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Investigation Of The Effect Of Microwave-Assisted Freeze-Drying Method On Quality Properties Of Strawberry

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Abstract – In this study, frozen strawberries were dried by using freeze-drying and microwave-assisted freeze-drying methods. Microwave assisted freeze drying aims to remove the water in the product by sublimation with the microwave energy fed to the system in the microwave oven. The effects of microwave energy on the processing time and product quality were observed. The quality characteristics were evaluated with the results of the physical (color, texture) analysis and the values of the two systems were compared.

Keywords – Strawberry, Drying, Microwave, Vacuum, Color

I. Introduction

Drying is the most common method used to preserve food and improve its stability. Its general purpose is to prevent the growth and reproduction of microorganisms and the occurrence of spoilage reactions by minimizing the moisture in the food [1]. In the majority of drying processes in the industry, hot air and flammable gases are used as drying media [2]. Hot air drying causes structural changes such as collapse and shrinkage of the product under high temperature, chemical reactions such as browning, and loss of nutrients (protein, sugar, vitamin, mineral) and bioactive components. In order to improve processing capacity, process control, product quality, cost, and energy consumption, new methods have been developed as an alternative to traditional methods [3].

Freeze drying (FD) produces the highest quality food product obtainable with any drying method [4]. Freeze drying is a drying method in which the water in the product is first frozen and then sublimated under low temperature and pressure. The freeze drying method has important advantages such as the ability to preserve the original structure and color, negligible nutrient loss and excellent rehydration ability due to the porous structure of the product. However, it is a dehydration process with high energy consumption, expensive and time-consuming. Therefore, obtaining high quality final product at low cost is the most important problem of freeze drying [5].

In the microwave drying system, the electromagnetic field provides the movements of polar and polar molecules in the food. The friction that occurs as a result of the movement produces heat in the food, that is, a volumetric heating takes place. It significantly shortens the volumetric heating process compared to conventional methods. However, microwave heating can cause problems such as textural damage and inhomogeneous heating [6].

Freeze drying was supported by the heat generated by microwave drying, and the combination of two different drying systems was realized and it was named as microwave freeze drying (MFD). It has been proven by the studies that the problems caused by the microwave method in the product are eliminated, and the quality of the final product is produced and the long process time of freeze drying is shortened [7].

II. Materials and Method

The strawberries used in the experiment were purchased from a local market. Strawberries were washed and separated from rotten and crushed strawberries in the same day. Strawberries to be used in drying experiments and analyzes were stored in a ziplock bag in the freezer at -30°C.

A. *Drying Methods*

In drying systems, drying was terminated when the final moisture content of the product fell below 10%. The dried strawberries obtained at the end of the drying experiment were packaged in packages with low oxygen and water vapor permeability and stored in an air-conditioning cabinet at 20 ℃. Drying experiments were carried out in duplicate.

Freeze Drying (FD)

Freeze drying was carried out in a lyophilizer (Cryodos-50, Spain). Strawberries frozen at -30°C were placed on trays in the lyophilizer drying chamber. Drying medium; The condenser temperature was set at -45 ℃ and the absolute pressure was 0.180 mbar.

Fig. 1. Lyophilizer

Microwave Freeze Drying (MFD)

Frozen strawberries (240 g) were placed in the desiccator on the plastic basket and drying was started. It was dried by applying microwave power at a pressure of 0.6 mbar.

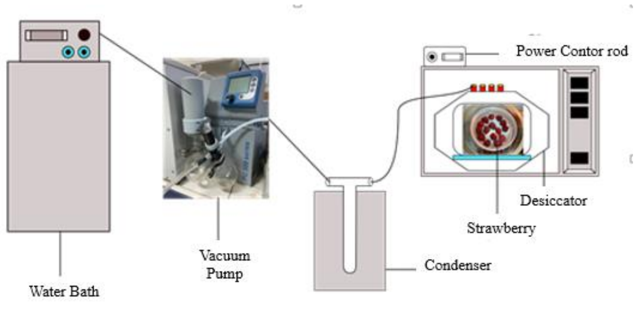


Fig. 2. Schematic image of the microwave assisted freeze drying system

Temperature Measurement

During the drying process, the temperature measurements of the strawberries were measured with fiber optic temperature probes (UMI-4, FISO, Canada).

B. *Physical Analysis*

Moisture content and water activity

After the dried samples were ground, the moisture analysis device (Radway, MA 60-3Y, Poland) device and the appropriate program for the strawberry in the data tab of the device were selected to determine the moisture value, and the measurement was made at 90 ℃. To determine the water activity value, a water activity analyzer (AG CH-8853, Novasina, Switzerland) was used.

Color measurement

Color of frozen and dried samples was measured with color mouse (CM2C, Color Savvy Systems Ltd., USA) operating with CIELAB (L*a*b*) and CIELCH (L*C*h*) three-dimensional color measurement system. Results are expressed as L*a*b* C*h*, respectively. L*(lightness): L*=0 black and L*=100 white, a*(red/green):+ red in a* direction and - green in a* direction, b*(yellow/blueness): +b* direction red and blue in the -b* direction. Chroma(C*) and hue(h*) values are calculated from a* and b* values. Chroma is also known as saturation. It is calculated with the following equation.

$$C^{*} = \sqrt{a^{*} + b^{*}}$$

Hue represents tone. It is calculated with the following equation.

$$h^{*} = \tan^{-1}\left(\frac{a^{*}}{b^{*}}\right)$$

In the CIELAB (L*a*b*) color system, the color difference of two samples can be expressed as a single value using the total color change (ΔE*) equation.

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

In equality; ΔL*=The difference between the L* values of two objects, Δa*=The difference between the a* values of the two objects, and Δb*=The difference between the b* values of the two objects [8].

Texture Analysis

Texture analyzer (TA-XT2i, Surrey, UK) was used to measure the texture of dried strawberry samples by applying the penetration test. During the analysis, the probe speed was recorded as 1mm/s before the test, the probe speed was 1mm/s at the time of the test, and the penetration depth was 15mm. Texture analysis was applied to three different whole strawberries selected after each drying experiment.

III. Results

Drying Time, Moisture Content and Water Activity Measurement

Drying times, final moisture contents and final water activity values of strawberry samples dried with two different methods, freeze drying (FD) and microwave assisted freeze drying (MFD), are given in Table 1.

Table 1. Drying times, moisture contents and water activity values of frozen strawberries and flowers dried with different methods

Drying method	System pressure(mbar)	Condenser temp.(°C)	Drying time (h)	Moisture content (%wb)	Water activity
Frozen strawberry				88,13±0,28	
MFD	0,6	-9/-11	11	6,76±0,96	0,134±0,0005
FD	0,180	-41,9	72	4,7±0,5	0,067±0,014

Color measurement

L*, a*, b*, C*, h* color parameters and one-way variance analysis results of frozen strawberry samples dried by two different methods (freeze drying and microwave assisted freeze drying) are given in Table 2.

Table 2. Color values of frozen and dried strawberry samples by different methods

Sample	L*	a*	b*	c*	H°	ΔE
Frozen strawberry	39,36^a±2,4	13,46^a±2,3	6,23^a±1,8	16,81^a±1,50	20,3^a±3,5	
FD	37,65^a±3,2	32,74^b±2,8	14,09^b±1,9	36,65^b±3,01	26,57^a±2,6	21,33^a±1,2
MFD	28,67^a±0,8	28,58^b±2,0	13,7^b±1,6	33,66^b±1,99	24,41^a±2,7	19,45^a±0,8


a

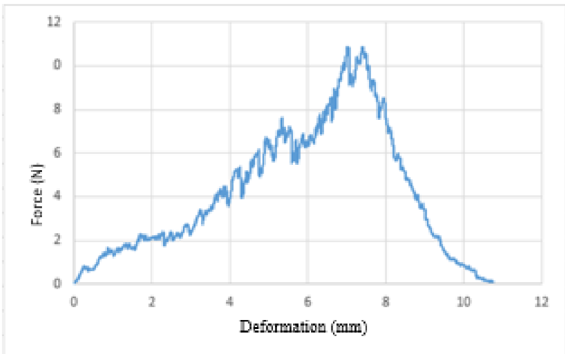

b


c

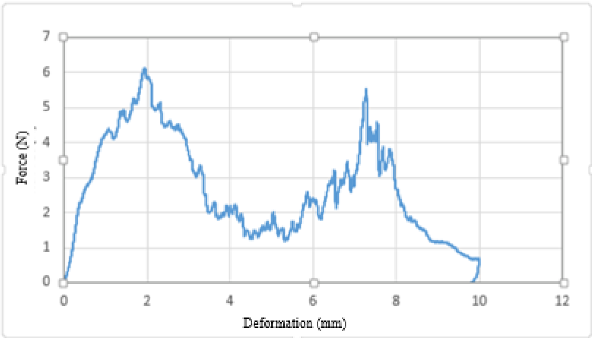
Fig. 3. Image of frozen (a), freeze-dried (b), and microwave-assisted freeze-dried (c) strawberry samples

Texture Analysis

Typical force deformation curves of freeze-dried and microwave-assisted freeze-dried strawberry samples are given in figure 4. and cross-sectional images are given in figure 5.



a



b

Fig. 4. Force-deformation curve of freeze-dried (a) and microwave-assisted freeze-dried (b) strawberry samples

a b

Fig. 5. Cross-sectional images of freeze-dried (a) and microwave-assisted freeze-drying (b) strawberry samples

IV. DISCUSSION

Drying Time, Moisture Content and Water Activity Measurement

Drying times are 72 hours with freeze drying and 11 hours with MFD drying. Supporting freeze drying with microwave reduces drying time by 84.7%.

Experimental studies have shown that MFD reduces the drying time by 50-75% compared to the traditional FD method [9].

In the study in which potato slices were dried by two different methods, the drying times of MFD and FD were recorded as 6.3 and 10 hours, respectively. MFD provides 37% reduction in drying time[10].

In another study on sea cucumbers, the FD process was carried out in a drying time of 18 hours. The drying time of the MFD treatment applied at different power ranges (1.6, 2, 2.3 W/g) varied between 9 and 11 hours. It was observed that the drying time decreased with the increase of microwave power [11].

Color measurement

The fact that freeze drying results in a higher L* value compared to other drying methods is attributed to the low amount of oxygen in the drying medium [12]. Among the drying methods, another factor that causes the formation of samples with low L* value in dark color is temperature. For this reason, microwave-assisted freeze-drying causes the L* value to decrease with the temperature increase created by the microwave in the product [13].

Freeze-dried and microwave-assisted freeze-dried strawberry samples resulted in higher a*value than the frozen strawberry sample. Jiang et al. [14] dried okra with various techniques and explained that the brightness and redness values of the samples dried with the MV technique decreased. They stated that the reason for this decrease, by showing the non-homogeneous heating of the sample, can be attributed to this situation.

Freeze-drying preserved the integrity of the product and the red color of the product, creating products with the appearance of fresh strawberries. . In the microwave-assisted freeze-dried samples, darkening occurred in some areas on the samples due to the inability of microwave drying to provide homogeneous heating.

Texture Analysis

Hardness; It is defined as the resistance power of the product against the applied effect [15]. Freeze dried strawberries max. It has a value of 10.87 N and max. It has a harder structure than microwave-assisted freeze-dried strawberries with a value of 6.08 N.

In Figure 4. cross-sectional images of strawberry samples dried by MFD and FD methods are given. In the samples dried with MFD, a large porous structure is formed with a hollow inside. Supporting freeze-drying with microwave can be explained by the fact that the internal pressure inside the product is higher than the external pressure as a result of the heating in the product. Thus, the first of the peaks observed in the MFD force deformation curve is caused by the outer shell and the second peak is due to the inner membrane.

V. CONCLUSION

Samples dried by microwave assisted freeze-drying provide physical quality properties close to those dried by freeze-drying. In addition, the MFD system provides a significant advantage in shortening the drying time to a great extent. According to the results, it has been shown that MFD drying can be an alternative drying method to freeze drying by saving time and energy in drying frozen products.

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