The Effect of the Drying Method on the Quality of Dried Kiwi Slices

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Abstract— **Drying is known as a food preservation method which increases the food's storage time by water reduction. Traditional drying consisted of open sun-drying, but different industrial dryers have been widely used in recent times. The new dryers consist of convective, infrared, ultrasound, freeze fluidized bed and freeze dryers. All of these dryers reduce the water content but under different mechanisms which leads to the end products with different qualities. In this study we aim to compare the difference in quality of kiwi fruit slices dried by three different dryers: 1. Convective tray dryer, 2. Microwave dryer and 3. Freeze dryer. The tray dryer experiments were conducted in two air temperatures of 60 and 80°C in the constant air velocity of 0.8 m/s. The microwave dryer operated in 3 output powers of 180, 270 and 360 W. The condenser temperature and pressure in the freeze dryer reduced to -50°C and 0.1 mbar, respectively. The operating conditions and time were regulated so that the moisture content of all dried samples reduced to nearly 10% in the wet basis. The three parameters of color change, ascorbic acid and antioxidant reduction were selected as the measuring criteria for the comparison of the product qualities. The experiments show that the freeze drying caused the minimum color change while the microwave drying in the maximum power of 360W caused the maximum amount of color change. The concentration of ascorbic acid was measured in the fresh fruits and dried samples by standard methods. The measurements proved that the ascorbic acid content of the freeze dried samples was 80% of the fresh fruits. The ascorbic acid content of other samples was much lower. The antioxidant activity of the dried samples and the fresh fruits was also measured by standard methods and the experimental data also showed that the freeze drying causes the minimum reduction in the antioxidant activity.**

Index Terms: **Drying method, kiwi fruit, drying quality, convective dryer, microwave dryer, freeze dryer.**

I. INTRODUCTION

The kiwifruit was first cultivated in China, but its cultivation is now common in many other parts of the world including Iran. Due to high level of vitamins, potassium, and fiber, kiwifruit is considered as a highly nutritional product.

The kiwifruit consumption is recommended for its benefits and industrial potential values [1]. The kiwi fruits are reported to have antioxidant effects which prevent certain diseases caused by oxidative stress [2]. It is even known that kiwi fruit smoothies may maintain a high level of antioxidant activity and prevent the heart diseases [3]. Due to the short shelf-life of this kind of fruits, they cannot be stored for long periods without refrigeration or drying [4].

Dried food is preserved by reducing the water content due to simultaneous heat and mass transfer processes. Drying is a food preservation method which minimizes the biochemical, chemical, and microbiological changes by removing the water content. Drying may be considered as one of the oldest chemical processes used by man. The ancient method of drying which is still customary in under-developed countries suffers from important problems such as lack of ability to control the drying operation properly, the length of the drying time, weather uncertainties, high labor costs, large area requirement, insect infestation, mixing with dust and other foreign materials and so on. Drying of the food products is reported to improve the food stability due to the reduction of water content and microbiological activity of the food material. This process also minimizes the un-pleasant physical and chemical changes during the storage, reduces spoilage and increases the shelf life, without chemical treatments [5].

The new techniques of drying such as infrared drying, freeze drying or microwave drying have been popular because of certain advantages over traditional methods including shorter drying time, high energy efficiency, higher product quality and temperature uniformity [6-7]. Microwave heating and drying technology has influenced the food industry due to its advantages such as rapid speed and great convenience. This technique has also been widely used for domestic food heating, reheating, cooking, and drying [8]. Energy may be supplied with microwaves to accelerate the drying process substantially, due to the providing of more energy inside the product. This technique may also provide more heating which causes the temperature rise needed for water evaporation [9].

The microwave dryer used in this study was the modified form of a commercial microwave dryer. The technical features of this constructed laboratory scale microwave dryer may be listed as follows: the turntable motor used in this work are 2.5/3 R.P.M., 50/60 Hz and 240Vand the turntable motor is installed on a digital balance by stool. Turntable hub is caused to swirl the rotating plate to ensure that the samples are dried evenly on all sides. A fan installed on the top of the microwave oven to circulate the inside air. A photo of the experimental set-up is shown in the Fig. 1.



Fig 1. Microwave Dryer.

Another well-known modern dryer for food materials may be the freeze dryer. Freeze-drying is a well-known dehydration process in the food industries because of its ability to preserve the biological activity of thermo-sensitive components and the original nutritional properties of the food materials. Another advantage of the freeze–dried materials may be the extended shelf-life [10].

Freeze-drying is reported to retain the quality of dehydrated materials such as the appearance, nutrients and flavor. The freeze-dried products are well-known for their high rehydration capacity [11-12]. The freeze –drying process consists mainly of freezing and dehydration under reduced pressure. The ice nucleation and growth during freezing directly impact the morphologies of the freeze-dried matrices [13].

In order to compare the quality of the infrared-dried and freeze-dried products with commercial air dried products, we have used a standard laboratory scale convective tray dryer. This dryer (UOP 8 Tray Dryer, Armfield, UK) has the overall dimensions of 1.40m in height, 2.95m in length and 0.73m in depth. The dryer consists of a floor standing tunnel, in one end of which is mounted an axial flow fan with a bank of electrically heated elements mounted at the end of the fan before the drying chamber. The chamber contains a rack of trays suspended from a balance (AND EK-6000i, Japan; 0.1 g accuracy) mounted on the top of the dryer. The weight of the samples is continuously determined and displayed by the balance. The air flow velocity is measured by a digital anemometer (Air flow, LCA 6000 VT; 0.01 m/s accuracy). Ducting upstream and downstream of the dryer is so that provides a uniform air flow. Figure 2 shows this standard tray-dryer.

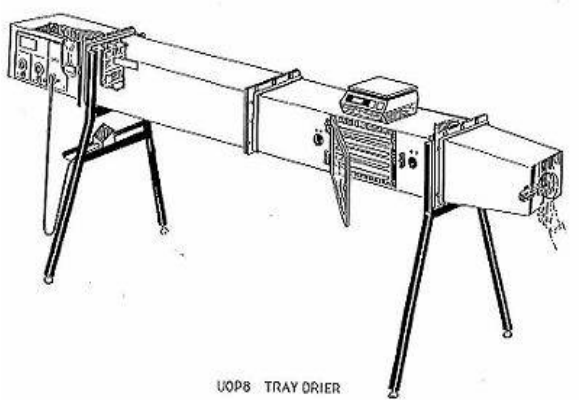

Fig 2. Standard Tray Dryer.

In this study we aim to compare the quality of dried kiwifruit slices produced in three different dryers. These three dryers include the laboratory scale tray dryer, microwave dryer and the freeze dryer.

II. MATERIALS

The kiwifruits were purchased from a local market in Babol, Mazandaran, Iran which is the most important kiwifruit producing area of the country. They were placed in a refrigerator in $^{0}5$ C before being peeled. Then the peeled fruits were divided into small pieces with 5 mm thickness and the average moisture of 82.38% (wet basis). Fresh kiwi fruit slices are shown in the Fig 3.



Fig 3. Fresh Samples of Kiwifruits.

III. THE EXPERIMENTAL PROCEDURE

The tray dryer experiments were run in two different temperatures of 60 and 80 $^{0}5$ C with constant air flow velocity of 0.8 m/s. It is reported that the air temperature may influence the drying kinetics and product quality [14]. The microwave dryer worked in three different power levels of 180, 270 and 360 W. It is also reported that the microwave power may influence the drying kinetics and product quality [15]. The temperature of the freeze dryer (the temperature of the condenser) was set on the -50 $^{0}5$ C and the vacuum pressure of 0.1 mbar. The drying time was so designed to reach the final moisture content of 10% (wet basis) for each method.

Finally, the color, Ascorbic acid content and the antioxidant content of the dried materials were selected as the quality measures for comparison of the three drying methods. These

quantities are considered by several researchers as the main measures for the quality of the dried samples.

A. Color Analysis

The color of the fresh and dried kiwifruits was determined using Minolta CR-400 calorimeter (made in Japan). All of the experiments were repeated 3 times and the averaged values were reported as the final values [16].

B. The Ascorbic Acid determination

The Ascorbic acid content was measured according to a standard procedure (the color change of DCPIP, 2,6 di CholoroPhhenol indophenol due to meta Phosphoric Acid) with a Shimadzu UV-1800 spectrophotometer (made in Japan) in the wavelength of 520 nm [17]. All of the determinations were repeated for three times and the averaged values were reported as the final results.

C. The Antioxidant Activity determination

The antioxidant content of the samples was determined by another standard procedure (the color change of DCPIP, 2,2 di Phenyl Pycryl Hydrazyl) with a Shimadzu UV-1800 spectrophotometer (made in Japan) in the wavelength of 517 nm [18]. All of the determinations were repeated for three times and the averaged values were reported as the final results.

IV. RESULTS AND DISCUSSIONS

A. The Color Change Results

It was found that the samples dried by the freeze dryer showed the least color change during the drying process. The degree of the color change is related to the microwave power level and the air temperature of the tray dryer. The samples dried with the highest microwave power level or air velocity showed the sharpest color change while the color change of samples dried with lower power level or air velocity was not so sharp. Figures 4-8 show some of the dried samples by different methods. The different colors of the samples are clear and may be observed without standard colorimetric analysis.

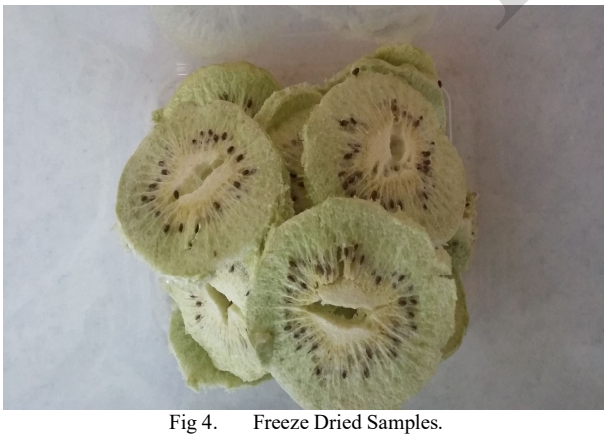

Fig 4. Freeze Dried Samples.



Fig.5. Air dried samples at 60^0 C.



Fig 5. Air Dried Samples at 800 C.



Fig 6. The Microwave Dried Samples at 180W



Fig 7. The Microwave Dried Samples at 270W

It is clear from these figures that the freeze dried samples maintain their original color while the air dried or microwave dried samples experience sharper color changes, but we have also used a more scientific approach and the different color parameters have been determined and reported in the table 1.

Table I. The Color Analysis of the Samples

Drying Method	Color Parameters					
	L^*	a^*	b^*	C	α	ΔE
Fresh	53.5	-3.9	27.3	27.5	-1.43	-
Hot air drying 60^0C	48.1	1.24	37.2	37.2	1.54	12.1
Hot air drying 80^0C	47.3	3.78	36.2	36.4	1.47	13.3
Microwave 180W	47.0	2.27	36.4	36.4	1.51	12.8
Microwave 270W	42.8	2.84	31.7	31.8	1.48	13.4
Microwave 360W	33.2	3.5	28.4	28.6	1.45	21.7
Freeze drying	57.7	-3.22	31.9	32.1	-1.47	6.3

The parameter a^* stands for (red/green) colors, b^* stands for blue/yellow colors and L^* stands for lightness/darkness of the samples. The other parameters ($(C,\alpha,\Delta E)$ stand for the color changes of the samples.

These parameters may be calculated by the following equations:

$$\Delta E = \sqrt{\left(L^* - L_0^*\right)^2 + \left(a^* - a_0^*\right)^2 + \left(b^* - b_0^*\right)^2} \quad (1)$$

$$C = (a)^2 + (b)^2 \quad (2)$$

$$\alpha = \tan^{-1}\left(\frac{b}{a}\right) \quad (3)$$

Where the parameters L_0^*, a_0^*, b_0^* refer to the fresh kiwi fruit samples.

Checking the colorimetric parameters of the table 1 clearly confirms our observations that the freeze dried samples show the lowest color change with respect to the fresh samples.

For example consider the parameter L^* which is equal to 53.5 for the fresh samples. this parameter is equal to 48.1 for hot air drying in 60^0C, 47.3 for hot air drying in 80^0C, 47.0 for microwave drying with 180W power, 42.8 for microwave drying with 270W power, 33.2 for microwave drying with 360W power and 57.7 for freeze dried samples. These results clearly show that the color change of the freeze dried samples is not so sharp and increasing the air temperature or the output power causes a more severe color change in air dried and microwave dried samples, respectively.

B. The Ascorbic Acid Results

The results showed that the ascorbic acid contents of all of the dried samples decreased but the ascorbic acid content of the freeze dried samples remained on the 80% of fresh kiwifruits.

The decrease in the ascorbic acid content of the samples was sharper at higher microwave powers for microwave drying and higher air velocities for tray dryer and the samples dried in lower air velocities or microwave powers maintained higher percentages of the original acid ascorbic content.

Fig. 9 shows the amount of residual Ascorbic Acid(ASA) content in the freeze dried, air dried in different air temperature and microwave dried in different output powers. It is clear that the ASA content of the freeze dried samples are the highest and rising the temperature or the microwave power lowers the residual ASA content.

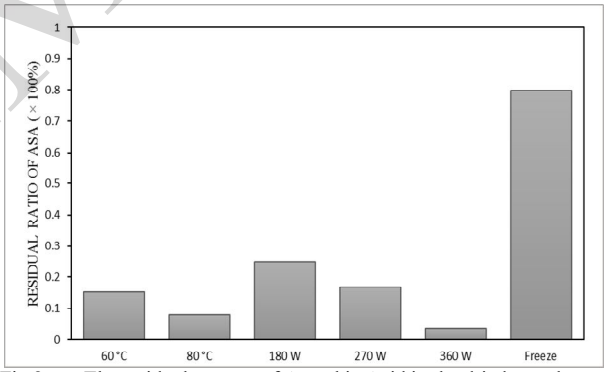

Fig 8. The residual amount of Ascorbic Acid in the dried samples

C. The Antioxidant Results

The antioxidant activity of the fresh samples was found to be lower due to the high moisture content of the fresh kiwi fruits. The antioxidant activity of the dried samples was higher which may be the result of the thermal processes and chemical reactions during the drying.

Fig. 10 shows the ratio of the antioxidant activity of the different dried samples compared to the fresh kiwi fruits. It clearly shows that the antioxidant activity of all of the dried samples is increased but the maximum increase belongs to the freeze dried samples. Again it can be observed that drying at higher temperature or output microwave powers leads to the substantial decrease in the antioxidant activity.

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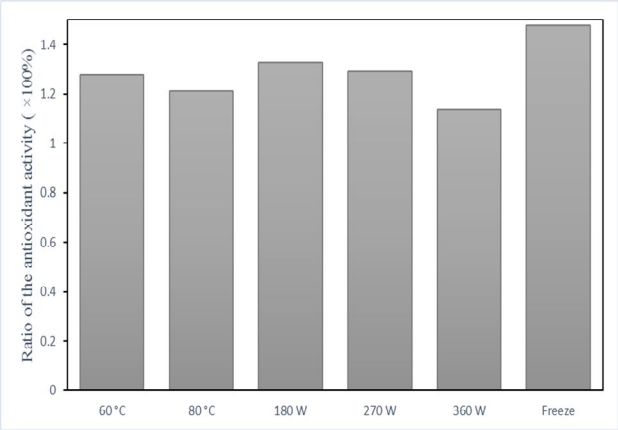

Fig 9. Ratio of the Antioxidant Activity according to the fresh samples.

V. CONCLUSIONS

This work clearly shows that the drying method has a sharp influence on the different quality aspects of the final dehydrated products. These differences may be very important for the market because of the nutritional values, the taste and the color and the appearance.

The kiwifruit samples dried by the freeze drying method preserved the original color and other quantities very better than the air dried or microwave dried samples.

The ascorbic acid (ASA) content of all the dried samples decreased but this decrease was not so distinct for the freeze dried samples. The experimental results also showed that more severe drying conditions such as higher temperatures or power levels leads to lower ASA content.

The antioxidant quantity of all of the dried samples increased, but the freeze dried samples showed the largest increase in the antioxidant activity. Again it was shown that more severe drying conditions such as higher temperatures or power levels may lead to lower antioxidant activity.

It may be concluded from this work that the freeze dried samples show the most valuable properties, but from realistic point of the view, the industrial manufactures still have some doubts about this drying method. The weak point of the freeze drying method is its high cost and lower production rate which are very important for the industrial producers. The most economic drying equipment may still be the traditional well-known tray dryer which removes the moisture content using a hot air stream, but this work and similar published works prove the superior quality of the freeze dried products. This fact may pave the way for application of more economic wide-scale freeze drying processes.

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