Chemical Quality of Osmotically Pretreated Freeze-Dried Strawberries

R. M. Putri, A. M. Fallah, W. Yuliani, Wagiman, and M. A. F. Falah(✉)

Department of Agroindustrial Technology, Faculty of Agricultural Technology, Universitas Gadjah Mada, Jl. Flora No 1 Bulaksumur, Yogyakarta 55281, Indonesia
affan_tip@ugm.ac.id

Abstract. The drying of fruits such as freeze-dried strawberries is an alternative to increase the added value of fresh strawberries, extend shelf life, have properties like fresh fruit, and have made it possible for consumers to be able to consume during all seasons. This study was aimed at examining the chemical quality of freeze-dried strawberries. Freeze-dried strawberries were made using a combination of pre-treatment by osmotic dehydration (OD) with the freeze-drying method. The combination of treatment materials and freeze-dried strawberries production processes used were the duration of storage in the freezer (4, 14, and 21 d), concentrate osmotic agents with (40, 50, and 60°Brix); splitting (vertically cuts strawberry) time (early, before OD, and after OD); immersion time for 120 min, and freeze-drying time of 24 h. The research chemical quality parameters of freeze-dried strawberries were water content, vitamin C, total phenolic content, total acid, and total soluble solids. The result showed that the lowest of water content (2.164%) and total acid (0.072%) then the highest of vitamin C (152.241 mg/100 g), total phenolic content (1.672%), and total soluble solids (22.333°Brix) were at the duration of storage in freezer 4 d, concentrate agents with 60°Brix, and splitting time before OD. Statistical testing showed that there was no significant difference (sig < 0.05) in all the parameters tested.

Keywords: freeze-drying · freeze-dried strawberries · chemical quality · osmotic dehydration

1 Introduction

One of the most essential horticultural crops in the world with high nutritional and financial value is the strawberry fruit (*Fragaria x ananassa*) [1]. In addition to being a good source of vitamins and phytochemicals, strawberries also rank among the best food sources for polyphenols [2]. However, strawberries also include perishable goods, so it's important to pay special attention to how they're handled after harvest.

From year to year, processed food sales have risen in popularity. Processed foods have started to take the place of fresh food categories because they have a longer shelf life and provide a higher level of safety. The global market for processing fruits and vegetables is anticipated to increase at a Compounded Annual Growth Rate (CAGR) of 8.3% from 2021 to 2026. This also applies to the market trend for the processing

J. Sumantyo et al. (Eds.): ICoSIA 2022, ABSR 29, pp. 304–311, 2023.
https://doi.org/10.2991/978-94-6463-122-7_27

of freeze-dried fruit, which is projected to increase by 6.6% CAGR in the worldwide market from 2021 to 2026 [3].

Compared to items dried using traditional techniques, products using freeze-drying have better flavour attributes. However, the amorphous and hygroscopic structure of this process undergoes several alterations [4]. Although it may help strawberries last longer on the shelf, this structure is particularly sensitive to changes in chemical properties. Low temperatures should also be taken into account while freeze-drying strawberries since they will affect how their sensory qualities alter.

Using a combination of osmotic dehydration (OD) pre-treatment and the freeze-drying technique, the chemical quality parameters (water content, vitamin C, total acid, total soluble solids, and total phenolic content) in freeze-dried strawberries will be discovered. To find the most effective method that prevents strawberry fruits from losing too much of their nutritional value, it is important to determine how freezing time, osmotic dehydration solution concentration, and strawberry splitting time affect the strawberry's amorphous and hygroscopic structure.

2 Materials and Methods

Inggit Strawberry Orchard, Ketep Pass Mountains, Banyuroto Village, Sawangan District, Magelang, Central Java, grows strawberries (*Fragaria x ananassa var. Mencir*) with a maturity level of 100% of the red color on the entire surface of the fruit. This strawberry orchard is situated 1200 m above sea level (masl) in longitudes 110°0 1′51″ and 110°26′58″ as well as latitudes 7°19′13″ and 7°42′16″. The plucked strawberries are subsequently transported to the UGM Faculty of Agricultural Technology for analysis while being kept in a cooling bag. A freeze dryer (BenchTop Pro with Omnitronics, BTP.3XL.OOX series 323257 IPSWICH, England) served as the study's primary instrument.

2.1 Production of Freeze-Dried Strawberries with Osmotic Dehydration

Strawberry petals are removed, cleaned, and strawberries are divided into two pieces according to the splitting time before being submerged in 4% $NaHCO_3$ solution for 4 h. After that, strawberries were drained and immersed in a solution of sucrose at various concentrations (40, 50, and 60°Brix) with ±60 g of strawberry agent and 200 ml distilled water for 2 h using a plate magnetic stirrer (C-MAG HS7, IKA, Selangor, Malaysia). When cells are submerged in a hypertonic solution, a process known as osmotic dehydration removes water from the material. This drop in water content is caused by a more significant osmotic pressure than that of a hypertonic solution [5].

The strawberries are then placed in a tightly sealed plastic container and frozen at a temperature of -18 ± 2 °C for 4, 14, and 21 d before being placed in a freeze dryer. To achieve the best results, the drying process is run for 24 h. Following the established specifications, samples of freeze-dried strawberries are further examined and assessed in terms of chemical quality. Figure 1 shows the procedure for creating freeze-dried strawberries and the equipment required for chemical testing.

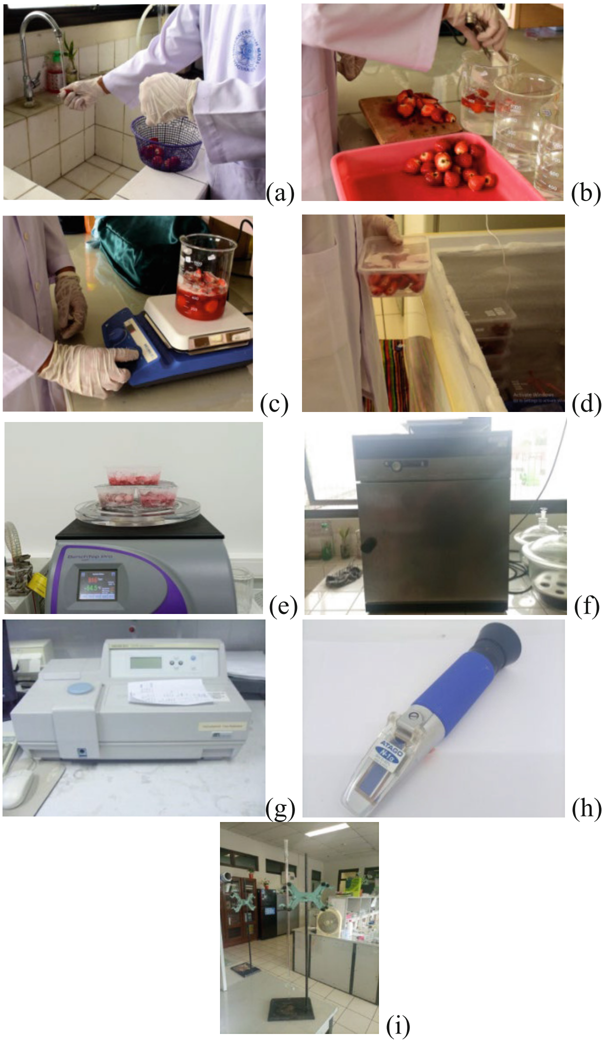

Fig. 1. The stages of making freeze-dried strawberries are (a) washing, (b) immersion in $NaHCO_3$ solution, (c) osmotic dehydration process, (d) storage in the freezer, (e) freeze-drying process in a freeze dryer, as well as the equipment used to chemical testing are (f) oven, (g) spectrophotometer, (h) refractometer, and (i) titration set.

2.2 Chemical Quality Parameter for Measurements

The quality measured in this study is chemical characteristics (water content, vitamin C, total acid, total soluble solids, and total phenolic content). Analysis of the chemical quality of strawberry water content was analysed using a thermo-gravimetric method, total phenolic content using Folin-Ciocalteu [6], vitamin C content was determined using indophenol titration method [7], soluble solid content (°Brix) was measured using a refractometer (PAL-1, Atago Co. Ltd. Japan), and the acidity of dehydrated fruit was measured using titratable acidity approach [7].

In accordance with SNI No. 8024 (2014), the size of the strawberry is determined based on the weight of the fruit, where code size A is for weight >20 g, code size B is for weight >15−20 g, and code C is for weight 12−15 g [8]. Based on the weight of the fruit, measurements were taken over 7 periods to determine the quality of the strawberries (April–July 2022). Each time, 79–118 strawberries were gathered, with the specifics being 8–24 pieces for code size B, 38–68 pieces for size C codes, and 24–40 pieces for size C codes that fell short of the minimum threshold.

2.3 Design System

In this study, the first step in creating a system design begins with identifying problems, followed by deciding on the goals and advantages of the research, conducting literature reviews, identifying the necessary data, choosing research methodologies, and deciding on the quantity and importance of factors. Three level variables were employed in this study, the first of which was freezing time, which had three levels (4, 14, and 21 d). The second element is the osmotic dehydration solution concentration, which has three levels (40, 50, and 60°Brix). The third variable is splitting time, which has three levels (initial splitting, splitting before OD, and splitting after OD). The determination of the freeze-dried strawberry quality characteristics that were discussed in the previous explanation is the final phase of the system design. SPSS version 24.0 was used for statistical computations, while Microsoft Excel 2010 (Microsoft Corporation) was used for tabulating and calculating all measurement data (SPSS Incorporation).

3 Results and Discussions

An essential processing step to increase strawberries' shelf life is drying. However, using ineffective drying techniques can result in a decrease in the quality of dried goods, including color degradation, form alterations, and nutrient loss [9, 10]. An osmotic dehydration procedure has been used to try and lessen the effects of freeze-drying. The mass transfer of soluble solids from the liquid medium into the strawberry slices and the mass transfer of water masses from strawberry slices to liquid media occur when sucrose solution is used in the osmotic dehydration process [11]. It is useful in creating a reduction in mass to speed the freeze-drying process [9] when the osmotic dehydration process is used as a pre-treatment before freezing. In addition, the freeze-drying process also affects changes in water content and water activity [12].

Figure 2 shows the chemical characteristics of fresh strawberries and freeze-dried strawberries for the water content, vitamin C, total acid, total soluble solids, and total phenolic content of the fruit at different pre-treatments. Moisture content, vitamin C, total acids, total soluble solids, and total phenols in freeze-dried strawberries have differences compared to fresh strawberries. On moisture content parameters, the value of freeze-dried strawberries (2.16%) tends to be smaller than that of fresh strawberries (93.5%) with the lowest value is a combination of 3 i.e. 4 d, 60°Brix, before OD. This decrease in water content is caused by the freeze-drying process where the extraction of water directly

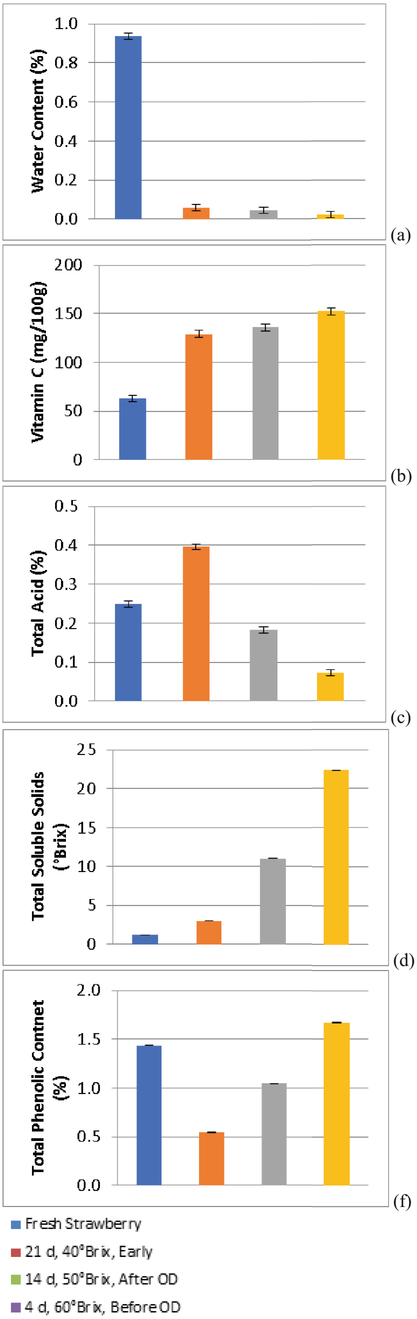

Fig. 2. Chemical quality parameter values of (a) water content, (b) vitamin C, (c) total acid, (d) total soluble solids, and (e) total phenolic content of fresh and freeze-dried strawberries. The data is the average of 3 samples with standard deviation.

from the solid phase with the sublimation process [12]. In addition, the occurrence of a decrease in the water content is also caused by the process of osmotic dehydration in the sucrose solution. Sucrose can penetrate tissues in plants, making plant cellular volume decrease and extracellular volume increase (water comes out so that osmotic solutions enter plant tissues) [13].

In contrast to the vitamin C content, the value of freeze-dried strawberries (152.241 mg/100 g) tends to be greater compared to fresh strawberries (63.102 mg/100 g) with the highest value is a combination of 3 i.e. 4 d, 60°Brix, before OD. This is because fresh strawberries are pre-treated in the form of osmotic dehydration using a mixture of sugar solution with strawberries, so that during the osmotic dehydration process some of the vitamin C content in the concentrate enters the fresh strawberry fruit, causing the level of vitamin C to increase.

The total acid content in freeze-dried strawberries (0.072%) tends to be smaller compared to fresh strawberries (0.248%) with the lowest value is a combination of 3 i.e. 4 d, 60°Brix, before OD. The decrease in total acid is due to the nature of the acid (citric acid) which is easily soluble in water in this study was given two types of pretreatment in the form of baths in the $NaHCO_3$ solution and osmotic dehydration solutions, so that the dissolving process becomes more optimal [14].

The total soluble solids in freeze-dried strawberries (22.333°Brix) tend to be greater compared to fresh strawberries (1.2°Brix) with the highest value is a combination of 3 i.e. 4 d, 60°Brix, before OD. The increase in the total content of soluble solids is due to the pre-treatment in the form of immersion in the osmotic dehydration solution, wherein the solution there is sucrose and strawberry concentrate.

The total phenol in freeze-dried strawberries (1.673%) tends to be greater compared to fresh strawberries (1.438%) with the highest value is a combination of 3 i.e. 4 d, 60°Brix, before OD. This is because the total phenol in strawberry berries is stable in an acidic state and will decrease in alkaline conditions [15]. Immersion in $NaHCO_3$ solution makes strawberry fruits have an alkaline pH so that the total phenols in the fruit decrease.

Giving a combination in the production of freeze-dried strawberry samples is intended to determine the overall effect of the process so that the optimal results are obtained in the production of freeze-dried strawberries. According to the results, the usage of variations in freezing time, the concentration of osmotic dehydration solution, and splitting time affect the results of the examined samples. Similar results were obtained, where the use of the same variation (freezing time, osmotic dehydration solution concentration, and splitting time) affected the results of the freeze-dried strawberry samples tested for color and texture. The highest degree of lightness and redness values in combination of 2, the lowest yellowness degree value in combination of 1, the lowest color change value in combination of 3, and the highest skin texture in combination of 3 [16].

From the calculations that have been carried out, an analysis was then carried out using the SPSS 24.0 independent sample T-test to see if there are differences between several groups that came from different samples. In this analysis, a comparison was made between fresh strawberries and each of the existing combinations for each of its parameters. According to the analysis that has been carried out, no parameter has a significant difference (sig <0.05).

4 Conclusion

The results of the study showed that the lowest water content (2.164%) and total acid (0.072%) and the highest of vitamin C (152.241 mg/100 g), total phenolic content (1.672%), and total soluble solids (22.333°Brix) were at the duration of storage in freezer 4 d, concentrate agents with 60°Brix, and splitting time before OD. This research was carried out in order to establish an alternative to the development of freeze-dried products, especially strawberries, so that they may be used as a reference for the society in the production of comparable products. Furthermore, it is necessary to carry out and test the shelf life to determine the damage to the content of freeze-dried strawberries.

Acknowledgments. Authors offers gratitude to the Directorate of Research at Universitas Gadjah Mada (UGM) for funding our research through the 2022 Rekognisi Tugas Akhir (RTA) Program, number 1525/UN1/DITLIT/Dit-Lit/PT.01.05/2022.

Authors' Contributions. **Refika Melina Putri:** Conducted experience – writing manuscript.. **Annas Miftahul Fallah:** Conducted experience – writing early manuscript.. **Wahyu Yuliani:** Supported Conducted experience – supported writing manuscript.. **Wagiman**: supported conducting experience **Mohammad Affan Fajar Falah:** Responsible for conducted experience, writing manuscript and project coordinator.

References

1. L. Tian-Yu, W. Shao-Xi, T. Xiao-Guang, D. Xiang-Xiang and L. He, The FvemiR167b-FveARF6 Module Increases the Number of Roots and Leaves in Woodland Strawberry, Scientia Horticulturae 293 (2021) 110692. https://doi.org/10.1016/j.scienta.2021.110692
2. S. Barkaoui, M. Mankai, N. B. Miloud, M. Kraïem, J. Madureira, S. C. Verde and N. Boudhrioua, E-Beam Irradiation of Strawberries: Investigation of Microbiological, Physicochemical, Sensory Acceptance Properties and Bioactive Content, Innovative Food Science and Emerging Technologies 73 (2021) 102769. https://doi.org/10.1016/j.ifset.2021.102769
3. Mordor Intelligence, Fruit and Vegetable Processing Market-Global Trends, COVID-19 Impact & Forecasts (2021–2026), 2021. *Available*: https://www.mordorintelligence.com
4. C. C. d. O. Alves, J. V. d. Resende, M. E. T. Prado and R. S. R. Cruvinel, The Effects of Added Sugars and Alcohols on The Induction of Crystallization and The Stability of The Freeze-Dried Peki (*Caryocar brasiliense Camb.*) Fruit Pulps, LWT - Food Science and Technology 43 (2010) 934–941. https://doi.org/10.1016/j.lwt.2010.01.029
5. I. Eren and F. Kaymak-Ertekin, Optimization of Osmotic Dehydration of Potato Using Response Surface Methodology, Journal of Food Engineering 79 (2007) 344–352. https://doi.org/10.1016/j.jfoodeng.2006.01.069
6. H. Coklar and M. Akbulut, Effect of Sun, Oven and Freeze Drying on Anthocyanins, Phenolic Compounds and Antioxidant Activity of Black Grape (*Ekşikara*) (*Vitis vinifera L.*), South African Journal for Enology and Viticulture 38 (2017) 264–274. https://doi.org/10.21548/38-2-2127

7. A.O.A.C, Official Methods of Analysis, Association of Official Analytical Chemists International, 1995.
8. SNI *Stroberi* 8026, BSN, 2014.
9. B. Xu, J. Chen, E. S. Tiliwa, W. Yan, S. M. R. Azam, J. Yuan, B. Wei, C. Zhou, H. Ma, Effect of multi-mode dual-frequency ultrasound pretreatment on the vacuum freeze-drying process and quality attributes of the strawberry slices, Ultrasonics Sonochemistry 78 (2021) 105714. https://doi.org/10.1016/j.ultsonch.2021.105714
10. X.-f. Wu, M. Zhang, Y. Ye and D. Xu, Influence of Ultrasonic Pretreatments on Drying Kinetics and Quality Attributes of Pweet Potato Slices in Infrared Freeze Drying (IRFD), LWT 131 (2020) 109801. https://doi.org/10.1016/j.lwt.2020.109801
11. N. K. Rastogi and K. S. M. S. Raghavarao, Mass Transfer During Osmotic Dehydration of Pineapple: Considering Fickian Diffusion in Cubical Configuration, LWT 37 (2004) 43–47. https://doi.org/10.1016/S0023-6438(03)00131-2
12. A. Ciurzynska, A. Lenart, K. J. Greda, Effect of pre-treatment conditions on content and activity water and colour of freeze-dried pumpkin, LWT-Food Science and Technology 59 (2014) 1075–1081. https://doi.org/10.1016/j.lwt.2014.06.035
13. J. Jiang, M. Zhang, S. Devahastin, D. Yu, Effect of ultrasound-assisted osmotic dehydration pretreatments on drying and quality characteristics of pulsed fluidized bed microwave freeze-dried strawberries, LWT 145 (2021) 111300. https://doi.org/10.1016/j.lwt.2021.111300
14. A. R. Nasution, I. Suhaidi and L. N. Limbong, Pengaruh Penambahan Natrium Bikarbonat ($NaHCO_3$) dan Asam Sitrat Terhadap Mutu Minuman Sari Buah Kedondong Berkarbonasi, Jurnal Rekayasa Pangan dan Pertanian 6 (2018) 202–210.
15. S. Thomas-Valdés, C. Theoduloz, F. Jiménez-Aspee and G. Schmeda-Hirschmann, Effect of simulated gastrointestinal digestion on polyphenols and bioactivity of the native Chilean red strawberry (*Fragaria chiloensis ssp. chiloensis f. patagonica*), Food Research Internationa 123 (2019) 106–114. https://doi.org/10.1016/j.foodres.2019.04.039
16. A. M. Fallah, R. M. Putri, W. Yuliani, Wagiman, M A F Falah, Physical quality of freeze-dried strawberries (*Fragaria x ananassa* var. Mencir), IOP Conf. Series: Earth and Environmental Sciences (2023) on progress.