

The use of lyophilization in the process of obtaining apple chips

Sándor RÓZSA^{1*}, Emanuel SOCACIU¹, Osolya BORSAL^{1*}, Tincuța GOCAN¹, Daniela POȘTA^{2*},

¹University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Horticulture and Business in Rural Development, Department of Horticulture and Landscape, Mănăștur St. 3-5, Cluj, Cluj-Napoca, Romania

²University of Life Sciences "King Mihai I" from Timisoara, Faculty of Engineering and Applied Technologies, Department of Horticulture, Aradului St. 119, Timisoara, Timis, Romania

*Corresponding author e-mail: orsolya.borsai@usamvcluj.ro, posta.daniela@gmail.com

Manuscript received: 18 November 2024; revised: 20 November 2024; accepted: 21 November 2024

Abstract

Lately, freeze-dried fruits are beginning to take over the processed fruit markets by modern preservation methods, such as lyophilization - freeze drying. Chips made from different varieties of apples are starting to attract more and more consumers of dehydrated fruit. Applying modern technologies in obtaining apple chips, superior quality products can be obtained, in terms of appearance and the aromatic compounds they contain. In the conducted experience, the varieties 'Pinova' and 'Golden Delicious' were used, which were subjected to lyophilization at a temperature of -60°C for 24 hours. After lyophilization, the rehydration capacity of the chips was monitored, which in the 'Pinova' variety showed 95.45% rehydration capacity, being highest value.

Key words: lyophilization, freeze-dried fruits, apple chips

Introduction

The problem of long-term preservation of biological products has concerned researchers from various parts of the world for a long time [3].

Of all the methods developed so far, freeze-drying has proven to be the most effective, due to the fact that it best ensures the long-term preservation of the product, without losing its biological properties [12].

This procedure, used in numerous branches of biology, has become indispensable for biochemistry, bacteriological, inframicrobiology laboratories, transfusion centers, ootherapy drug factories, but also for the food industry [7].

It is universally recognized that lyophilization has happily solved the most thorny problems related to targeted microbial variability, preparation and preservation of live vaccines and microbial antigens [10].

The sphere of use of lyophilization has also significantly expanded in the animal and vegetable food industry, where the results of the application of this method seem to give full satisfaction to the consumers' requirements. Indeed, this process proved to be superior, compared to the industrial methods still used [18].

Lyophilization means the process of rapid drying of substances, by sublimation of water in a vacuum, after prior freezing [2].

The term lyophilization derives from the word 'liofil', which in turn comes from the Greek words 'luein' and 'philos', meaning solvent-loving [11].

This term was assigned to products dried by lyophilization due to the fact that they have a very high affinity for the dispersion liquid, which they bind chemically or by adsorption, keeping the original ability to be redissolved unchanged, due to the non-modification of their structure by drying chemical colloids [16].

Freezing is the first operation performed on the material subjected to lyophilization [5].

The use of this process for drying products by lyophilization was necessary due to the fact that, on the one hand, it keeps intact most of the active properties of biological preparations, in that it immediately stops any fermentation, any enzymatic action, so it makes the products keep exactly in the physiological state that they had it at the time of freezing, and on the other hand it avoids the foaming process of the lyophilizer during drying [17].

The way in which freezing is performed has a great importance on the success of lyophilization of different materials [15].

The temperature to which the material intended for drying freezes is usually 10°—20°C lower than the maximum temperature reached during the first phase of drying. Once frozen, the product must be kept in this

condition until it is subjected to drying. But we must take into account the fact that even if the frozen product is kept at temperatures below 0°C, it still undergoes some small changes in terms of aroma, color and taste, as we know from the preservation of various foods [1].

The cause of these changes is the much attenuated, but not suspended, action of the enzymes [9].

The temperature limit below which enzyme action is definitely suspended cannot yet be indicated. Thus, for example, the action of lipase is interrupted at -24.5 °C, and of invertase at -18 °C. It is generally considered that for good preservation by freezing the temperature must be at least -40 °C [4].

The main factors involved in the vacuum drying process are: the state of water aggregation, the sublimation of water from the frozen material and the removal of water vapor from the container with the material undergoing drying [14].

The state of aggregation of water is a function of pressure and temperature.

Above 0°C is the liquid and gas phase, and below the freezing point is the solid and gas phase, except in cases of extremely high pressure [8].

At atmospheric pressure and at a temperature of 0 °C, the transition from the solid state to the liquid state occurs, and at the temperature of 100 °C, the transition from the liquid state to the gaseous state.

Above the triple point (+0.01°C), where all three states of aggregation of water (solid, liquid and gaseous) coexist, a pressure expressed in Torri (mmHg) is exerted on the surface of the water, with a value very close to that of expressing the water temperature in degrees Celsius. In other words, a pressure of about 10 Torri is established at the surface of water with a temperature of +10 °C.

At the triple point, i.e. close to 0°C, a pressure of 4.6 Torri is exerted above water and ice; above the ice at -20 °C a pressure of 0.8 Torri, and above the ice at -60 °C a pressure of 0.01 Torri is exerted.

In case of a change in pressure, the corresponding temperature also changes.

The vacuum is necessary, to the greatest extent, for the rapid removal of sublimated water vapor from the surface of the material subjected to drying, because at atmospheric pressure the speed of vapor diffusion through an inert gas is very low [13].

As demand for nutritious, shelf-stable snacks grows, freeze-dried fruits, especially apple chips, have become popular in the processed fruit market. Lyophilization, or freeze-drying, is a sophisticated dehydration technique favored for its ability to preserve the sensory and nutritional qualities of heat-sensitive foods.

Like any other preservation method, lyophilization has certain advantages, but also some disadvantages, which are presented in Figure 1.

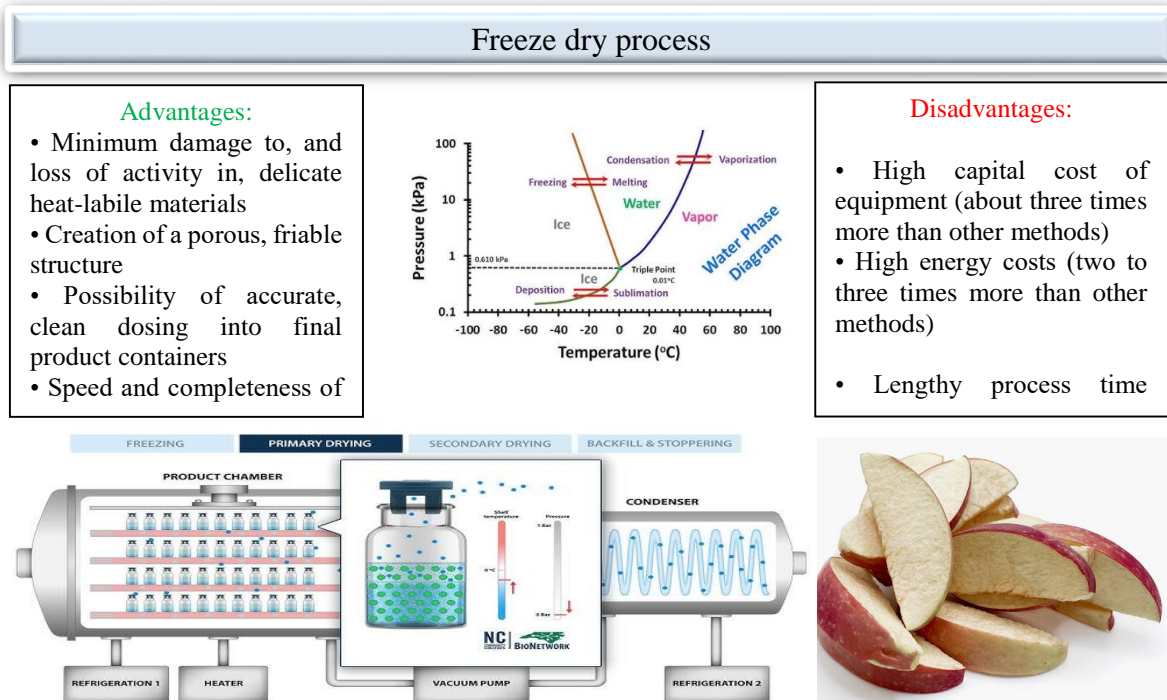


Figure 1. Freeze dried food general characteristics.

Source: <https://www.youtube.com/watch?app=desktop&v=3DsavLiwshY>

Apples are among the most well-known and healthiest fruits, thousands of varieties of apples are grown and eaten all over the world. Apples are extremely quickly assimilated and have a high content of phosphates and vitamins, so we can instantly get energy from them, which can be of great help in intellectual activities. Apples contain all the important nutrients absolutely necessary for a healthy diet and lifestyle [6].

The pectin and dietary fibers present in apples contribute to digestive activity, cleanse the body and promote metabolism. They are recommended for people with high stomach acidity, because the acid content of the fruit is not as high as that of fresh apples.

Material and Method

Two varieties of apples were used in the study: Golden Delicious (Figure 2) and Pinova (Figure 3). The biological material was harvested from the orchard of the University of Agricultural Sciences and Veterinary Medicine in Cluj-Napoca.



Figure 2. 'Golden delicious' variety
Source: original.



Figure 3. 'Pinova' variety
Source: original.

After harvesting, the biological material was cleaned and subjected to physical measurements. The physical-chemical determinations were carried out at the Faculty of Horticulture and Business in Rural Development from Cluj-Napoca, in the laboratory of the Horticultural Products Technology discipline (Figure 4).



Figure 4. Establishing experimental variants in the laboratory
Source: original.

Before freezing at a temperature of -20 °C, the biological material was cleaned and the inedible parts were removed.

For the lyophilization process was used the LIO-2 FP lyophilizer from FreezeDry GmbH Germany (Figure 5).

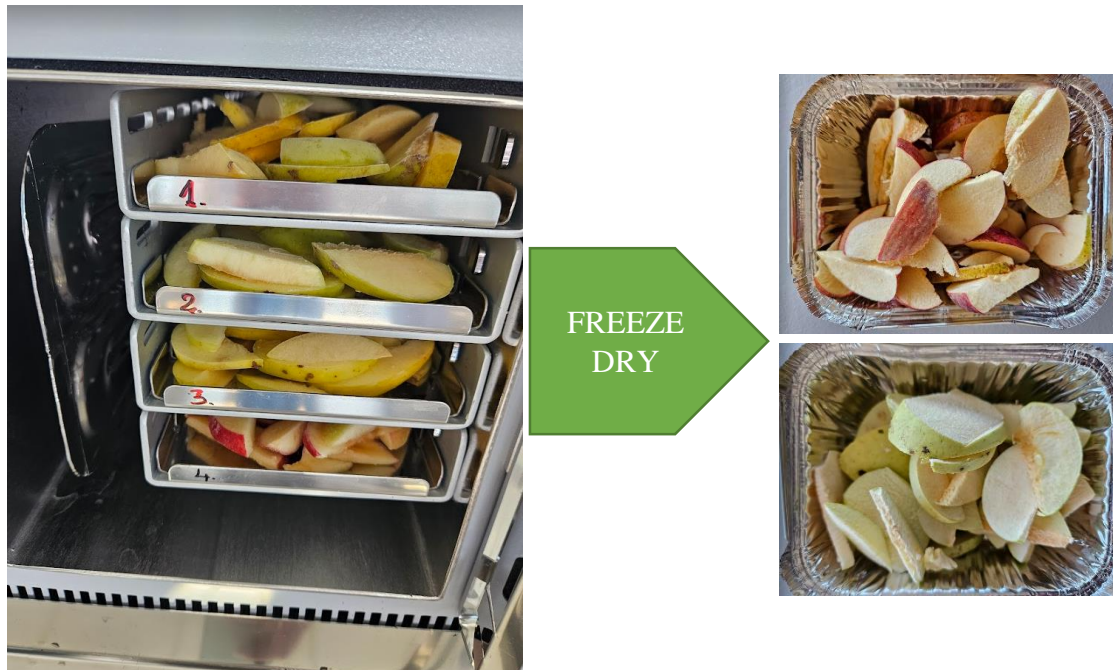


Figure 5. Obtaining the finished product - freeze-dried apple chips.
 Source: original.

The duration of a lyophilization cycle was 24 hours. After lyophilization, the chips were packed in hermetically sealed polyethylene bags.

Results and Discussions

For the processing of horticultural products, the weight, volume and density of the raw material are of particular importance.

The weight variation of the analyzed samples for the two varieties are presented in the Figure 6.

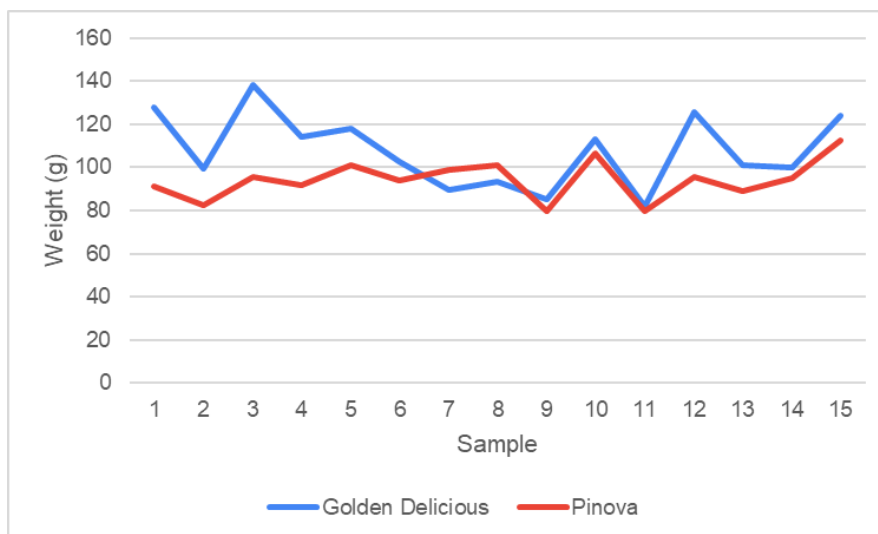


Figure 6. The weight variation of the analyzed samples.
 Source: original.

In the climatic conditions of 2024, the analyzed samples had an average weight of 107.59 g for the 'Golden Delicious' variety and 94.23 g for the 'Pinova' variety'. The maximum value was recorded for the delicious 'Golden variety' (138.02 g), and the minimum value (94.23 g) for the 'Pinova' variety.

The volume variation of the analyzed samples for the two varieties are presented in the Figure 7.

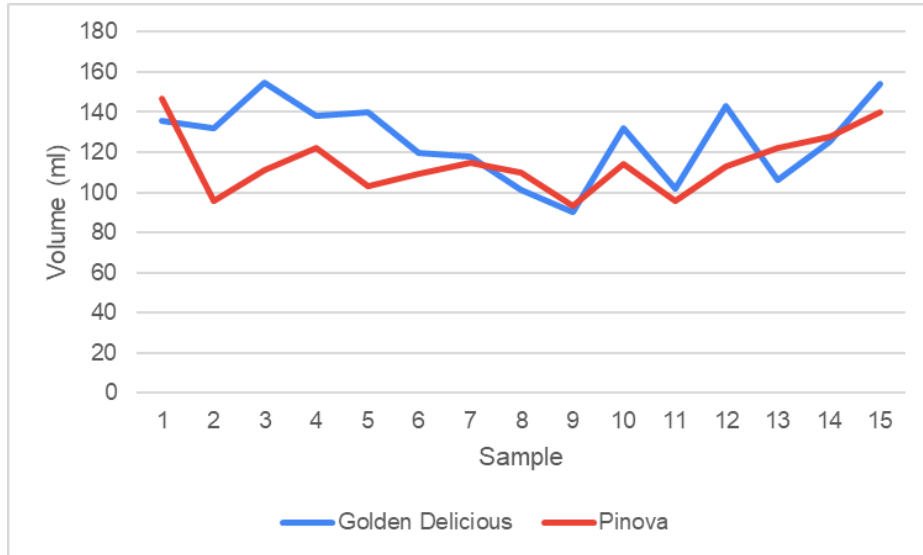


Figure 7. The volume variation of the analyzed samples.
Source: original.

The analyzed samples showed an average volume of 126.13 ml for the 'Golden Delicious' variety and 114.6 ml for the 'Pinova' variety. Both the maximum value (155 ml) and the minimum value (90 ml) were recorded in the 'Golden Delicious' variety.

For the automation of the technological flows of conditioning and processing apples, the density of the fruits presents a very important characteristic, providing us with information about the degree of the fruits maturity. The data recorded for the analyzed samples are presented in the Figure 8.

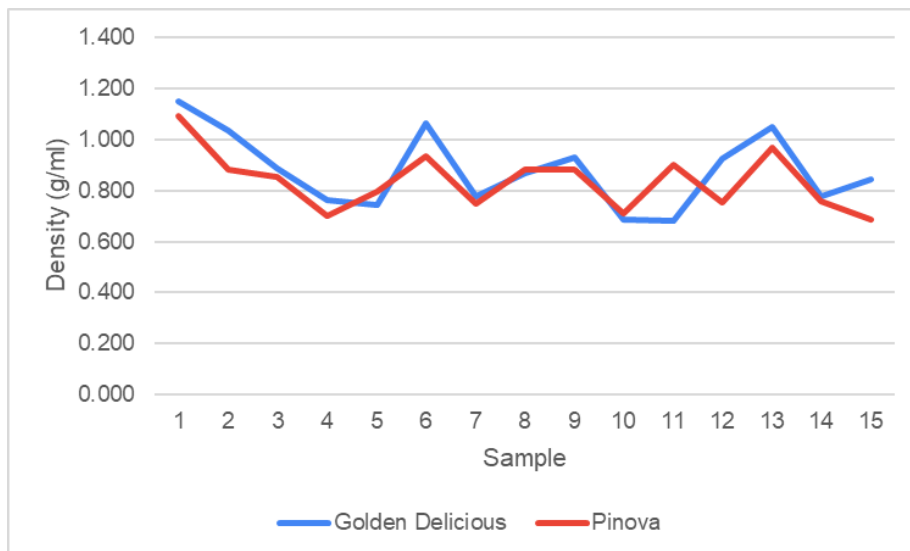


Figure 8. The density variation of the analyzed samples.
Source: original.

The average density of the samples shows similar values for both varieties, the 'Golden Delicious' variety registering an average value of 0.88 g/ml, and the 'Pinova' variety 0.84 g/ml. The maximum value (1.15

g/ml) was recorded for the 'Golden Delicious' variety, and the minimum value (0.68 g/ml) for the 'Pinova' variety.

In both varieties, the shape index shows similar values (Figure 9).

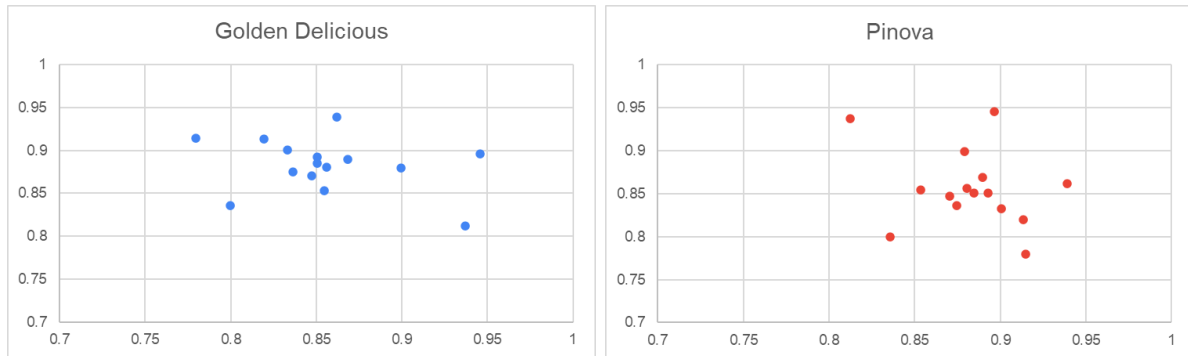


Figure 9. Samples shape index.
 Source: original.

For the 'Golden Delicious' variety, the shape index has an average value of 0.88, and for the 'Pinova' variety, 0.84. The minimum value was recorded for the 'Pinova' variety (0.68) and the maximum value (1.15) for the 'Golden delicious' variety.

The cleaning aims to remove the parts without technological and food value (seminal house, peduncles, peels, skins) obtaining products with the highest degree of finishing.

After the elimination of the seminal house in apples, we record a decrease in the amount of raw material that is subject to processing (Figure 10).

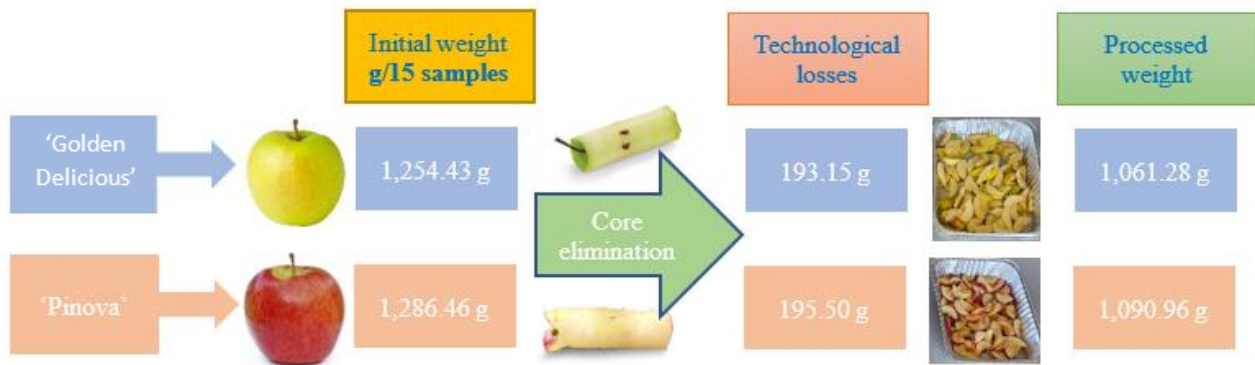


Figure 10. The evolution of the weight of the raw material during its preparation.
 Source: original.

The losses recorded during the preparation of the raw material for processing were 15.20% for the 'Pinova' variety and 15.39% for the 'Golden Delicious' variety.

The fruit lyophilization process involves removing the water level from the fruit so that the fruit remains perfectly crisp even after lyophilization.

Additionally, the freeze-drying method does a remarkable job of preserving the inherent flavors of the fruit. The concentrated flavors remain intact as the water is evaporated by sublimation, resulting in intensely flavored dried fruit. Food manufacturers who use freeze-dried fruit as ingredients in a variety of products such as cereals, baked goods and trail mixes especially benefit from this flavor preservation. The dynamic taste of freeze-dried organic products can enhance the overall flavor profile of these items without requiring artificial additives.

Through the lyophilization process, the analyzed samples lost between 83.15 and 86.43% of their water content.

After lyophilization, the rehydration capacity of the chips was monitored, which in the 'Pinova' variety presented the highest value, namely 95.45%, and the 'Golden Delicious' variety 94.15%.

Conclusions

Based on the experimental results obtained regarding the use of freeze-dried processes in apple chips preparations, the following can be concluded:

- ✓ both varieties analyzed are suitable for obtaining apple chips;
- ✓ the very high rehydration capacity of both varieties, highlighting a superior quality product.

References

- [1] Ahmed, M., Ali, A., Sarfraz, A., Hong, Q., & Boran, H. (2022), *Effect of Freeze-Drying on Apple Pomace and Pomegranate Peel Powders Used as a Source of Bioactive Ingredients for the Development of Functional Yogurt*. Journal of Food Quality, 2022(1), 3327401.
- [2] Baeghbali, V., Ngadi, M., & Niakousari, M. (2020), *Effects of ultrasound and infrared assisted conductive hydro-drying, freeze-drying and oven drying on physicochemical properties of okra slices*. Innovative Food Science & Emerging Technologies, 63, 102313.
- [3] Bao, X., Min, R., Zhou, K., Traffano-Schiffo, M. V., Dong, Q., & Luo, W. (2023), *Effects of vacuum drying assisted with condensation on drying characteristics and quality of apple slices*. Journal of Food Engineering, 340, 111286.
- [4] Bhatta, S., Stevanovic Janezic, T., & Ratti, C. (2020), *Freeze-drying of plant-based foods*. Foods, 9(1), 87.
- [5] Ciużyńska, A., Marczak, W., Lenart, A., & Janowicz, M. (2020). *Production of innovative freeze-dried vegetable snack with hydrocolloids in terms of technological process and carbon footprint calculation*. Food Hydrocolloids, 108, 105993.
- [6] Fan, K., Zhang, M., & Mujumdar, A. S. (2019), *Recent developments in high efficient freeze-drying of fruits and vegetables assisted by microwave: A review*. Critical reviews in food science and nutrition, 59(8), 1357-1366.
- [7] Fauster, T., Giancaterino, M., Pittia, P., & Jaeger, H. (2020), *Effect of pulsed electric field pretreatment on shrinkage, rehydration capacity and texture of freeze-dried plant materials*. Lwt, 121, 108937.
- [8] Harguindeguy, M., & Fissore, D. (2020), *On the effects of freeze-drying processes on the nutritional properties of foodstuff: A review*. Drying Technology, 38(7), 846-868.
- [9] Kahraman, O., Malvandi, A., Vargas, L., & Feng, H. (2021), *Drying characteristics and quality attributes of apple slices dried by a non-thermal ultrasonic contact drying method*. Ultrasonics Sonochemistry, 73, 105510.
- [10] Karwacka, M., Ciużyńska, A., Galus, S., & Janowicz, M. (2022), *Freeze-dried snacks obtained from frozen vegetable by-products and apple pomace—Selected properties, energy consumption and carbon footprint*. Innovative Food Science & Emerging Technologies, 77, 102949.
- [11] Kidoń, M., & Grabowska, J. (2021), *Bioactive compounds, antioxidant activity, and sensory qualities of red-fleshed apples dried by different methods*. LWT, 136, 110302.
- [12] Liapis, A. I., & Bruttini, R. (2020), *Freeze drying*. In Handbook of industrial drying (pp. 309-343). CRC press.
- [13] Liu, Y., Zhang, Z., & Hu, L. (2022), *High efficient freeze-drying technology in food industry*. Critical Reviews in Food Science and Nutrition, 62(12), 3370-3388.
- [14] Rajoriya, D., Shewale, S. R., & Hebbar, H. U. (2019), *Refractance window drying of apple slices: Mass transfer phenomena and quality parameters*. Food and Bioprocess Technology, 12, 1646-1658.
- [15] Rybak, K., Wiktor, A., Witrowa-Rajchert, D., Parniak, O., & Nowacka, M. (2021), *The quality of red bell pepper subjected to freeze-drying preceded by traditional and novel pretreatment*. Foods, 10(2), 226.
- [16] Waghmare, R. B., Choudhary, P., Moses, J. A., Anandharamakrishnan, C., & Stapley, A. G. (2022), *Trends in approaches to assist freeze-drying of food: A cohort study on innovations*. Food Reviews International, 38(sup1), 552-573.
- [17] Yuste, S., Macià, A., Motilva, M. J., Prieto-Diez, N., Romero, M. P., Pedret, A., Rubió, L. (2020), *Thermal and non-thermal processing of red-fleshed apple: how are (poly) phenol composition and bioavailability affected?*. Food & function, 11(12), 10436-10447.
- [18] Zhu, J., Liu, Y., Zhu, C., & Wei, M. (2022), *Effects of different drying methods on the physical properties and sensory characteristics of apple chip snacks*. Lwt, 154, 112829.