Why the control (fresh fruits) only for some analysis?
Fig.6 Please check the redness (L?) and Yellowness (L?)on y axis
Sensory test: pleas erevise this part It's no clear at wich Plate temperature was performed, then could be interesting also to evaluate the fresh fruits as control.

Results:

Considering The missing information about the sensory test that authors must to improve it' no possible to sfirm343-3444 (but don't significantly influence the aroma and flavor parametres…..

Discussion:
Please improve the conclusion suggesting the possible use of these processed strawberry

Bibliography/References:
Others: Please check the use of English see line 136-137….
Decision: Major revisons

Reviewer #3: This paper deals with new product development from of strawberries (Fragaria Ananassa Duch.) which will be of interest to the readers of Heliyon. However, in my opinion, this manuscript suffers from a lot of flaws and lack of sufficient insights to inspire the readers as required for publication quality. Therefore, I recommend rejection of this manuscript.

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New product development from of strawberries (*Fragaria Ananassa* Duch.)

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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 product from strawberries produced from a vacuum freeze dryer. 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 hours. 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 paramaters 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 hours drying time. Frozen strawberries most

preferred by panelists are those that are freeze-dried at 50 °C and a drying time of 36 hours because they have aroma and flavor that seem fresh strawberries.

Keywords: frozen strawberry; moisture content; texture; color; aroma; taste.

1. Introduction

Strawberry fruit (*Fragaria ananassa* Duch.) can be found in every country because almost all countries in the world have cultivated its (Falah, Husna, Dewi, & Jumeri, 2016; MacInnis, Buddle, & Forrest, 2020). This fruit is loved for consumption because it has nutrients that are very beneficial for human health (Curi et al., 2016; Blanch & Castilo, 2012; Giampieri et al., 2015; Watson, Noling, & Desaeger, 2020). Strawberries also contain large amounts of folate (Marian et al., 2020; Hu, Lu, Guo, & Zhu, 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, Ahmeda, Salehabadi, Zangeneh, & Zangeneh, 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. (Gaston, Osorio, Denoyes, & Rothan, 2019).

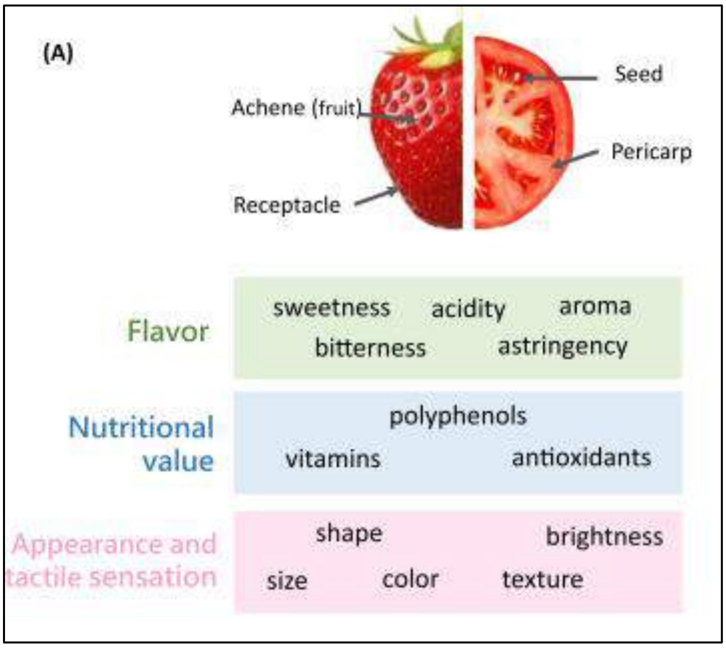


Figure 1. Physical structure and nutrient content of fresh strawberries.

The post-harvest strawberries have a short shelf life that can only last one day if stored at environmental temperatures (Souza, Pereira, Silva, Lima, & Pio, 2014; Ozturk & Singh, 2019). This strawberry fruit cannot be sold to consumers if the skin has blisters or bruises (Balasooriya, Dasanayake, & Ajlouni, 2019). To maintain and increase the shelf life of strawberries, post-harvest processing for these fruits is necessary (An, Li, Zude-Sasse, Tchuenbou-Magaia, & Yang, 2020; Silva, Meireles, & Saldaña, 2020).

Postharvest processing methods for fruits that are commonly used are drying (Ansar, Nazaruddin, & Azis, 2020; Hwang et al., 2020). However, the skin of strawberries is very thin, so it is easily broken if dried using conventional dryers (Tang, Ma, Li, & Wang, 2020). Also, strawberries dried with conventional dryers have a non-uniform color, so they are less favored by consumers (Karoline Martinsen, Aaby, & Skrede, 2020). Anthocyanins contained in strawberries can also be damaged during the conventional drying process. Anthocyanins are unstable at high temperatures, so the stability of these compounds can be disrupted during the conventional drying process (Mainil, Aziz, Harianto, & Maini, 2020; Dash, Chase, Agehara, & Zotarell, 2020).

Frozen fruit is one of the processed fruit products that are very popular with consumers today (Khattab, Guirguis, Tawfik, & Farag, 2019). Frozen fruit is popular because it has color, aroma, and taste still like fresh fruit (Bongoni, Steenbekkers, Verkerk, van Boekel, & Dekker, 2013). Frozen products that have been widely circulating on the market today such as frozen cassava sticks made from fresh cassava are specially processed, hygienic, and without preservatives, to produce products that are high in flavor and healthy for consumption by all ages (Galus & Kadzińska, 2015). Other frozen products are frozen grilled bananas made from fresh bananas which are split and flattened and then burned (Maringgal, Hashim, Mohamed Amin Tawakkal, & Muda Mohamed, 2019). The shelf life of this frozen product is still short because it has high water content (Thi Phan, Truong, Wang, & Bhandari, 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, Jielin, Guangming, & Qin, 2017; Obeidat, Sahni, Kessler, & Pikal, 2017). This freeze vacuum dryer has been used extensively to obtain high-quality dry products (Qiao, Fang, Huang, & Zhang, 2012; Reyes, et al., 2010; Schulze, Hubbermann, & Schwarz, 2014). Frozen vacuum dryers can be applied to strawberries (Xu, Zhang, Mujumdar, Duan, & Jin-cai, 2006; Silva, Meireles, & Saldaña, 2020). Frozen products produced are in line with the desires and needs of consumers for quality processed products that are hygienic and quality (Alikhani & Daraei Garmakhany, 2012; Sun, Li, Jiang, Sun, & Li, 2016).

Research on the freeze-drying process for fruits has been widely reported (Lohachoompol, Srzednicki, & Craske, 2004; Giuffre, Louadj, Rizzo, De Salvo, & Sicari, 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-Lara, et al., 2015), the combined effect of gamma irradiation and MAP on the antioxidant and antimicrobial properties of strawberries (Kirkin & Gunes, 2018), evaluation of the effect of modified atmospheric packaging (MAP) on strawberry storage (Peano, Girgenti, & Giuggioli, 2014), coating method to maintain the organoleptic and functional properties of strawberries (Sicari, Loizzo, Pellicano, Giuffre, & Poiana, 2020), and effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry fruit during cold storage (Moshari-Nasirkandi, Alirezalu, & Hachesu, 2020).

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

2. Material and methods

2.1. Sample Preparation

The research sample was strawberries with Sweet Charlie variety. It was obtained from farmers in Sembalun, 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 hours. 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):

$$Weight\ loss = \frac{w_f - w_d}{w_f}\ 100\% \qquad (1)$$

where, w_f = mass of the sample before drying (gram), w_d = 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 (Ansar, Nazaruddin, & Azis, 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:

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

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):

$$L^* = \frac{\text{Lightness}}{255} x100 \qquad (3)$$

$$a^* = \frac{240a}{255} - 120 \qquad (4)$$

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

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, who aged 18-40 years old. The samples were presented by panelists with 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= dislike extremely, 2 = dislike moderately, 3 = dislike, 4 = like moderately, and 5 = like extremely. The sensory evaluation includes the intensity of aroma and taste (Van de Velde, Esposito, Grace, Pirovani, & Lila, 2018).

2.8. Statistical Analysis

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 F-count value is greater than F-crit, it means there is a significant difference in effect at the 95% significance level. The most influential variables can be calculated using Duncan’s Multiple Ranges Test (Yu, Low, & Zhou, 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 hours and then tends to slope until the duration drying is 48 hours. After reaching the freezing point, the weight loss not yet change. Based on Figure 2 it is also shows that the higher of heating plate temperature, the higher the percentage of strawberry weight loss.

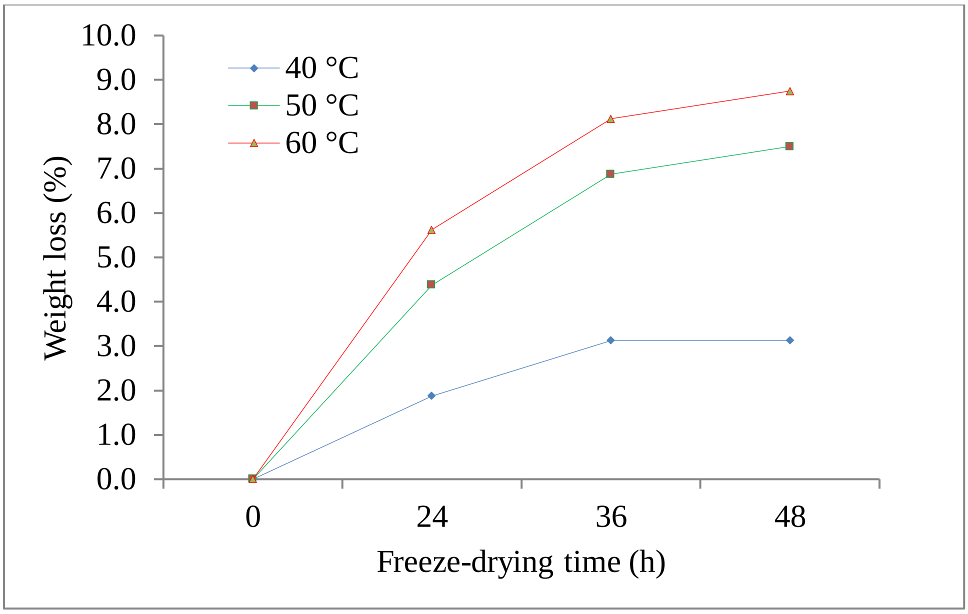


Figure 2. A profile of strawberry weight loss during freeze-vacuum drying at variations of heating plate temperature.

The strawberry fruit was freeze-dried at heating plate temperature 60 °C and drying time 48 hours 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.

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**
Rows	27.79	2	13.89	7.96	0.020	5.14
Columns	78.48	3	26.16	14.98	0.003	4.76
Error	10.48	6	1.75			
Total	116.76	11				

The fruit weight loss is generally affected by the evaporation of moisture content during the drying process (Jaster, 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-Valdés, Theoduloz, Jiménez-Aspee, & Schmeda-Hirschmann, 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 drop dramatically until 24th hour, then they decrease at 36th hour and they stable at 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-Valdés, S; Theoduloz, C; Jiménez-Aspee, F; Burgos-Edwards, A; Schmeda-Hirschmann, G, 2018).

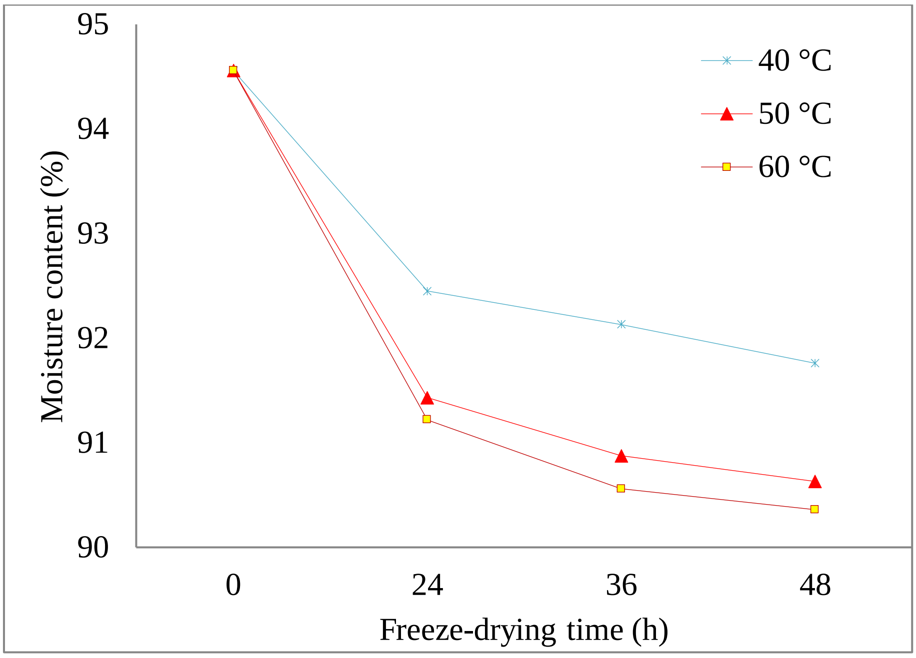


Figure 3. Evaporation of strawberry moisture content during a vacuum-freeze drying at heating plate temperature and freeze-drying time variations.

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, Zhang, Zhu, Mao, & Tu, 2014).

Evaporation of moisture content from fruit cells occurs during the drying process as a result 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, Husna, Dewi, & Jumeri, 2016).

The analysis of variance results shows that F-count (8.68) is greater than the F-crit value (5.14) (Table 2). This means that variations at the 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 Gaston et al. (2019) that the strawberry moisture content decreases during freeze-drying.

Table 2. Results analysis of variance 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**
Rows	2.49	2	1.25	8.68	0.017	5.14
Columns	25.34	3	8.44	58.91	7.65E-05	4.76
Error	0.86	6	0.14			
Total	28.67	11				

3.3. Texture Determination

The frozen strawberry texture was determinates 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 hours 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 hours, the F-max values are 0.16; 0.15; and 0.15 N, and at heating plate temperature 60 °C and freeze-drying time 24; 36; and 48 hours, 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 Asioli, et al. (2018) that mechanical resistance to compression, shear force, and strawberry stiffness decreases after drying.

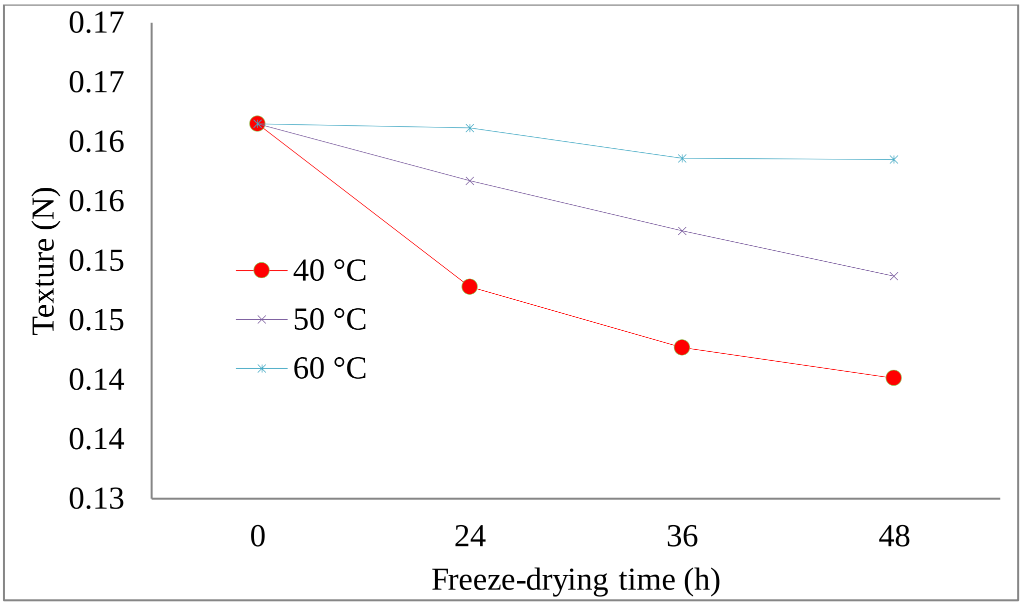


Figure 4. Graph of texture changes of frozen strawberries during vacuum-freeze dryer at heating plate temperature variations.

Frozen strawberries have a soft and wrinkled texture because some moisture content has evaporated. This is in line with the report Alikhani and Daraei Garmakhany (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 (Asioli, 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 (5,143) (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.

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
Rows	2.86	2	1.43	8.18	0.02	5.14
Columns	2.67	3	0.89	5.09	0.044	4.76
Error	1.05	6	0.17			
Total	6.57	11				

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

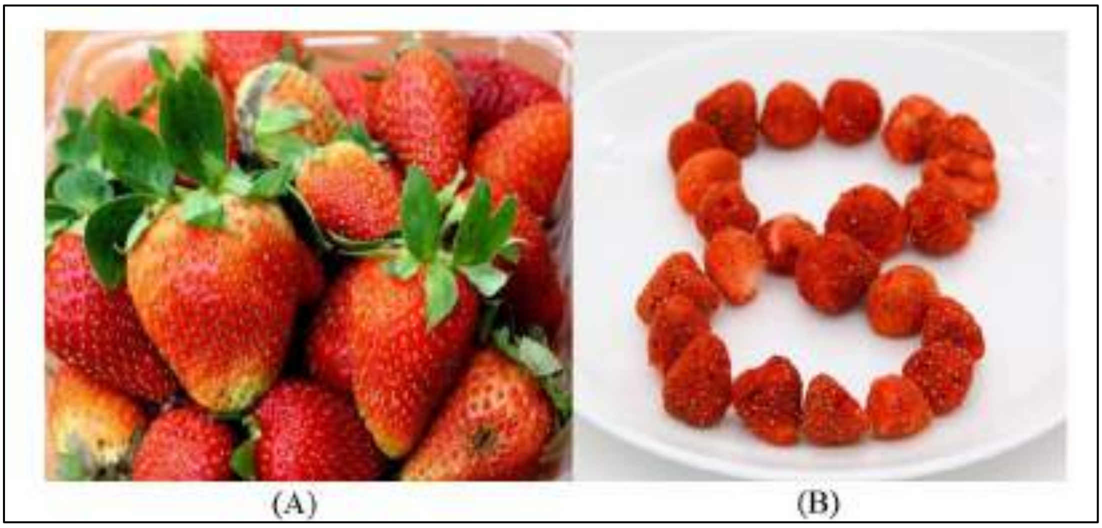
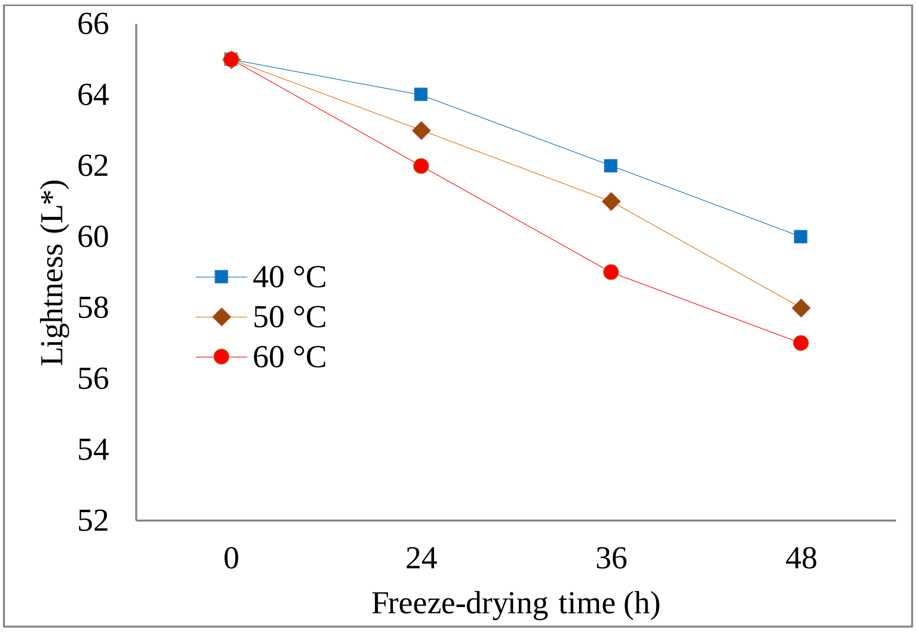
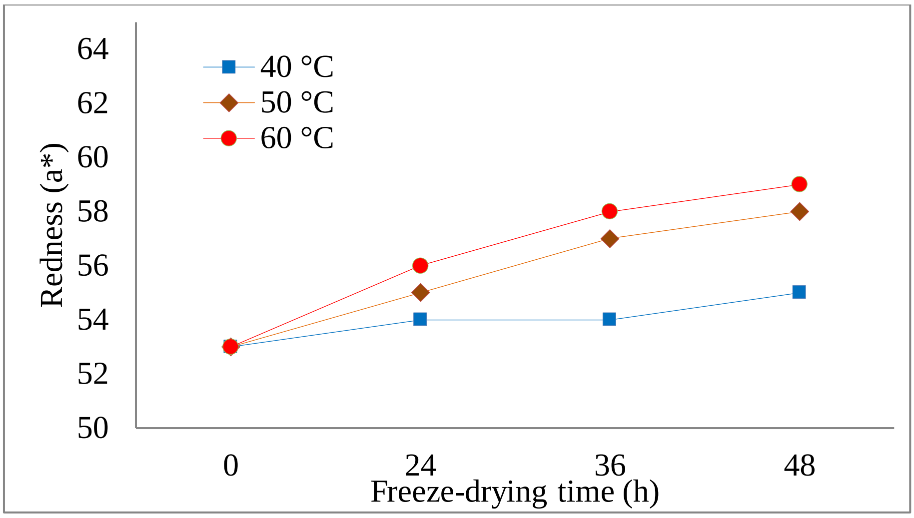


Figure 5. Strawberry fruit, (A) before freeze-drying and (B) after freeze-drying

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.



(A)



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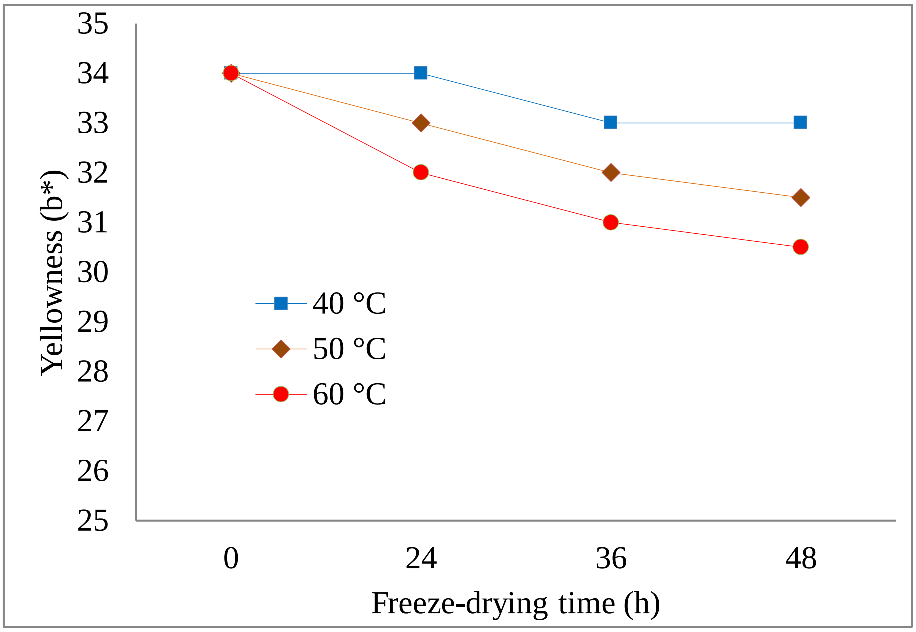


(C)

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

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 (Chisari, Riccardo, Barbagallo, & Spagna, 2007). Some researchers also report that color is the most important criterion for consumers in determining product choices (Yue, Shang, Yang, Huang, & Wang, 2019).

The results analysis of variance obtained F-count values (5.84) greater than the F-crit value (5.14) (Table 4). This data showed variations 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.

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

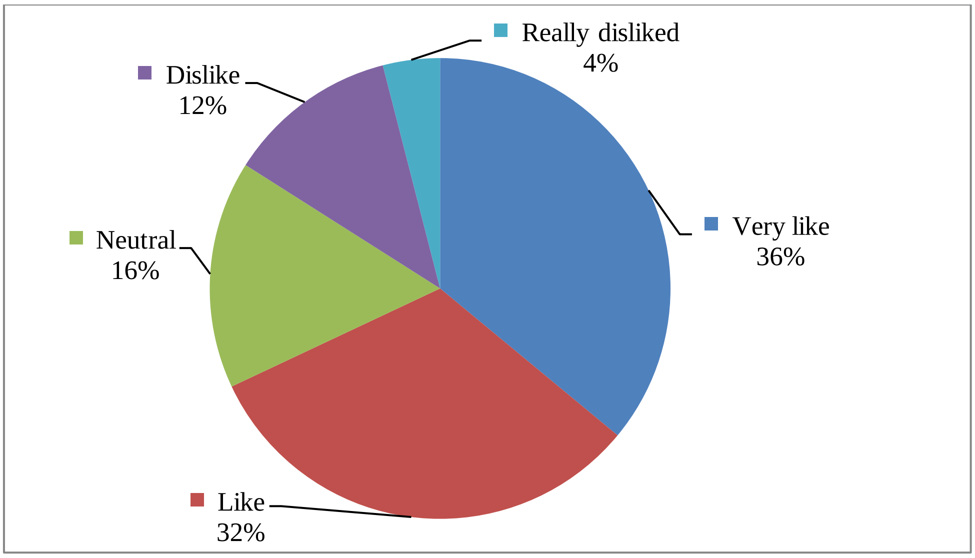
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F-crit**
Rows	6.17	2	3.08	5.84	0.04	5.14
Columns	68.33	3	22.78	43.16	0.00	4.76
Error	3.17	6	0.53			
Total	77.67	11				

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).

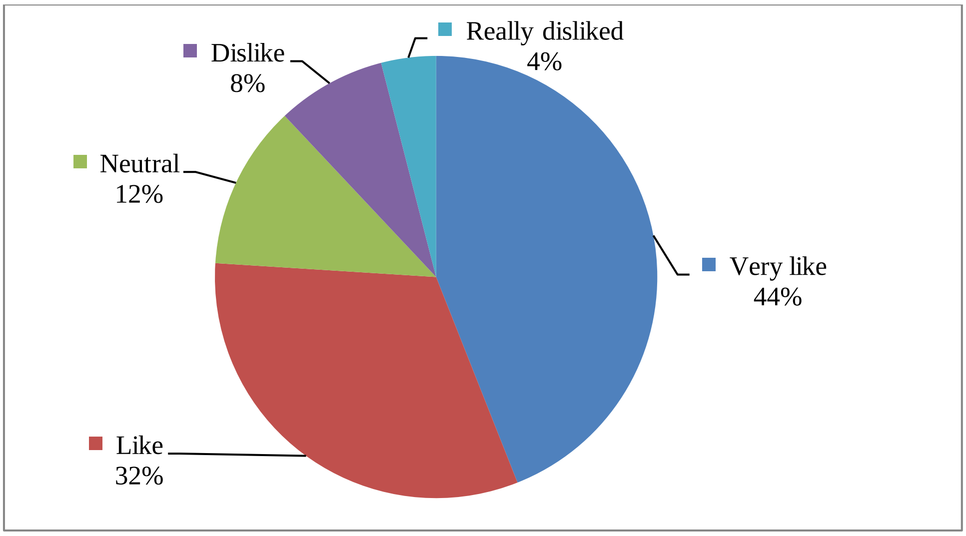
The strawberry fruit has a red pigment that comes from the concentration of anthocyanins (Patras, Brunton, Pieve, & Butler, 2009; Gaston, Osorio, Denoyes, & Rothan, 2019). The lower the concentration of anthocyanins, the color of the fruit becomes purple, on the contrary, if the concentration of anthocyanins is very high, the color of the fruit can be blackish (Asioli, et al., 2018). For low pH, anthocyanins 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 (Ozcan & Barringer, 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, Durst, Wrolstad, & De Jong, 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 parameters 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 7B.



(A)



(B)

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

Based on data from the judicial assessment of the aroma of frozen strawberries, it is known that 36% of panelists answered very like, 32% said they liked, and only 16% stated neutral, 12% disliked, and 4% said they really disliked (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 temperature. Karoline et al. (2020) have also reported that samples that are dried in freeze-drying are first frozen, then dried using low pressure, resulting in a sublimation process in which the water content that 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 they really liked, 32% said they liked, 12% said they were neutral, 8% said they didn't like it, and only 4% who said they really didn't like it (Figure 7B). Based on this 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 (Ansar, Nazaruddin, & Azis, 2019). Strawberry fruit has a sweet and sour taste (citrus) that is fresh and soft (Yue, Shang, Yang, Huang, & Wang, 2019). This compound is not easily evaporated by the influence of environmental temperature (Souza, Pereira, Silva, Lima, & Pio, 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 does not change significantly after was frozen and they seem fresh fruit. 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.

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CONFLICT OF INTEREST

The all authors not have any conflict of interest.

References

Alikhani, M., & Daraei Garmakhany, A. (2012). Effect of microencapsulated essential oils on storage life and quality of strawberry (Fragaria ananassa cv. Camarosa). *Quality Assurance and Safety of Crops & Foods, 4*(1), 106–112.

Amelio, M. (2019). Olive oil sensory evaluation: An alternative to the robust coefficient of variation (Cvr %) for measuring panel group performance in official tasting sessions. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.02.044.

An, X., Li, Z., Zude-Sasse, M., Tchuenbou-Magaia, F., & Yang, Y. (2020). Characterization of textural failure mechanics of strawberry fruit. *Journal of Food Engineering, 282*(110016). doi:10.1016/j.jfoodeng.2020.110016.

Ansar, Nazaruddin, & Azis, A. D. (2019). Effect of vacuum freeze-drying condition and maltodextrin on the physical and sensory characteristics of passion fruit (Passiflora edulis sims) extract. *IOP Conference Series: Earth and Environmental Science* (pp. 1-12). Makassar: IOP Publishing. doi:10.1088/1755-1315/355/1/012067.

Ansar, Nazaruddin, & Azis, A. D. (2020). Caking mechanisms of passion fruit powder during storage. *International Journal of Innovation, Creatifity, and Change*, *13*(2), 618-628.

Asioli, D., Rocha, C., Wongprawmas, R., Popa, M., Gogus, F., & Almli, V. L. (2018). Microwave-dried or air-dried? Consumers’ stated preferences and attitudes for organic dried strawberries. A multi-country investigation in Europe. *Food Research International, 76*, 645–653. doi:10.1016/j.foodres.2018.11.037.

Balasooriya, H., Dasanayake, K., & Ajlouni, S. (2019). Bioaccessibility of micronutrients in fresh and frozen strawberry fruits grown under elevated carbon dioxide and temperature. *Food Chemistry*, 1-9. doi:10.1016/j.foodchem.2019.125662

Battino, M., Giampieri, F., Cianciosi, D., Ansary, J., Chen, X., Zhang, D., Gil, E., Forbes-Hernández, T. (2020). The roles of strawberry and honey phytochemicals on human health: a possible clue on the molecular mechanisms involved in the prevention of oxidative stress and inflammation. *Phytomedicine*, *153170*. doi:10.1016/j.phymed.2020.153170.

Blanch , G. P., & Castilo, M. L. (2012). Changes in strawberry volatile constituents after pre-harvest treatment with natural hormonal compounds. *Flavour and Fragrance Journal, 27*(1), 180-187.

Bongoni, R., Steenbekkers, L. A., Verkerk, R., van Boekel, M. S., & Dekker, M. (2013). Studying consumer behaviour related to the quality of food: A case on vegetable preparation affecting sensory and health attributes. *Trends in Food Science & Technology, 33*(2), 139-145. doi:10.1016/j.tifs.2013.08.004.

Brown, C. R., Durst, R. W., Wrolstad, R., & De Jong, W. (2008). Variability of phytonutrient content of potato in relation to growing location and cooking method. *Potato Reearch, 51*(4), 259-270.

Buvé, C., Neckebroeck, B., Haenen, A., Kebede, B., Hendrickx, M., Grauwet, T., & Van Loey, A. (2018). Combining untargeted, targeted and sensory data to investigate the impact of storage on food volatiles: A case study on strawberry juice. *Food Research International, 113*, 382–391. doi:10.1016/j.foodres.2018.07.022.

Chapman, J., Elbourne, A., Truong, V. K., Newman, L., Gangadoo, S., Rajapaksha Pathirannahalage, P., & Cozzolino, D. (2019). Sensomics - from conventional to functional NIR spectroscopy-shining light over the aroma and taste of foods. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.07.013.

Chisari, M., Riccardo, N., Barbagallo, & Spagna, G. (2007). Characterization of polyphenol oxidase and peroxides and influence on browning of cold stored strawberry fruit. *Journal of Agriculture and Food Chemistry, 55*(1), 3469-3476.

Curi, P. N., Tavares, B. S., Almeida, A. B., Pio, R., Peche, P. M., & Souza, V. R. (2016). Influence of subtropical region strawberry cultivars on jelly characteristics. *Journal of Food Science, 81*(6), 15-20.

Dash, P. K., Chase, C. A., Agehara, S., & Zotarell, L. (2020). Heat stress mitigation effects of kaolin and s-abscisic acid during the establishment of strawberry plug transplants. *Scientia Horticulturae, 267*(109276). doi:10.1016/j.scienta.2020.109276.

Falah, M. A., Husna, H., Dewi, A. R., & Jumeri. (2016). Quality evaluation of fresh strawberry (Fragaria sp. cv. Earlybrite) during storage in a tropical environment. *AIP Conference Proceedings*, 1-6.

Fernández-Lara, R., Gordillo, B., Rodríguez-Pulido, F. J., Lourdes González-Miret, M., del Villar-Martínez, A. A., Dávila-Ortiz, G., & Heredia, F. G. (2015). Assessment of the differences in the phenolic composition and color characteristics of new strawberry (Fragaria x ananassa Duch.) cultivars by HPLC–MS and Imaging Tristimulus Colorimetry. *Food Research International, 76*, 645–653. doi:10.1016/j.foodres.2015.07.038.

Galus, S., & Kadzińska, J. (2015). Food applications of emulsion-based edible films and coatings. *Trends in Food Science & Technology, 45*(2), 273-283. doi:10.1016/j.tifs.2015.07.011.

Gaston, A., Osorio, S., Denoyes, B., & Rothan, C. (2019). Applying the Solanaceae Strategies to Strawberry Crop Improvement. *Trends in Plant Science*. doi:10.1016/j.tplants.2019.10.003.

Giampieri, F., Alvarez Suarez, J., & Battino, M. (2014). Strawberry and human health: Effects beyond antioxidant activity. *Journal of Agricultural and Food Chemistry, 62*(18), 3867-3876. doi:10.1021/jf405455n

Giampieri, F., Forbes-Hernandez, T. Y., Gasparrini, M., Alvarez-Suarez, J. M., Afrin, S., Bompadre, S., Quiles, J.L., Mezzetti, B., Battino, M. (2015). Strawberry as a health promoter: an evidence based review. *Food & Function, 6*(5), 1386-1398. doi:10.1039/c5fo00147a.

Giuffre, A. M., Louadj, L., Rizzo, P., De Salvo, E., & Sicari, V. (2019). The influence of film and storage on the phenolic and antioxidant properties of red raspberries (Rubus idaeus L.) cv. Erika. *Antioxidants, 8*(8), 254. doi:10.3390/antiox8080254.

Hanif, Z. (2015). Quality improvement of fresh strawberry fruit through harvest and postharvest handling. *Journal of Balitjestro, 15*(1), 1-6.

Hemmati, S., Ahmeda, A., Salehabadi, Y., Zangeneh, A., & Zangeneh, M. M. (2020). Synthesis, characterization, and evaluation of cytotoxicity, antioxidant, antifungal, antibacterial, and cutaneous wound healing effects of copper nanoparticles using the aqueous extract of Strawberry fruit and L-Ascorbic acid. *Polyhedron, 114425*. doi:10.1016/j.poly.2020.114425.

Hu, X., Lu, L., Guo, Z., & Zhu, Z. (2020). Volatile compounds, affecting factors and evaluation methods for rice aroma: A review. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2020.01.003.

Hung, D. V., Tong, S., Tanaka, F., Yasunaga, D. H., Hamanaka, D., & Hiruma, N. (2011). Controlling the weight loss of fresh produce during postharvest storage under a nano-size mist environment. *Journal of Food Engineering, 106*, 325-330.

Hwang, E. J., Jeong, S. Y., Kim, M. J., Jeong, J. S., Lee, K. H., Jeong, N. R., & Kim, I. (2020). Year-round trap capture of the spotted-wing drosophila, Drosophila suzukii (Diptera: Drosophilidae), in Korean strawberry greenhouses. *Journal of Asia-Pacific Entomology, 23*(1), 204–213. doi:10.1016/j.aspen.2020.01.004.

Jaster, H., Arend, G. D., Rezzadori, K., Chaves, V. C., Reginatto, F. H., & Petrus, J. C. (2018). Enhancement of antioxidant activity and physicochemical properties of yogurt enriched with concentrated strawberry pulp obtained by block freeze concentrated strawberry pulp obtained by block freeze concentration. *Food Research International, 104*, 119-125. doi:10.1016/j.foodres.2017.10.006.

Jedlinska , A., Samborska, K., Janiszewska-Turak, E., Witrowa-Rajchert, D., Seuvre, A. M., & Voilley, A. (2018). Physicochemical properties of vanilla and raspberry aromas microencapsulated in the industrial conditions by spray drying. *Journal of Food Process Engineering*, e12872.

Jiang, N., Liu, C., Li, D., Zhang, Z., Liu, C., Wang, D., Niu, L., Zhang, M. (2017). Evaluation of freeze drying combined with microwave vacuum drying for functional okra snacks: Antioxidant properties, sensory quality, and energy consumption. *LWT-Food Science and Technology, 82*, 216-226. doi:10.1016/j.lwt.2017.04.015.

Jiang, Y., Yu, L., Hu, Y., Zhu, Z., Zhuang, C., Zhao, Y., & Zhong, Y. (2020). The preservation performance of chitosan coating with different molecular weight on strawberry using electrostatic spraying technique. *International Journal of Biological Macromolecules*. doi:10.1016/j.ijbiomac.2020.02.169.

Jorge, A., Sauer Leal, E., Sequinel, R., Sequinel, T., Kubaski, E. T., & Tebcherani, S. M. (2018). Changes in the composition of tomato powder (Lycopersicon esculentum Mill) resulting from different drying methods. *Journal of Food Processing and Preservation*, e13595.

Karoline Martinsen, B., Aaby, K., & Skrede, G. (2020). Effect of temperature on stability of anthocyanins, ascorbic acid and color in strawberry and raspberry jams. *Food Chemistry, 126297*. doi:10.1016/j.foodchem.2020.126297.

Khattab, A. R., Guirguis, H. A., Tawfik, S. M., & Farag, M. A. (2019). Cheese ripening: A review on modern technologies towards flavor enhancement, process acceleration and improved quality assessment. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.03.009.

Kirkin, C., & Gunes, G. (2018). Modified atmosphere packaging and gamma-irradiation of some herbs and spices: Effects on antioxidant and antimicrobial properties. *Journal of Food Processing and Preservation*, 1-13.

Lohachoompol, V., Srzednicki, G., & Craske, J. (2004). The change of total anthocyanins in blueberries and their antioxidant effect after drying and freezing. *Journal of Biomedicine Biotechnology*, *5*, 248–252. doi:10.1155/S1110724304406123.

Lesme, H., Courcoux,, P., Alleaume, C., Famelart, M. H., Bouhallab, C., Prost, C., & Rannou, C. (2020). Contribution of temporal dominance of sensations performed by modality (M-TDS) to the sensory perception of texture and flavor in semi-solid products: a case study on fat-free strawberry yogurts. *Food Quality and Preference*, *80*, 1-13. doi:10.1016/j.foodqual.2019.103789.

MacInnis, G., Buddle, C. M., & Forrest, J. K. (2020). Small wild bee abundance declines with distance into strawberry crops regardless of field margin habitat. *Basic and Applied Ecology*. doi:10.1016/j.baae.2020.02.007.

Mainil, A. K., Aziz, A., Harianto, J., & Maini, R. I. (2020). Comparative assessment of closed loop heat pump dryer and direct solar dryer system for banana drying. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 66*(2), 136-144.

Marian, M., Ohno, T., Suzuki, H., Kitamura, H., Kuroda, K., & Shimizu, M. (2020). A novel strain of endophytic Streptomyces for the biocontrol of strawberry anthracnose caused by Glomerella cingulate. *Microbiological Research, 126428*. doi:10.1016/j.micres.2020.126428.

Maringgal, B., Hashim, N., Mohamed Amin Tawakkal, I. S., & Muda Mohamed, M. T. (2019). Recent advance in edible coating and its effect on fresh/fresh-cut fruits quality. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.12.024.

Moshari-Nasirkandi, A., Alirezalu, A., & Hachesu, M. A. (2020). Effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry (Fragaria×ananassa Duch. cv. Sabrina) fruit during cold storage. *Biocatalysis and Agricultural Biotechnology, 25*(101613).

Nguyen, V. B., Nguyen, D. H., & Nguyen, H. V. (2020). Combination effects of calcium chloride and nano-chitosan on the postharvest quality of strawberry (Fragaria x ananassa Duch.). *Postharvest Biology and Technology, 162*(111103). doi:10.1016/j.postharvbio.2019.111103.

Obeidat, W. M., Sahni, E., Kessler, W., & Pikal, M. (2017). Development of a Mini-Freeze Dryer for Material-Sparing Laboratory Processing with Representative Product Temperature History. *AAPS PharmSciTech, 19*(12), 599-609. doi:10.1208/s12249-017-0871-5.

Ozcan, G., & Barringer, S. (2011). Effect of enzymes on strawberry volatiles during storage, at different ripeness level, in different cultivars, and during eating. *Journal of Food Science, 76*(2), 324-334.

Ozturk, O. K., & Singh, T. P. (2019). Selected physical and viscoelastic properties of strawberries as a function of heated-air drying conditions. *Drying Technology*, 1-11. doi:10.1080/07373937.2018.1543701

Pan, L., Zhang, W., Zhu, N., Mao, S., & Tu, K. (2014). Early detection and classification of pathogenic fungal disease in post-harvest strawberry fruit by electronic nose and gas chromatography–mass spectrometry. *Food Research International*, *62*, 162–168. doi:10.1016/j.foodres.2014.02.020.

Patras, A., Brunton, N. P., Pieve, S. D., & Butler, F. (2009). Impact of high pressure processing on total antioxidant activity, phenolic, ascorbic acid, anthocyanin content and colour of strawberry and blackberry purees. *Innovative Food Science & Emerging Technologies, 10*(1), 308–313.

Peano, C., Girgenti, V., & Giuggioli, N. R. (2014). Change in quality and volatile constituents of strawberries (cv. Evie2) under MAP storage. *Journal of Food, Agriculture & Environment, 12*(2), 93-100.

Qiao, F., Fang, C., Huang, L., & Zhang, S. (2012). The Effect of Different Heating Patterns on Vacuum Freeze-Drying of Litchi Pulp. *Journal of Food Process Engineering, 36*(4), 407-411. doi:10.1111/j.1745-4530.2012.00680.x.

Reyes, V., Bubnovich, R., Bustos, M., Vásquez, R., Vega, R., & Scheuermann , E. (2010). Comparative study of different process conditions of freeze drying of 'Murtilla' berry. *Drying Technology: An International Journal, 28:12, 1416-1425, 28*(12), 1416-1425. doi:10.1080/07373937.2010.482687.

Schulze, B., Hubbermann, E. M., & Schwarz, K. (2014). Stability of quercetin derivatives in vacuum impregnated apple slices after drying (microwave vacuum drying, air drying, freeze drying) and storage. *LWT-Food Science and Technology, 57*(1), 426-433. doi:10.1016/j.lwt.2013.11.021.

Shaozhi, Z., Jielin, L., Guangming, C., & Qin, W. (2017). Thermodynamic analysis of a freeze-dryer utilizing hygroscopic solution. *Drying Technology*. doi:10.1080/07373937.2017.1308952.

Shiraz, S., Djebbi-Simmons, D., Alhejaili, M., Danos, K., Janes, M., Fontenot, K., & Xu, W. (2020). Evaluation of the microbial safety and quality of Louisiana strawberries after flooding. *Food Control, 110*(106970). doi:10.1016/j.foodcont.2019.106970.

Sicari, V., Loizzo, M. R., Pellicano, T. M., Giuffre, A. M., & Poiana, M. (2020). Evaluation of aloe arborescens gel as new coating to maintain the organoleptic and functional properties of strawberries (Fragaria x ananassa cv. Cadonga) fruits. *International Food Science and Technology, 55*(2), 861-870. doi:10.1111/ijfs.14349.

Silva, E. K., Meireles, M. A., & Saldaña, M. A. (2020). Supercritical carbon dioxide technology: A promising technique for the non-thermal processing of freshly fruit and vegetable juices. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2020.01.025.

Singh, S. P., & Pal, R. K. (2009). Ionizing radiation treatment to improve postharvest life and maintain quality of fresh guava fruit. *Radiation Physics and Chemistry., 78*(1), 135-140.

Singh, Z., & Khan, A. S. (2010). Physiology of plum fruit ripening. *Stewart Postharvest Review, 2*(1), 3-12.

Souza, V. R., Pereira, P. A., Silva, T. L., Lima, L. C., & Pio, R. (2014). Determination of the bioactive compounds, antioxidant activity and chemical composition of Brazilian blackberry, red raspberry, strawberry, blueberry, and sweet cherry fruits. *Food Chemistry, 56*(1), 362-368.

Sun, K., Li, R., Jiang, W., Sun, Y., & Li, H. (2016). Comparison of three-dimensional printing and vacuum freeze-dried techniques for fabricating composite scaffolds. *Biochemical and Biophysical Research Communications, 477*(4), 1085-1091. doi:10.1016/j.bbrc.2016.07.050.

Tang, Y., Ma, X., Li, M., & Wang, Y. (2020). The effect of temperature and light on strawberry production in a solar greenhouse. *Solar Energy, 195*, 318-328. doi:10.1016/j.solener.2019.11.070.

Thi Phan, K. K., Truong, T., Wang, Y., & Bhandari, B. (2019). Nanobubbles: Fundamental characteristics and applications in food processing. *Trends in Food Science & Technology*. doi:10.1016/j.tifs.2019.11.019.

Thomas-Valdés, S., Theoduloz, C., Jiménez-Aspee, F., & Schmeda-Hirschmann, G. (2019). Effect of simulated gastrointestinal digestion on polyphenols and bioactivity of the native Chilean red strawberry (Fragaria chiloensis ssp. chiloensis f. patagonica). *Food Research International, 123*, 106-114. doi:10.1016/j.foodres.2019.04.039.

Thomas-Valdés, S; Theoduloz, C; Jiménez-Aspee, F; Burgos-Edwards, A; Schmeda-Hirschmann, G. (2018). Changes in polyphenol composition and bioactivity of the native Chilean white strawberry (Fragaria chiloensis spp. chiloensis f. chiloensis) after in vitro gastrointestinal digestion. *Food Research International, 105*, 10-18. doi:10.1016/j.foodres.2017.10.074.

Van de Velde, F., Esposito, D., Grace, M. H., Pirovani, M. E., & Lila, M. A. (2018). Anti-inflammatory and wound healing properties of polyphenolic extracts from strawberry and blackberry fruits. *Food Research International, 121*, 453-462. doi:10.1016/j.foodres.2018.11.059.

Watson, T. T., Noling, J. W., & Desaeger, J. A. (2020). Fluopyram as a rescue nematicide for managing sting nematode (Belonolaimus longicaudatus) on commercial strawberry in Florida. *Crop Protection*, *132*, 105108. doi:10.1016/j.cropro.2020.105108.

Xu, Y., Zhang, M., Mujumdar, A. S., Duan, X., & Jin-cai, S. (2006). A two-stage vacuum freeze and convective air drying method for strawberries. *Drying Technology: An International Journal*, *24*(8), 1019-1023. doi:10.1080/07373930600776209.

Yu, P., Low, M. Y., & Zhou, W. (2018). Design of experiments and regression modelling in food flavour and sensory analysis: A review. *Trends in Food Science & Technology, 71*, 202-215. doi:10.1016/j.tifs.2017.11.013.

Yuan, Z., Shi, Y., Cai, F., Zhao, J., Xiong, Q., Wang, Y., & Zheng, Y. (2019). Isolation and identification of polysaccharides from pythium arrhenomanes and application to strawberry fruit (*Fragaria ananassa* Duch.) preservation. *Food Chemistry, 309,* 125604. doi:10.1016/j.foodchem.2019.125604.

Yue, X. Q., Shang, Z. Y., Yang, J. Y., Huang, L., & Wang, Y. Q. (2019). A smart data-drivenrapid method to recognize the strawberry maturity. *Information Processing in Agriculture*. doi:10.1016/j.inpa.2019.10.005.

Yusufe, M., Mohammed, A., & Satheesh, N. (2017). Effect of duration and drying temperature on characteristics of dried tomato (Lycopersicon esculentum L.) cochoro variety. *Journal of Food Technology*, *21*(1), 41-50.

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Research article

New frozen product development from strawberries (*Fragaria Ananassa* Duch.)

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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 seem fresh strawberries.

1. Introduction

Strawberry fruit (*Fragaria ananassa* Duch.) can be found in every country because almost all countries in the world have cultivated its (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 (Curi et al., 2016; Blanch and Castilo, 2012; Giampieri et al., 2015; Watson et al., 2020). Strawberries also contain large amounts of folate (Marian 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 (Gaston 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; Ozturk and Singh, 2019). This strawberry fruit cannot be sold to consumers if the skin has blisters or bruises (Balasooriya 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 (Tang et al., 2020). Also, strawberries dried with conventional dryers have a non-uniform color, so they are less favored by consumers (Karoline Martinsen 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 (Mainil et al., 2020; Dash et al., 2020).

Frozen fruit is one of the processed fruit products that are very popular with consumers today (Khattab et al., 2019). Frozen fruit is popular because it has color, aroma, and taste still like fresh fruit (Bongoni et al., 2013). Frozen products that have been widely circulating on 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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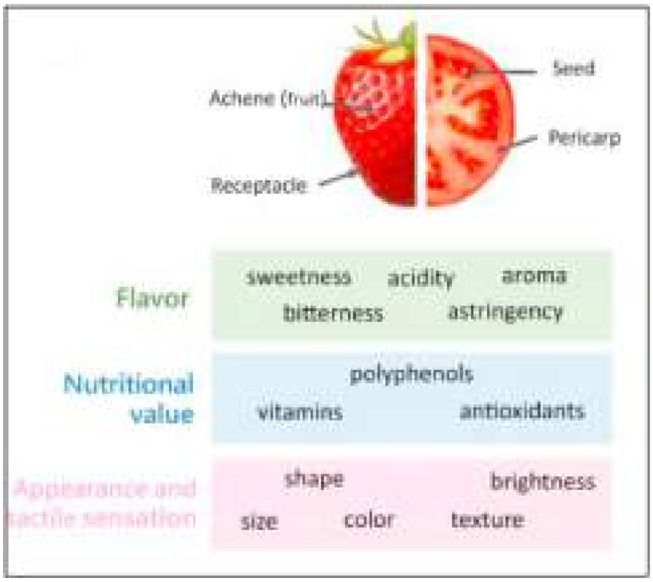

Figure 1. Physical structure and nutrient content of fresh strawberries.

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 burned (Maringgal et al., 2019). The shelf life of this frozen product is still short because it has high water content (Thi Phan 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; Obeidat 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 (Xu 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 (Alikhani and Daraei Garmakhany, 2012; Sun et al., 2016).

Research on the freeze-drying process for fruits has been widely reported (Lohachoompol et al., 2004; Giuffre 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-Lara et al., 2015), the combined effect of gamma irradiation and MAP on the antioxidant and antimicrobial properties of strawberries (Kirkin and Gunes, 2018), evaluation of the effect of modified atmospheric packaging (MAP) on strawberry storage (Peano 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-Nasirkandi 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 form strawberries.

2. Material and methods

2.1. Sample preparation

The research sample was strawberries with Sweet Charlie variety. It was obtained from farmers in Sembalun, 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):

$$Weight\ loss = \frac{w_f - w_d}{w_f} 100\% \tag{1}$$

where, w_f = mass of the sample before drying (gram), w_d = 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 (Ansar and Azis, 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:

$$M_c = \frac{a - b}{a} \times 100\% \tag{2}$$

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):

$$L^* = \frac{\text{Lightness}}{255} \times 100 \tag{3}$$

$$a^* = \frac{240a}{255} - 120 \tag{4}$$

$$b^* = \frac{240b}{255} - 120 \tag{5}$$

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

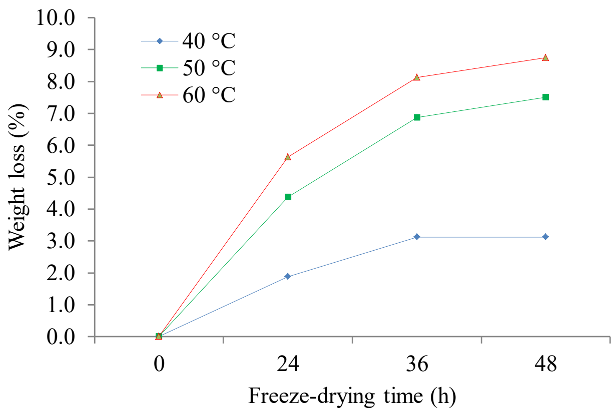

Figure 2. A profile of strawberry weight loss during freeze-vacuum drying at variations of heating plate temperature.

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 Velde et al., 2018). 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 (Jaster 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-Valdés 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-Valdés 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 (8.68) is greater than the F-crit value (5.14) (Table 2). This means that variations at the

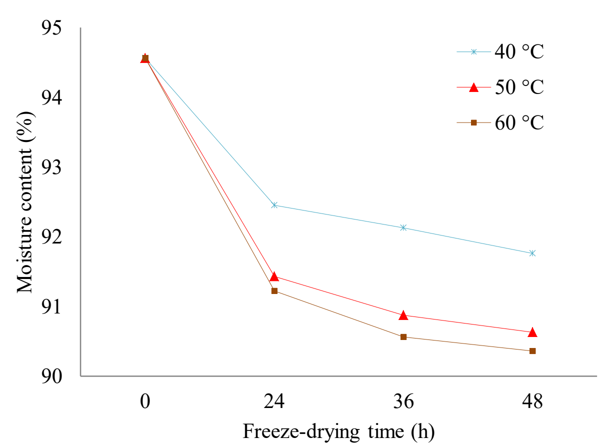

Figure 3. Evaporation of strawberry moisture content during a vacuum-freeze drying at heating plate temperature and freeze-drying time variations.

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
Rows	27.79	2	13.89	7.96	0.020	5.14
Columns	78.48	3	26.16	14.98	0.003	4.76
Error	10.48	6	1.75			
Total	116.76	11				

Table 2. Results analysis of variance 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
Rows	2.49	2	1.25	8.68	0.017	5.14
Columns	25.34	3	8.44	58.91	7.65E-05	4.76
Error	0.86	6	0.14			
Total	28.67	11				

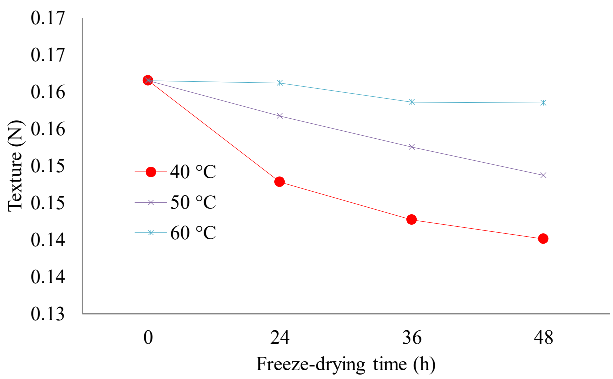

Figure 4. Graph of texture changes of frozen strawberries during vacuum-freeze dryer at heating plate temperature variations.

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 Gaston 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 Asioli 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 Alikhani and Daraei Garmakhany (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 (Asioli 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 (5,143) (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
Rows	2.86	2	1.43	8.18	0.02	5.14
Columns	2.67	3	0.89	5.09	0.044	4.76
Error	1.05	6	0.17			
Total	6.57	11				

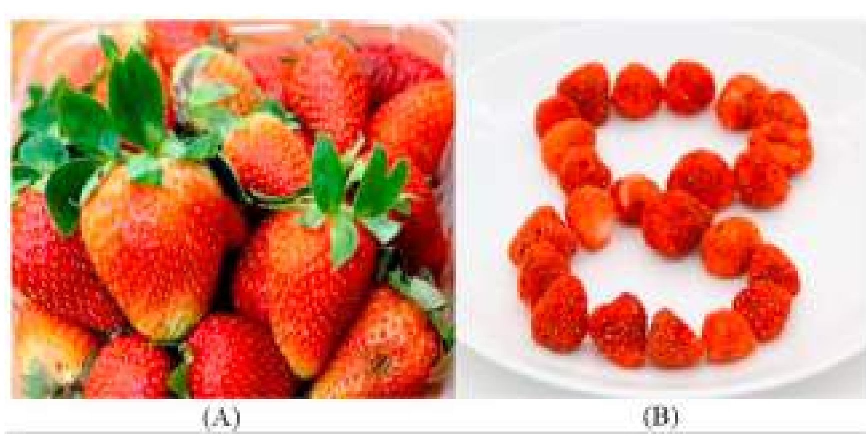

Figure 5. Strawberry fruit, (A) before freeze-drying and (B) after freeze-drying.

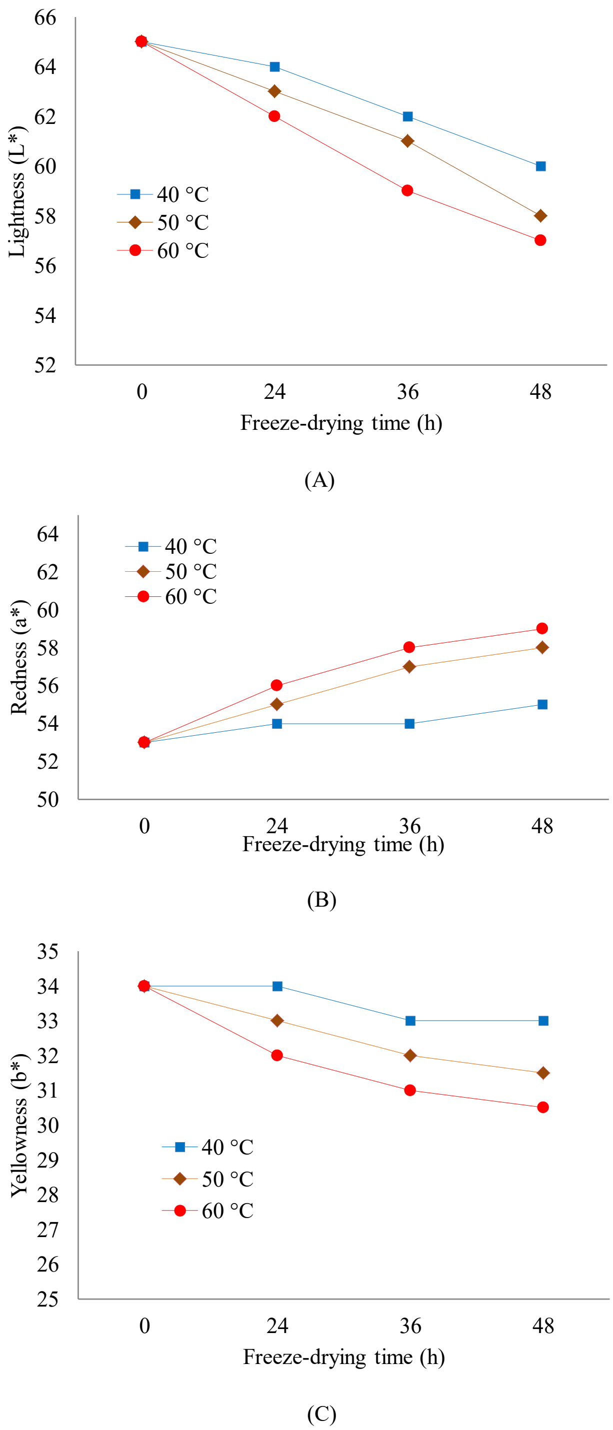

Figure 6. Graph of color change (A) lightness (L*), (B) redness (a*), and (C) yellowness (b*) of frozen strawberry at heating plate temperature variation.

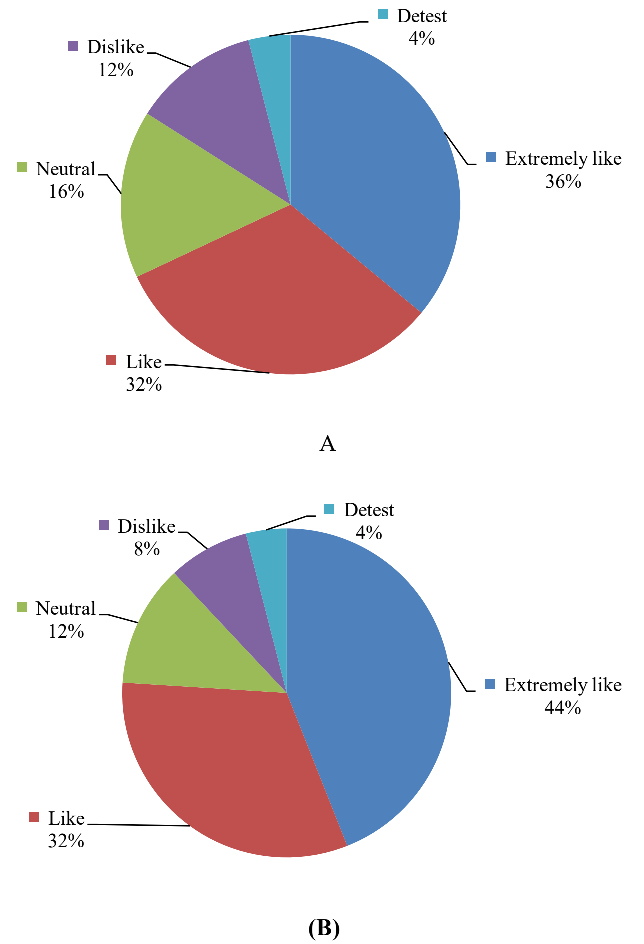

Figure 7. The results of the panelist's assessment of the aroma (A) and taste (B) of frozen strawberries.

difference between fresh and frozen strawberries from the results of this study is shown in Figure 5. Based on this figure it is 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 (Chisari 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
Rows	6.17	2	3.08	5.84	0.04	5.14
Columns	68.33	3	22.78	43.16	0.00	4.76
Error	3.17	6	0.53			
Total	77.67	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 variations 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; Gaston 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 (Asioli et al., 2018). 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 (Ozcan and Barringer, 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 parameters 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 36% 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 (Ansar and Azis, 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 (Souza 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

Ansar: 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.

Atri D. Azis: 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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References

Alikhani, M., Daraei Garmakhany, A., 2012. Effect of microencapsulated essential oils on storage life and quality of strawberry (Fragaria ananassa cv. Camarosa). Qual. Assur. Saf. Crop Foods 4 (1), 106–112.

An, X., Li, Z., Zude-Sasse, M., Tchuenbou-Magaia, F., Yang, Y., 2020. Characterization of textural failure mechanics of strawberry fruit. J. Food Eng. 282 (110016).

Ansar, Nazaruddin, Azis, A.D., 2019. Effect of vacuum freeze-drying condition and maltodextrin on the physical and sensory characteristics of passion fruit (Passiflora edulis Sims) extract. IOP Conf. Ser. Earth Environ. Sci. 1–12. Makassar: IOP Publishing.

Ansar, Nazaruddin, Azis, A.D., 2020. Caking mechanisms of passion fruit powder during storage. Int. J. Innovat. Creativ. Change 13 (2), 618–628.

Asioli, D., Rocha, C., Wongprawmas, R., Popa, M., Gogus, F., Almli, V.L., 2018. Microwave-dried or air-dried? Consumers' stated preferences and attitudes for organic dried strawberries. A multi-country investigation in Europe. Food Res. Int. 76, 645–653.

Balasooriya, H., Dasanayake, K., Ajlouni, S., 2019. Bioaccessibility of micronutrients in fresh and frozen strawberry fruits grown under elevated carbon dioxide and temperature. Food Chem. 1–9.

Battino, M., Giampieri, F., Cianciosi, D., Ansary, J., Chen, X., Zhang, D., Gil, E., Forbes-Hernández, T., 2020. The roles of strawberry and honey phytochemicals on human health: a possible clue on the molecular mechanisms involved in the prevention of oxidative stress and inflammation. Phytomedicine 153170.

Blanch, G.P., Castilo, M.L., 2012. Changes in strawberry volatile constituents after pre-harvest treatment with natural hormonal compounds. Flavour Fragrance J. 27 (1), 180–187.

Bongoni, R., Steenbekkers, L.A., Verkerk, R., van Boekel, M.S., Dekker, M., 2013. Studying consumer behavior related to the quality of food: a case on vegetable preparation affecting sensory and health attributes. Trends Food Sci. Technol. 33 (2), 139–145.

Brown, C.R., Durst, R.W., Wrolstad, R., De Jong, W., 2008. Variability of phytonutrient content of potato in relation to growing location and cooking method. Potato Res. 51 (4), 259–270.

Buvé, C., Neckebroeck, B., Haenen, A., Kebede, B., Hendrickx, M., Grauwet, T., Van Loey, A., 2018. Combining untargeted, targeted, and sensory data to investigate the impact of storage on food volatiles: a case study on strawberry juice. Food Res. Int. 113, 382–391.

Chapman, J., Elbourne, A., Truong, V.K., Newman, L., Gangadoo, S., Rajapaksha Pathirannahalage, P., Cozzolino, D., 2019. Sensomics - from conventional to functional NIR spectroscopy-shining light over the aroma and taste of foods. Trends Food Sci. Technol.

Chisari, M., Riccardo, N., Barbagallo, Spagna, G., 2007. Characterization of polyphenol oxidase and peroxides and influence on browning of cold-stored strawberry fruit. J. Agric. Food Chem. 55 (1), 3469–3476.

Curi, P.N., Tavares, B.S., Almeida, A.B., Pio, R., Peche, P.M., Souza, V.R., 2016. Influence of subtropical region strawberry cultivars on jelly characteristics. J. Food Sci. 81 (6), 15–20.

Dash, P.K., Chase, C.A., Agehara, S., Zotarell, L., 2020. Heat stress mitigation effects of kaolin and s-abscisic acid during the establishment of strawberry plug transplants. Sci. Hortic. 267, 109276.

Falah, M.A., Husna, H., Dewi, A.R., Jumeri, 2016. Quality evaluation of fresh strawberry (Fragaria sp. cv. Earlybrite) during storage in a tropical environment. AIP Conf. Proc. 1–6.

Fernández-Lara, R., Gordillo, B., Rodríguez-Pulido, F.J., Lourdes González-Miret, M., del Villar-Martínez, A.A., Dávila-Ortiz, G., Heredia, F.G., 2015. Assessment of the differences in the phenolic composition and color characteristics of new strawberry (Fragaria x ananassa Duch.) cultivars by HPLC–MS and Imaging Tristimulus Colorimetry. Food Res. Int. 76, 645–653.

Galus, S., Kadzińska, J., 2015. Food applications of emulsion-based edible films and coatings. Trends Food Sci. Technol. 45 (2), 273–283.

Gaston, A., Osorio, S., Denoyes, B., Rothan, C., 2019. Applying the solanaceae strategies to strawberry crop improvement. Trends Plant Sci.

Giampieri, F., Forbes-Hernandez, T.Y., Gasparrini, M., Alvarez-Suarez, J.M., Afrin, S., Bompadre, S., Quiles, J.L., Mezzetti, B., Battino, M., 2015. Strawberry as a health promoter: an evidence-based review. Food Funct. 6 (5), 1386–1398.

Giuffre, A.M., Louadj, L., Rizzo, P., De Salvo, E., Sicari, V., 2019. The influence of film and storage on the phenolic and antioxidant properties of red raspberries (Rubus idaeus L.) cv. Erika. Antioxidants 8 (8), 254.

Hemmati, S., Ahmeda, A., Salehabadi, Y., Zangeneh, A., Zangeneh, M.M., 2020. Synthesis, characterization, and evaluation of cytotoxicity, antioxidant, antifungal, antibacterial, and cutaneous wound healing effects of copper nanoparticles using the aqueous extract of Strawberry fruit and L-Ascorbic acid. Polyhedron 114425.

Hu, X., Lu, L., Guo, Z., Zhu, Z., 2020. Volatile compounds, affecting factors and evaluation methods for rice aroma: a review. Trends Food Sci. Technol.

Hung, D.V., Tong, S., Tanaka, F., Yasunaga, D.H., Hamanaka, D., Hiruma, N., 2011. Controlling the weight loss of fresh produce during postharvest storage under a nano-size mist environment. J. Food Eng. 106, 325–330.

Hwang, E.J., Jeong, S.Y., Kim, M.J., Jeong, J.S., Lee, K.H., Jeong, N.R., Kim, I., 2020. Year-round trap capture of the spotted-wing drosophila, Drosophila suzukii (Diptera: drosophilidae), in Korean strawberry greenhouses. J. Asia Pac. Entomol. 23 (1), 204–213.

Jaster, H., Arend, G.D., Rezzadori, K., Chaves, V.C., Reginatto, F.H., Petrus, J.C., 2018. Enhancement of antioxidant activity and physicochemical properties of yogurt enriched with concentrated strawberry pulp obtained by block freeze concentrated strawberry pulp obtained by block freeze concentration. Food Res. Int. 104, 119–125.

Jiang, N., Liu, C., Li, D., Zhang, Z., Liu, C., Wang, D., Niu, L., Zhang, M., 2017. Evaluation of freeze-drying combined with microwave vacuum drying for functional okra snacks: antioxidant properties, sensory quality, and energy consumption. LWT-Food Sci. Technol. 82, 216–226.

Jiang, Y., Yu, L., Hu, Y., Zhu, Z., Zhuang, C., Zhao, Y., Zhong, Y., 2020. The preservation performance of chitosan coating with different molecular weights on strawberry using electrostatic spraying technique. Int. J. Biol. Macromol.

Jorge, A., Sauer Leal, E., Sequinel, R., Sequinel, T., Kubaski, E.T., Tebcherani, S.M., 2018. Changes in the composition of tomato powder (Lycopersicon esculentum Mill) resulting from different drying methods. J. Food Process. Preserv., e13595

Karoline Martinsen, B., Aaby, K., Skrede, G., 2020. Effect of temperature on the stability of anthocyanins, ascorbic acid, and color in strawberry and raspberry jams. Food Chem. 126297.

Khattab, A.R., Guirguis, H.A., Tawfik, S.M., Farag, M.A., 2019. Cheese ripening: a review of modern technologies towards flavor enhancement, process acceleration, and improved quality assessment. Trends Food Sci. Technol.

Kirkin, C., Gunes, G., 2018. Modified atmosphere packaging and gamma-irradiation of some herbs and spices: effects on antioxidant and antimicrobial properties. J. Food Process. Preserv. 1–13.

Lohachoompol, V., Srzednicki, G., Craske, J., 2004. The change of total anthocyanins in blueberries and their antioxidant effect after drying and freezing. J. Biomed. Biotechnol. 5, 248–252.

Lesme, H., Courcoux, P., Alleaume, C., Famelart, M.H., Bouhallab, C., Prost, C., Rannou, C., 2020. Contribution of temporal dominance of sensations performed by modality (M-TDS) to the sensory perception of texture and flavor in semi-solid products: a case study on fat-free strawberry yogurts. Food Qual. Prefer. 80, 1–13.

MacInnis, G., Buddle, C.M., Forrest, J.K., 2020. Small wild bee abundance declines with distance into strawberry crops regardless of field margin habitat. Basic Appl. Ecol.

Mainil, A.K., Aziz, A., Harianto, J., Maini, R.I., 2020. Comparative assessment of closed-loop heat pump dryer and direct solar dryer system for banana drying. J. Adv. Res. Fluid Mechanic. Thermal Sci. 66 (2), 136–144.

Marian, M., Ohno, T., Suzuki, H., Kitamura, H., Kuroda, K., Shimizu, M., 2020. A novel strain of endophytic Streptomyces for the biocontrol of strawberry anthracnose caused by Glomerella cingulate. Microbiol. Res. 126428.

Maringgal, B., Hashim, N., Mohamed Amin Tawakkal, I.S., Muda Mohamed, M.T., 2019. Recent advances in edible coating and its effect on fresh/fresh-cut fruits quality. Trends Food Sci. Technol.

Moshari-Nasirkandi, A., Alirezalu, A., Hachesu, M.A., 2020. Effect of lemon verbena bio-extract on phytochemical and antioxidant capacity of strawberry (Fragaria×ananassa Duch. cv. Sabrina) fruit during cold storage. Biocatal. Agricult. Biotechnol. 25, 101613.

Obeidat, W.M., Sahni, E., Kessler, W., Pikal, M., 2017. Development of a mini-freeze dryer for material-sparing laboratory processing with representative product temperature history. AAPS PharmSciTech 19 (12), 599–609.

Ozcan, G., Barringer, S., 2011. Effect of enzymes on strawberry volatiles during storage, at different ripeness levels, in different cultivars, and during eating. J. Food Sci. 76 (2), 324–334.

Ozturk, O.K., Singh, T.P., 2019. Selected physical and viscoelastic properties of strawberries as a function of heated-air drying conditions. Dry. Technol. 1–11.

Pan, L., Zhang, W., Zhu, N., Mao, S., Tu, K., 2014. Early detection and classification of pathogenic fungal disease in post-harvest strawberry fruit by electronic nose and gas chromatography-mass spectrometry. Food Res. Int. 62, 162–168.

Patras, A., Brunton, N.P., Pieve, S.D., Butler, F., 2009. Impact of high-pressure processing on total antioxidant activity, phenolic, ascorbic acid, anthocyanin content, and color of strawberry and blackberry purees. Innovat. Food Sci. Emerg. Technol. 10 (1), 308–313.

Peano, C., Girgenti, V., Giuggioli, N.R., 2014. Change in quality and volatile constituents of strawberries (cv. Evie2) under MAP storage. J. Food Agric. Environ. 12 (2), 93–100.

Qiao, F., Fang, C., Huang, L., Zhang, S., 2012. The effect of different heating patterns on vacuum freeze-drying of litchi pulp. J. Food Process. Eng. 36 (4), 407–411.

Reyes, V., Bubnovich, R., Bustos, M., Vásquez, R., Vega, R., Scheuermann, E., 2010. Comparative study of different process conditions of freeze-drying of 'Murtilla' berry. Dry. Technol.: Int. J. 28 (12), 1416–1425.

Schulze, B., Hubbermann, E.M., Schwarz, K., 2014. Stability of quercetin derivatives in vacuum impregnated apple slices after drying (microwave vacuum drying, air drying, freeze-drying) and storage. LWT-Food Sci. Technol. 57 (1), 426–433.

Shaozhi, Z., Jielin, L., Guangming, C., Qin, W., 2017. Thermodynamic analysis of a freeze-dryer utilizing the hygroscopic solution. Dry. Technol.

Sicari, V., Loizzo, M.R., Pellicano, T.M., Giuffre, A.M., Poiana, M., 2020. Evaluation of aloe arborescent gel as a new coating to maintain the organoleptic and functional properties of strawberries (Fragaria x ananassa cv. Cadonga) fruits. Int. Food Sci. Technol. 55 (2), 861–870.

Silva, E.K., Meireles, M.A., Saldaña, M.A., 2020. Supercritical carbon dioxide technology: a promising technique for the non-thermal processing of fresh fruit and vegetable juices. Trends Food Sci. Technol.

Souza, V.R., Pereira, P.A., Silva, T.L., Lima, L.C., Pio, R., 2014. Determination of the bioactive compounds, antioxidant activity and chemical composition of Brazilian blackberry, red raspberry, strawberry, blueberry, and sweet cherry fruits. Food Chem. 56 (1), 362–368.

Sun, K., Li, R., Jiang, W., Sun, Y., Li, H., 2016. Comparison of three-dimensional printing and vacuum freeze-dried techniques for fabricating composite scaffolds. Biochem. Biophys. Res. Commun. 477 (4), 1085–1091.

Tang, Y., Ma, X., Li, M., Wang, Y., 2020. The effect of temperature and light on strawberry production in a solar greenhouse. Sol. Energy 195, 318–328.

Thi Phan, K.K., Truong, T., Wang, Y., Bhandari, B., 2019. Nanobubbles: fundamental characteristics and applications in food processing. Trends Food Sci. Technol.

Thomas-Valdés, S., Theoduloz, C., Jiménez-Aspee, F., Schmeda-Hirschmann, G., 2019. Effect of simulated gastrointestinal digestion on polyphenols and bioactivity of the native Chilean red strawberry (Fragaria chiloensis ssp. chiloensis f. Patagonia). Food Res. Int. 123, 106–114.

Thomas-Valdés, S., Theoduloz, C., Jiménez-Aspee, F., Burgos-Edwards, A., Schmeda-Hirschmann, G., 2018. Changes in polyphenol composition and bioactivity of the native Chilean white strawberry (Fragaria chiloensis spp. chiloensis f. chiloensis) after in vitro gastrointestinal digestion. Food Res. Int. 105, 10–18.

Van de Velde, F., Esposito, D., Grace, M.H., Pirovani, M.E., Lila, M.A., 2018. Anti-inflammatory and wound healing properties of polyphenolic extracts from strawberry and blackberry fruits. Food Res. Int. 121, 453–462.

Watson, T.T., Noling, J.W., Desaeger, J.A., 2020. Fluopyram as a rescue nematicide for managing sting nematode (Belonolaimus longicaudatus) on commercial strawberry in Florida. Crop Protect. 132, 105108.

Xu, Y., Zhang, M., Mujumdar, A.S., Duan, X., Jin-cai, S., 2006. A two-stage vacuum freeze and convective air-drying method for strawberries. Dry. Technol.: Int. J. 24 (8), 1019–1023.

Yu, P., Low, M.Y., Zhou, W., 2018. Design of experiments and regression modeling in food flavor and sensory analysis: a review. Trends Food Sci. Technol. 71, 202–215.

Yuan, Z., Shi, Y., Cai, F., Zhao, J., Xiong, Q., Wang, Y., Zheng, Y., 2020. Isolation and identification of polysaccharides from pythium arrhenomanes and application to strawberry fruit (*Fragaria ananassa* Duch.) preservation. Food Chem. 309, 125604.

Yue, X.Q., Shang, Z.Y., Yang, J.Y., Huang, L., Wang, Y.Q., 2019. A smart data-driven rapid method to recognize strawberry maturity. Informat. Process. Agricult.

Yusufe, M., Mohammed, A., Satheesh, N., 2017. Effect of duration and drying temperature on characteristics of dried tomato (Lycopersicon esculentum L.) cochoro variety. J. Food Technol. 21 (1), 41–50.