J. BIOL. ENVIRON. SCI.,
2024, 18(52), 1-7

Original Research Article

Effect of Freeze Drying Method on Drying Characteristics, Colour and Rehydration Ratio of Some Apple Varieties

Muhammet Candas[1*] and Nazmi Izli[2]
1 Bursa Uludağ University, Graduate School of Natural and App. Science, Department of Biosystems Engineering, Bursa, TURKEY
2 Bursa Uludağ University, Faculty of Agriculture, Department of Biosystems Engineering, Bursa, TURKEY

Received: 10.06.2024; Accepted: 25.06.2024; Published Online: 26.03.2025

ABSTRACT

This study investigated the effect of the freeze-drying method on drying characteristics, color, and rehydration ratio of Gala, Granny Smith and Starking apple samples. Experimental results showed that the drying rate decreased with increasing drying time and decreasing moisture content of the samples. All color parameters of fresh Gala, Granny Smith and Starking apple samples were affected by freeze-drying. Freeze drying caused a decrease in L* and α° values, while a*, b* and C values increased. The highest rehydration rate value of 4.673 was obtained from Gala apple samples.

Keywords: Freeze drying, Colour changes, Rehydration ratio, Gala, Granny Smith, Starking

INTRODUCTION

Agricultural products, which play an essential role in human nutrition, quality losses at various stages, from production to consumption. It has been determined that the losses in cereals from harvest to use are 10% of the annual production and this rate reaches 28% in hay production. Losses in fruits and vegetables are estimated to reach 35-40% of annual production (Işık and Alibaş 2000). Considering the total production amounts in the world, it is understood that these losses are pretty significant (İzli 2007).

Fruits are perishable products with high post-harvest losses. Worldwide, these losses vary between 20% and 40%. These losses are leading causes of inappropriate harvesting techniques and transportation and storage conditions. Many physical processes are involved, from picking the fruit to reaching the consumer. These losses can exceed 50% in sensitive products (Kader, 2002). The surplus of fruit produced in season can be solved by storing the products, but cold storage facilities are costly for establishment and operation.

Fruit drying facilitates storage and transportation when there is a mass reduction of up to 80% in tonnage. Most fruits can be stored under favorable conditions after drying, especially in energy-free environments (Fan *et al.*, 2005). Drying has been an important method of food preservation for humans throughout history. Even meat drying has saved humanity from starvation when food was inaccessible. The purpose of drying is to remove water from the food and reduce the water content to about 10%. Thus, bacteria in food cannot be consumed because they cannot access water (Vadivambal and Jayas 2007).

Freeze drying is a method used for the long-term preservation of foods and dates back to the early 1900s. This method removes water by sublimation, preserving the natural structure and nutritional value of foods. This technology, first developed for military purposes and spaceships, has found many uses in the food sector over time (Yöney 2005).

The freeze-drying process consists of three main stages: freezing, primary drying, and secondary drying. During this process, the product's water content is frozen into ice and then evaporated by sublimation under low pressure. The main advantage of this method is that the aroma, taste, color and nutritional value of foods are largely preserved (Aschkenasy 1989).

Almost all kinds of fruits can be freeze-dried, and fruits such as strawberries, peaches, raspberries, blackberries, oranges, lemons and pineapples are frequently preferred. In addition, tropical fruits such as kiwi, pear, papaya, banana, apricot, grape, and apple are freeze-dried (Leibowitz 2006). This method allows fruits to be produced in slices, cubes, or powdered form, which can be used in various food products.

[*]Corresponding author: muhammetcandas@gmail.com

The advantages of freeze drying include year-round availability, a wide range of uses, aroma preservation, color, taste, shape, and odor preservation, no need for refrigeration, light packaging and ease of transportation, long shelf life, no need for rehydration and additives (Fellows 2009). These features make the drying method indispensable in the food sector.

This study aimed to determine the drying kinetics, colour and rehydration ratio changes in freeze drying of Gala, Granny Smith and Starking apple samples.

MATERIALS AND METHODS

Sample preparation and drying procedure

The fresh Gala, Granny Smith and Starking apple samples used in the analyses were bought from a local market in Bursa, a province of Turkey, and they were stored at 4 ± 0.5°C before the experiments. Before drying, the apple samples were first sliced into cubes (0.7 cm^3) using a dicer (Börner, Belgium) and dried in this form. These samples' initial moisture level was specified using a forced air convection oven (ED115 Binder, Germany) operating at 105°C for 24 h.

Freeze-drying experiments were conducted using a laboratory-type freeze dryer (Alpha 1-2 LD Plus, Germany) at a pressure of 52 Pa and a processing temperature of −50°C in the drying chamber. The amount of moisture lost throughout the drying process was determined using a digital balance (Radwag, Poland) with an accuracy of ± 0.01 g. The measurements were carried out in three repetitions.

Drying curves

The following equations were used to calculate moisture ratio (MR) and drying rate (DR) during drying experiments:

$$MR = \frac{M_t - M_e}{M_o - M_e} \quad (1)$$

$$DR = \frac{M_{d+dt} - M_t}{dt} \quad (2)$$

Where,

M_t corresponds to the moisture content at a given time (g water.g dry matter^{-1}),

M_o corresponds to the initial moisture content (g water.g dry matter^{-1}),

M_e corresponds to the equilibrium moisture content (g water.g dry matter^{-1}),

M_{t+dt} moisture content at t+dt (g water.g dry matter^{-1}),

and

t is drying time (min) (Thorat *et al*. 2012).

Colour measurement

A Hunterlab Color Analyzer (MSEZ-4500L, Reston, Virginia, USA) was used to determine the colour attributes of fresh (as the reference value) and dried Gala, Granny Smith and Starking apple samples in terms of the colour parameters L* (lightness), a* (redness/greenness), and b* (yellowness/blueness). The Chroma (C) and Hue angle (α°) were calculated according to Equation 3 and 4 given below, where L, a, and b represent the reference values (Xie *et al*. 2017).

$$C = \sqrt{(a^2 + b^2)} \quad (3)$$

$$\alpha = \tan^{-1}(\frac{b}{a}) \quad (4)$$

Rehydration ratio

Dried samples were rehydrated by immersion in a distilled water bath at a controlled temperature of 21±1 °C. The volume of water was set at 30 times of the dried fruit's volume. Rehydration of dried fruits was stopped after three hours. Then, the excess water from the surface of the samples was removed with tissue paper. The data were quantified in terms of the rehydration ratio (RR) with the use of the following formula (Equation 5):

$$RR = \frac{W_R}{W_D} \quad (5)$$

Here,
RR, stands for rehydration ratio (g.g^{-1}, dry basis),
W_R, stands for the weight of rehydrated samples (g),
and
W_D stands for weight of dehydrated samples (g), (Zielinska *et al*. 2016).

Statistical analysis
All the measurements in freeze drying were carried out in triplicate. The mean values of three replicates (mean ± standard deviation) were used to exhibit the results of compound contents. The experimental data were compared using the statistical software statistic product of JMP (Version 7.0, SAS Institute Inc., Cary, NC, USA) and analyses of variance (ANOVA) were conducted by one-way analysis of variance. To identify significant differences among samples within the evaluated parameters, The Least Significant Difference test (LSD) at a 95% confidence level ($P < 0.05$) was considered.

RESULTS AND DISCUSSION

Drying characteristics
Figure 1 shows the changes in moisture content of Gala, Granny Smith and Starking apple samples dried by freeze drying method over time. When the experimental results were analyzed, the average total drying time for Gala, Granny Smith and Starking apple samples was 150, 120 and 120 minutes, respectively. The results showed that the moisture content decreased continuously as the drying time increased (Sacilik 2007).

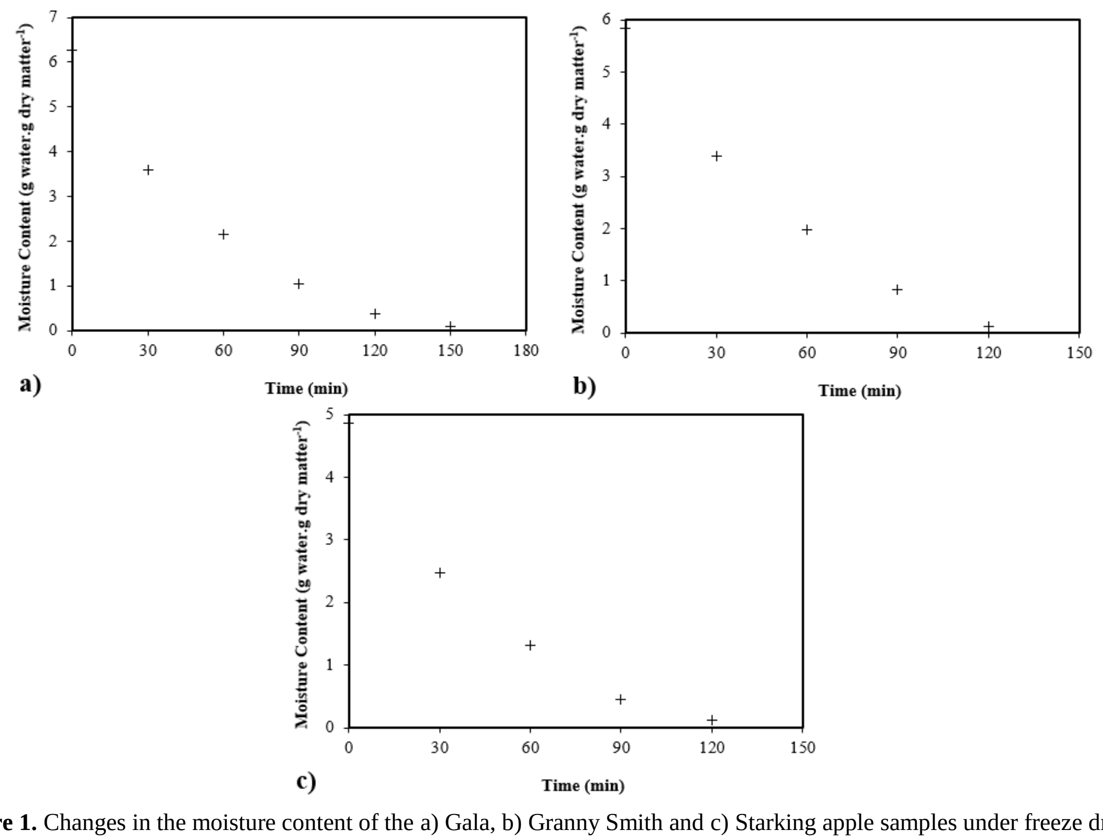

Figure 1. Changes in the moisture content of the a) Gala, b) Granny Smith and c) Starking apple samples under freeze drying conditions.

Figure 2 shows the changes in drying rates of Gala, Granny Smith and Starking apple samples with moisture content. When Figures 1 and 2 are examined together, the samples dry rapidly at the beginning of the drying process, then the drying rate decreases over time. As a result, the freeze-drying process of the samples was realized in a decreasing period. Acar *et al*. (2015) reported similar results in their freeze-drying process study. In addition, as can be seen from the figures, when the drying rate values obtained from low and high moisture levels of the dried samples were compared, it was determined that the drying rate values obtained at high moisture levels were higher than the drying rate values obtained at low moisture levels (Mundada *et al*. 2010).

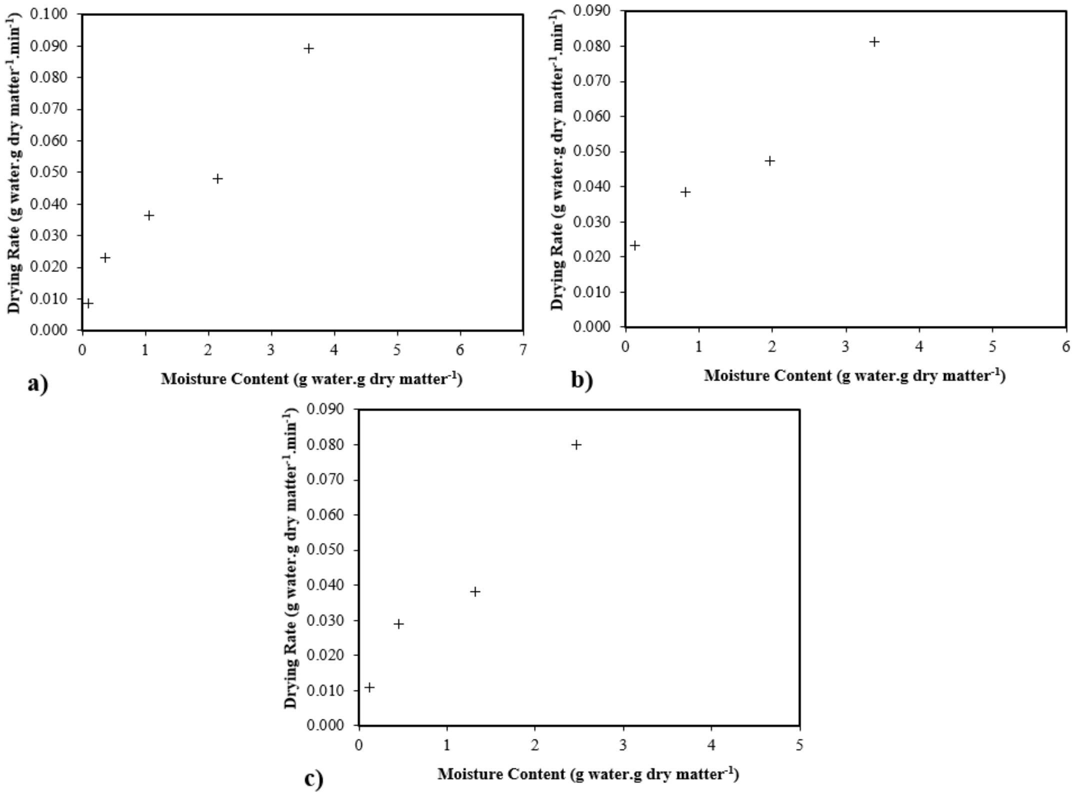

Figure 2. The drying rates of a) Gala, b) Granny Smith and c) Starking apple samples versus the moisture contents at freeze-drying conditions.

Colour analysis results

The colour parameters L*, a*, b*, Chroma (C) and Hue angle (α°) values of fresh and freeze-dried Gala, Granny Smith and Starking apple samples are presented in Figure 3-5.

According to the results obtained, L* value decreased from 76.936 to 74.882, α° value decreased from 86.584 to 83.137, a* value increased from 1.460 to 4.244, b* value increased from 24.154 to 35.044 and C value increased from 24.198 to 35.300 (Figure 3). All color parameters of fresh Gala samples were statistically significantly different from those of dried samples ($P<0.05$).

The L* value decreased from 85.062 to 69.340, α° value decreased from 99.313 to 81.298, a* value increased from -3.346 to 3.602, b* value increased from 20.314 to 23.422 and C value increased from 20.588 to 23.697 (Figure 4). All color parameters of fresh Granny Smith samples were statistically significantly different from those of dried samples ($P<0.05$).

The L* value of Starking samples decreased from 76.844 to 47.504, α° value decreased from 93.225 to 68.125, a* value increased from -1.218 to 14.124, b* value increased from 21.338 to 35.124 and C value increased from 21.373 to 37.858 (Figure 5). All color parameters of fresh Starking samples were statistically significantly different from those of dried samples ($P<0.05$).

When the results were analyzed, freeze-drying application caused a decrease in L* and α° values, while a*, b* and C values increased. When the previous studies were examined, İzli and Polat (2019) reported that L*, b*, C and α° values of fresh and freeze-dried samples decreased and only a* values increased in the freeze-drying study of quince slices.

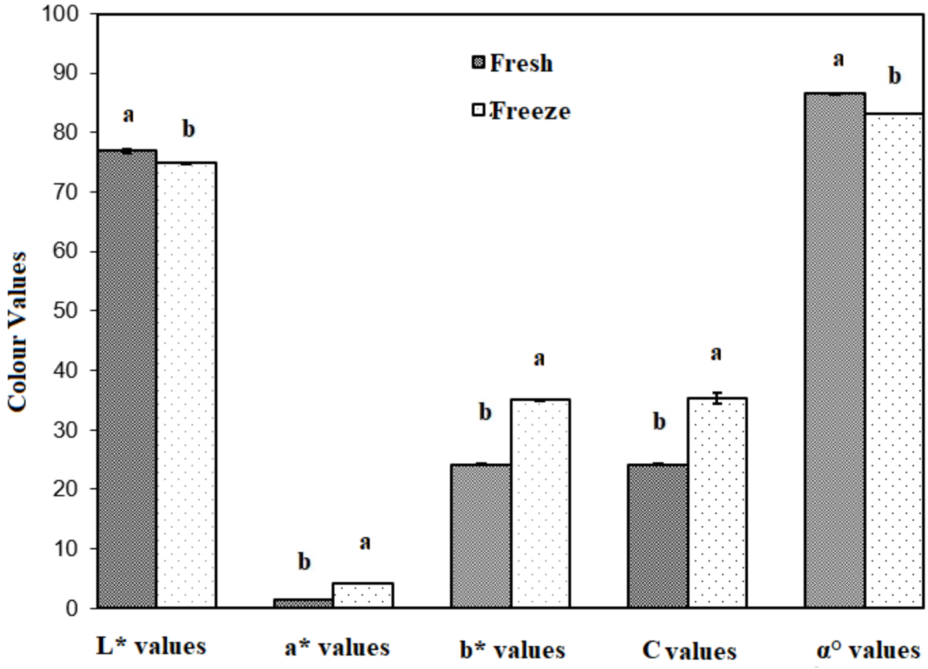

Figure 3. Colour values of fresh and dried Gala apple samples at freeze-drying conditions

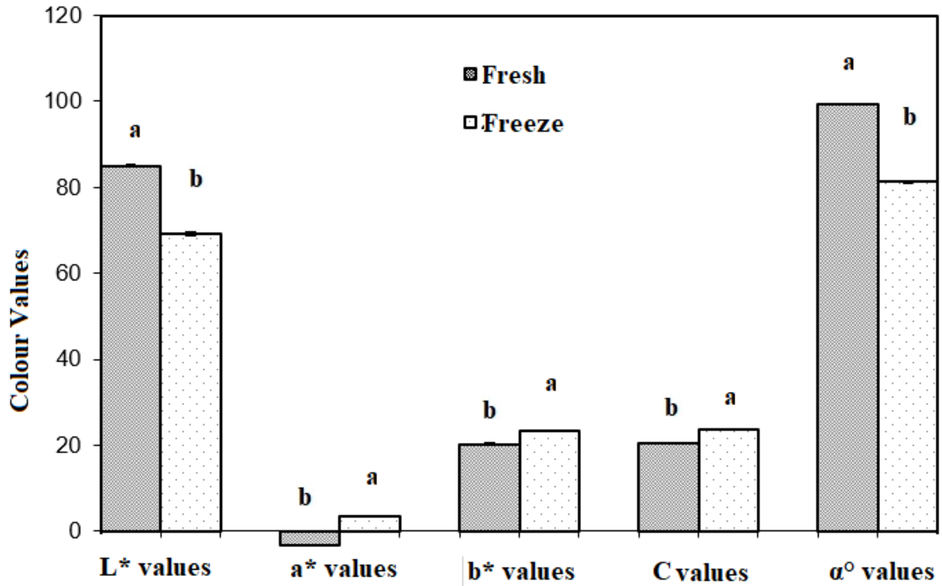

Figure 4. Colour values of fresh and dried Granny Smith apple samples at freeze-drying conditions

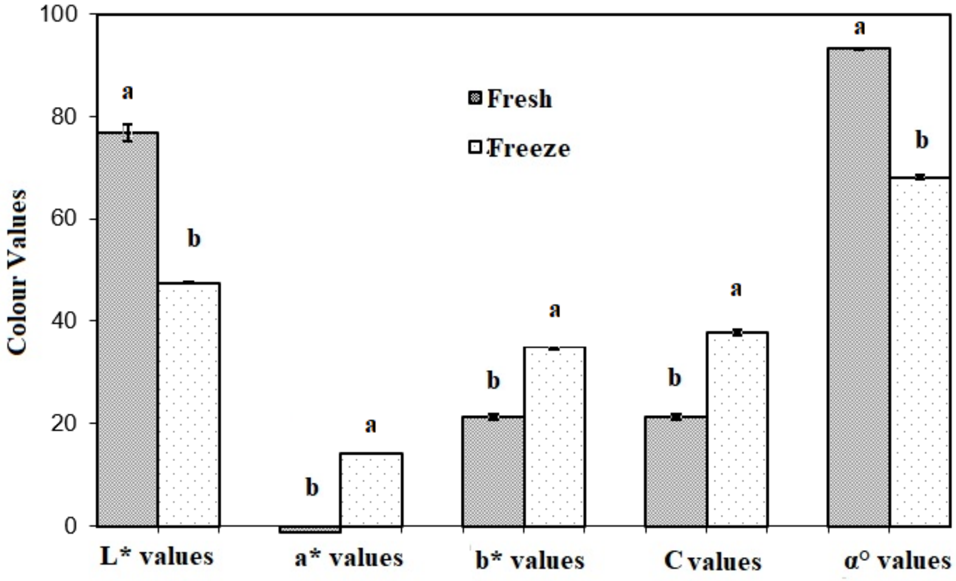

Figure 5. Colour values of fresh and dried Starking apple samples at freeze-drying conditions

Rehydration ratio

The rehydration rate results of Gala, Granny Smith and Starking apple samples are given in Figure 6. According to these results, the rehydration rate value of Gala samples was 4.673, the rehydration rate value of Granny Smith samples was 4.440 and the rehydration rate value of Starking samples was 3.325. All rehydration rate values of Gala, Granny Smith and Starking samples are statistically significantly different (P<0.05). İzli and Polat (2016) found the rehydration rate value as 5.20 in freeze-drying studies of ginger samples.

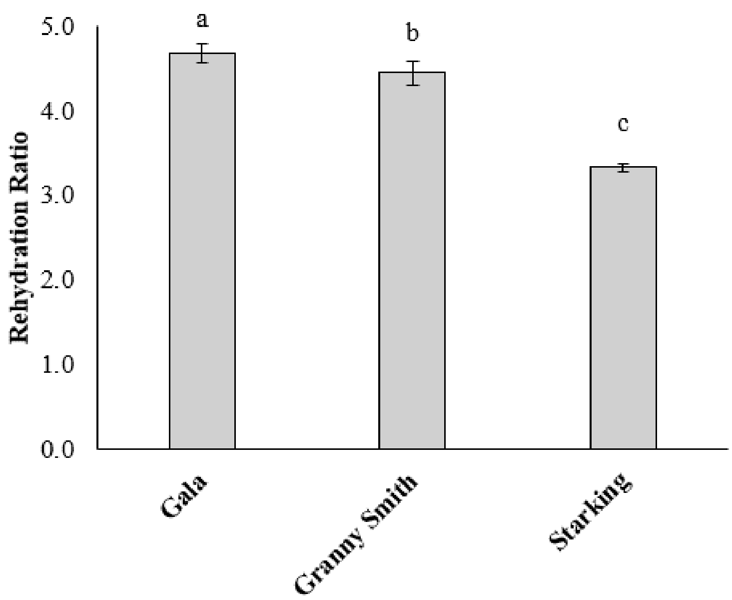

Figure 6. Effect of freeze drying method on rehydration ratio of Gala, Granny Smith and Starking apple samples

CONCLUSIONS

The present study investigated the effect of freeze drying on drying characteristics, color and rehydration rate of Gala, Granny Smith and Starking apple samples. The average total drying time for Gala, Granny Smith and

Starking apple samples was 150, 120 and 120 minutes, respectively., and the drying process took place at a decreased time. When the results were evaluated regarding color values, the freeze-drying treatment caused a decrease in L* and α° values, while a*, b*, and C values increased. In addition, the rehydration ratio values of the dried samples were determined as 4.673, 4.440, and 3.325 for the Gala, Granny Smith, and Starking samples, respectively. As a result, positive results were obtained regarding drying characteristics, color, and rehydration rate of Gala, Granny Smith, and Starking apple samples dried by freeze drying method.

REFERENCES

Acar B, Sadikoglu H, Doymaz, I (2015). Freeze ‐ drying kinetics and diffusion modeling of saffron (Crocus sativus L.). Journal of Food Processing and Preservation, 39(2),142-149.

Aschkenasy H (1989). Applications of Freeze Dried Fruits in Confectionary Products.

Fan K, Chen C, Zhang J (2005). Research on energy saving in drying process. Renewable Energy, 30(14), 2131-2142.

Fellows P (2009). Food Processing Technology: Principles and Practice, 3rd ed.; CRC Press: Cambridge, UK; Woodhead Pub.: Boca Raton, FL, USA.

Işık H, Alibaş K (2000). Tarım ürünlerindeki hasat sonrası kayıplar. Tarım Bilimleri Dergisi, 6(2),85-92.

İzli N (2007). Mısırın sıcak hava akımıyla kurutulmasında kurutma parametrelerinin belirlenmesi (Master's thesis, Bursa Uludag University, Turkey).

İzli N, Polat A (2016). Effect of freeze drying method on drying characteristics, colour, microstructure and rehydration properties of ginger. Journal of Agricultural Faculty of Gaziosmanpasa University, 33,126-136

Izli N, Polat A (2019). Freeze and convective drying of quince (Cydonia oblonga Miller.): Effects on drying kinetics and quality attributes. Heat Mass Transfer, 55,1317-1326.

Kader AA (2002). Postharvest technology of horticultural crops (Vol. 3311). University of California Agriculture and Natural Resources.

Leibowitz W (2006). Freeze Dried Fruit vs. Fresh Fruit: Which is Better for You?. A Guide to the UPS and Downs of Fresh and Dried Fruit, San Francisco, Ca.

Mundada M, Hathan BS, Maske S (2010). Convective dehydration kinetics of osmotically pretreated pomegranate arils. Biosystems Engineering, 107,307–316.

Sacilik K. (2007). Effect of drying methods on thin layer drying characteristics of hull-less seed pumpkin (Cucurbita pepo L.). Journal of Food Engineering, 79,23-30.

Thorat ID, Mohapatra D, Sutar, RF (2012). Mathematical Modeling and Experimental Study on Thin-Layer Vacuum Drying of Ginger (Zingiber Officinale R.) Slices. Food Bioprocess Technol 5,1379–1383.

Vadivambal R, Jayas DS (2007). Changes in quality of microwave-treated agricultural products—A review. Biosystems Engineering, 98(1), 1-16.

Xie L, Mujumdar AS, Zhang Q, Wang J, Liu S, Deng L, ... & Gao ZJ (2017). Pulsed vacuum drying of wolfberry: Effects of infrared radiation heating and electronic panel contact heating methods on drying kinetics, color profile, and volatile compounds. Drying Technology, 35(11),1312-1326.

Yöney T (2005). Gıdaları dondurarak kurutup saklamak nasıl çalışır. Bilim teknik dergisi, 12, 101.

Zielinska M, Sadowski P, Błaszczak W (2015). Freezing/thawing and microwave-assisted drying of blueberries (Vaccinium corymbosum L.). Lebensmittel-Wissenschaft + Technologie, 62(1),555-563.