

INVESTIGATION OF MICROWAVE APPLICATION IN AGRICULTURAL PRODUCTION DRYING

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Abstract: Drying is one of the conventional methods in order to maintain the food in which due to lower product moisture content, it minimizes the rate of reactions and undesired microbial activity and increases the storage time by maintaining the appearance of products. In the present research, in order to evaluate drying of apple slices, undergoing microwave method, one microwave drier was designed and manufactured. In the manufactured drier, one circuit was employed for feeding Magnetron lamp with nominal power of 1.3 kW and frequency of 2.45 GHz in order to produce microwaves. This drier is capable of controlling microwaves power and during drying process, changes in mass and total consumption power can be simultaneously measured. The research results showed that increasing microwaves power causes the drying time to considerably reduce and drying rate to increase. minimum drying time occurs in the highest microwave power. But after reviewing the images on the product quality testing, it is determined that the quality of products can be impaired in high microwave power.

Keywords- Drying, microwave power, drying time, drying rate, apple.

I. Introduction

Drying is one of the earliest methods for increasing the storage time of product by decreasing its moisture content. thus the growth of undesirable micro-organisms and the chemical reactions are minimized and its shelf-life increase (Barbosa and Mercado, 1996). Due to decrease in thermal conductivity of foods in descending period rate of drying process with convection method, the rate of heat transfer to the inner parts of food is reduced (Adu and Otten, 1996 and Feng, 1998). In order to overcome these problems and reduce the drying time to achieve an efficient and rapid heat transfer process, the use of microwaves for drying food has been developed. Microwave is a rapid method for drying food. Drying out the moisture with microwave is faster and also due to the energy concentration, microwave system requires only 20% to 35% space compared to other drying methods (Maskan, 2000). Microwave drying process is a relatively inexpensive method that has attracted the attention of many investigators. In microwave drying, the heat is resulted from the conversion of microwave energy into thermal energy within the moist materials and provides desired heat and pressure in order to dry material quickly (Zirjany and Tavakoli, 1389). The less is the drying time period, the less is reduced production costs (Tavakoli et al, 1387).

Passing the electromagnetic microwaves with long wavelength (frequency 2450 MHz) through food texture, polar molecules such as water and salt vibrate and this vibration causes the conversion of microwave energy into heat. It should be noted that in this method unlike other drying methods in which the heat must diffuse from the surface to depth, the heat is produced in the food texture. Thus, this method prevents the damage and burn to surface area of food (Funebo et al, 2000 and Prothon et al, 2001).

Electromagnetic spectrum penetrate the product between 300 MHz and 300 GHz frequencies, make the material's molecules move by changing their polarity and spread the heat throughout the food by creating friction between molecules (Motevalli et.al, 1388). Unlike conventional heating systems, because of microwave diffusion into the food, the heat is spread throughout the food. In this regard, heat transfer in the microwave method is faster than other methods (Mertens, 1992 and Abbasi, 2007). Microwave drying method has many advantages such as high-speed operation, energy savings, accurate process control, faster startup and automatic shutdown in comparison with other methods (Meredith, 1998 and Datta and Anantheswaran, 2001 and Botha et. al., 2011). Change in microwave power and consequently change in the energy required for drying, increases drying rate (Botha et.al., 2011).

Khoshtaghaza et.al, in 1389, in a research titled "Drying kinetics of pomegranate seeds and the energy consumption in microwave drying method", investigated the effects of various drying conditions on product's quality, moisture elimination and effective diffusion coefficient, determination of the best mathematical drying model and determination of activation energy values and energy consumption in two species of sweet and sour pomegranate using microwave dryer.

In 2008, a paper was presented by Karaaslan and Tuncer in order to investigate the effects of the microwave power change in microwave, convection and combined microwave and convection methods on drying time, evaporation rate and color changes. They concluded that in these three methods, changes observed in drying time, evaporation rate and color make clear the major impact of microwave power and drying methods on the aforementioned parameters.

Al-Harashsheh et al in 2009 investigated the kinetics of drying tomatoe by microwaves, results showed that increasing microwaves power, decreases the drying time.

In another study by Salimi et al (2009), the effect of dryer (hot air flow and microwave) on the main composition and water reabsorbing capacity of dried potato products were investigated and the results showed that the microwave maintain the value and texture of food products due to drying time reduction.

II. Materials and Methods

To implement this plan, a dryer was constructed by the investigator according to figure (1), including a microwave generator, product container and control panel.

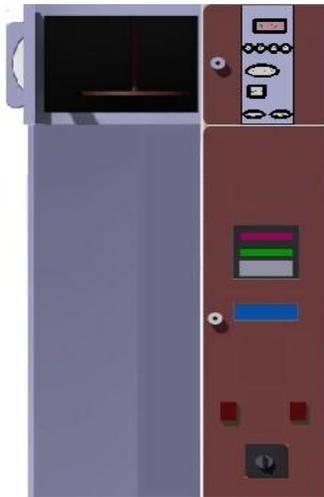


Figure1. A schematic of manufactured drier (front side of product container and control panel)

A magnetron lamp with nominal power of 1.3 kW and frequency of 2.45 GHz is used in the dryer for microwave production (figure 2). Magnetron lamp that actually acts as an electron accelerator is supplied by high voltage circuit. The designed circuit includes a 1:10 transformer and also a LC circuit which doubles voltage. After the 220 volts AC power passes through the transformer and LC circuit, it is converted to 4500 volts which is the threshold voltage of magnetron lamp. Since some heat is produced during operation of magnetron lamp, one fan is used to cool it down. For applying necessary settings on the microwave generator, a control panel is used. Through this board, microwave applied power during operation and microwave magnetron lamp operation time can be controlled.



Figure 2: magnetron lamp

The product container is designed as a cube according to the type of magnetron tubes used in the dryer. Since the microwave does not have the ability to pass through metal, the container is made of galvanized sheets. Because of the polarity

of metal molecules and their reaction to microwave, the interior body of container is covered by paint. For simultaneous measurement of product mass during drying process at desired time intervals, one load cell (sewhacnm, AB120) with accuracy to 1gr was used. Product tray was hanged from load cell by a connector that passes through a hole above the container. One inherent disadvantages of microwave is its inconsistent distribution inside the drier container. To overcome this problem, one engine was employed to rotate the product tray with constant speed to avoid heating some part of product too much (figure 3).

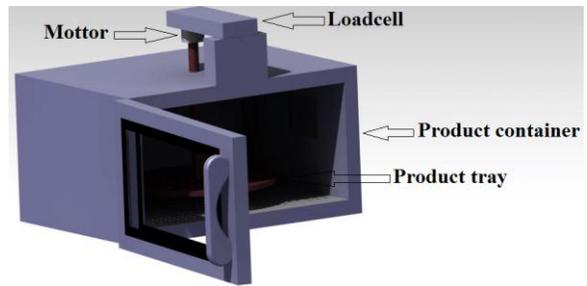


Figure 3: product container, product tray, loadcell, mottor

For evaluating operation of manufactured drier, apple slices of Golden Delicious were used for experiments. Apples were provided from the West Azerbaijan's orchards in Iran and they were kept in cold storage to maintain the initial moisture content. Before the experiment, the initial moisture content of apples was calculated according to standard (AOAC, 1980) by vacuum oven fan and obtained at about 74.82%. In the beginning of the tests, apple skins were removed by sharp knife and then cylindrical apple slices with 4 mm thickness were prepared by a slicer. Apple slices were dried in 10 samples and 4 replications by microwave to 20% moisture content (wet basis). Some of the tested apple samples are shown in figure (4).

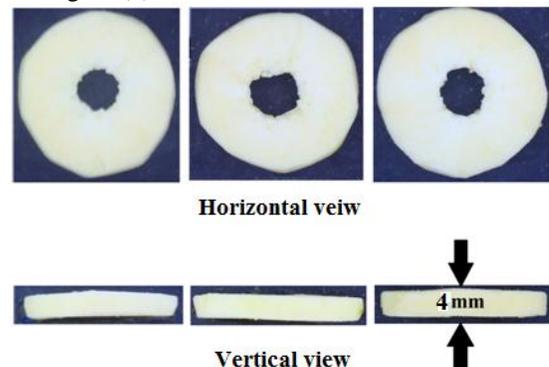


Figure 4: the images of the tested apple samples

experiments have been performed at four microwave power levels of 500, 1000, 1500 and 2000 W. moisture ratio and drying rate were studied for experiments. Moisture ratio is an important factor in controlling drying process. Drying rate is also defined as the amount of moisture emerges from product per unit time and is an important factor in description of drying process. Dimensionless moisture ratio (MR) and drying rate (DR) in terms of (kgr moisture/ kgr dry product ×second) are obtained by below equations (Kaya and Aydın, 2009):

$$MR = \frac{M - M_e}{M_o - M_e} \quad (2)$$

$$DR = \frac{M_{t+\Delta t} - M_t}{\Delta t} \quad (3)$$

Where M , M_o , M_e , $M_{t+\Delta t}$ and M_t represents respectively instantaneous moisture, initial moisture, equilibrium moisture and moisture at the moments of $t+\Delta t$ and t in terms of (kgr moisture/ kgr dry product) and t is drying time in terms of second.

To compare the microwave energy consumption in each experiment, at the end of experiments the number indicated by the power meter, were recorded.

III. Results and discussion

Inorder to investigate effects of microwave power on drying process of apple, The experiments were carried out in four microwave power levels of 500, 1000, 1500 and 2000 W. Results showed that drying time reduces when microwave power increases and the minimum drying time corresponds to the highest microwave power. As shown in figure 5, along with microwave power increase from 500 to 2000 watts, drying time drops more than 105 min.

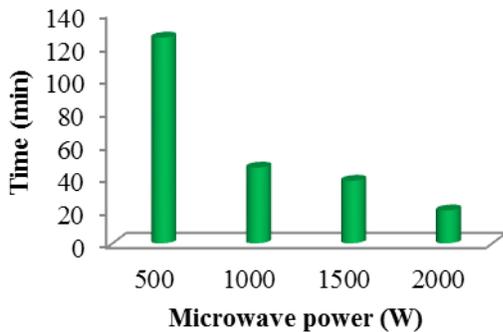


Figure (5): Drying time changes with microwave power

Product moisture ratio Changes as a function of drying time in microwave drying can be divided into three steps (figure 6). Initially moisture ratio of product decreases slowly (until point A) while the product is being heated. Then, moisture ratio decreases progressively (until point B). This step, during which a part of drying process occurs, is the drying process with constant rate. Then decreasing step of drying process begins during which moisture ratio decreases with a decreasing slop until the end of process. This result is in agreement with results obtained by Al-Harashsheh et al (2009) in drying process of tomato.

Based on Figure 6, it is obvious that increasing microwave power has a important effect on reduction of drying time. For example, when power is increased from 500 w to 2000 w, drying time reduces from 125 min to 20 min (figure 12). Consequently, process time until desired moisture content is decreased to one-sixth.

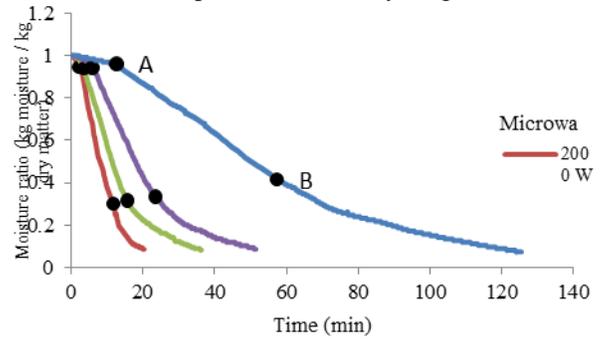


Figure (6): Changes of moisture ratio of product as a function of drying time in microwave drying process with different powers

Figure 7 shows that when the product is being heated, drying rate increases until it reaches a maximum point and then drying process continues with a constant rate slope and then a drying process continues with a constant rate slope during a small time interval. Next step is the decreasing step of drying process during which a reduction in drying rate continues till the desired moisture content is achieved. Effect of increasing microwave power on decreasing drying time and increasing drying rate is clearly observable such that increasing microwave power causes drying rate to have higher slopes in all steps of drying. This can be attributed an increase in internal temperature of the product due to rising microwave power and consequently increasing moisture gradient.

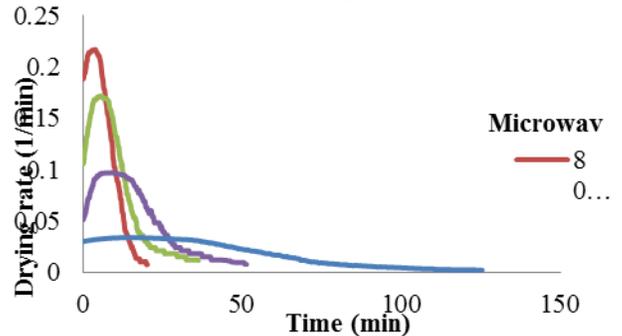


Figure (7): Changes of drying rate versus drying time in microwave drying method with different powers

As it is illustrated in figure (8), the lowest energy consumption and drying time carry out in power 2000 watt. In other words, increase microwave power leads to energy drying time reduction. Thus, energy consumption is reduced.

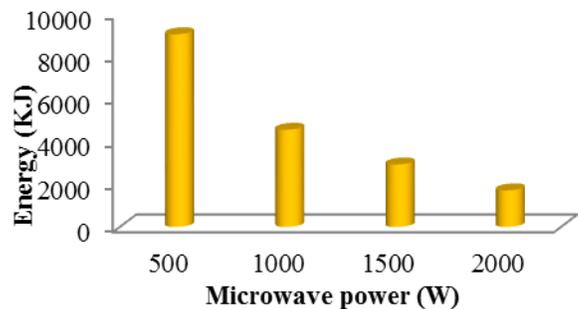


Figure (8): Changes of energy consumption with different powers

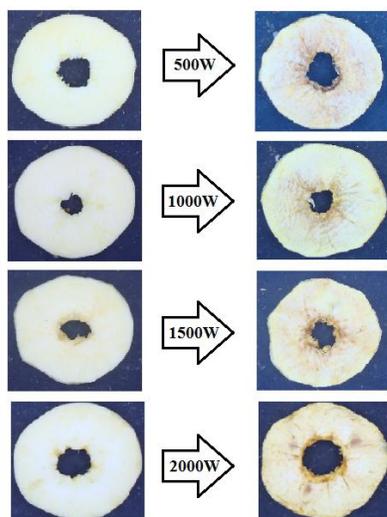


Figure (9): the images of the product, before and after the drying process

Another issue that is discussed in this paper is the effect of microwave power on the quality of the product. The dried product quality, including the amount of shrinkage, color change, and the volume change is much more desirable in the microwave drying compared to conventional methods. This could be resulted from the short drying time and also heat creation inside the product and drying the product within the volume and prevention of damage to the surface. Images of the product, before and after the drying process in four power levels are presented in figure (9). It should be noted that all the above tests, which were numerically investigated, were also studied in this step, but due to limitations in this article only the results of four experiments are presented. according to the figure (9), high microwave powers can result in deformed surfaces and shrinkage in the product. An increase in microwave power can reduce the dried product volume adversely, which can be resulted from the high rate of water discharge in the product pores. Finally, based on the images of the experiments conducted in this study, it can be stated that although the high microwave power decrease the drying time, the high microwave power can damage the product quality.

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