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The effect of microwave power on the drying time of the egg tray

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ABSTRACT

Today, drying with microwave is used for many products as an alternative to traditional drying methods. In our country, drying studies are mostly performed in the food sector. The drying process with effective heating power of microwaves take place quickly. Thus, along with faster production, costs reduce and more environmentally-friendly production occurs.In this study, drying studies of egg tray have been performed with different magnetron (MGN) output powers and belt speeds. The effect of microwave power on the drying time of the egg tray have been examined.

1. Introduction

Microwave technology which firstly were used in studies on the design and production of military equipment during the Second World War, has been developed in time and continued to be used in different areas. These areas; food processing (heating, defrosting, quality control, and etc.), drying of industrial products (paper, wood, etc..), acceleration of chemical reactions (micro-reaction control), the melting of industrial products (glass, rubber, slurries), sintering (ceramic, metal powder), plasma production, mineral processes (rock breaking, crushing), waste treatment and recycling processes.

In western countries, although drying process on the materials with the microwave method has been performing in different industrial areas since half a century, in Turkey, drying with the microwave method is mostly applied in the food industry.

MW (microwave) drying method, along a certain medium, does not depend on heat transfer. In this method, because of the heat is directly generated on the material, heating, not on the surface of the material, but simultaneously starts on each point of it. Therefore, according to the traditional drying methods, besides the effect of heating is very fast and uniform, its heating efficiency is also high. The basis of the MW drying technique depends on ensuring the water molecules to act quickly by polarizing them, whereby the resulting molecular friction is to create thermal energy. That is to say, the water molecules are directly heat up and evaporate during drying.

Basically, the raw material used to create the egg tray is the paper (torn into pieces), and, very small amounts of aluminium oxide and paraffin are added into it, then it is mixed with water (≅%75). The mixture that was made into a pulp is sent to the oven after taking shape of egg tray into the molded fiber plates for drying process. In industry, egg tray drying process is made by traditional drying systems. In the traditional drying systems, the important part of the energy consumed is ensured through the natural energy sources (coal, natural gas, etc.) Nowadays, which the energy sources is rapidly declining, efficiently usage of existing energy sources is important.

In terms of shape, egg tray that is not smooth is a material having sharp corners. In this regard, drying the egg tray by MW and determining parameters/optimum drying model for the egg tray reveals the unique side of the study. It will be determined dry ability of the materials having no smooth surface by determining magnetron (MGN) powers and the required band speed.

The information in the analysis of the literature, it has been defined that in the drying processes performed by MW technology, in terms of shape, materials having smooth surface had been generally used and the drying materials having no smooth surface in the MW system were difficult. Many studies about the characteristics of microwave drying are available in the literature. The outstanding studies relating subject can be summarized as follows.

The study done by Eraslan, the effect of drying hazelnut with MW on aspergillus flavus fungus has been tested with different forces in

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different periods. The maximum decrease in the total amount of fungus and in the total percentage of moisture has been obtained with applying of 3x1000W power, 420 seconds. It has been observed that a decrease of % 37.2in the amount of fungus. On the contrary drying in the sun, that it is possible to obtain a better quality product by drying MW has been concluded [1].

In the operation for drying Macadamia nuts by using MW energy, the drying time has been realized in a shorter time (4.5 to 5.5 h) than the necessary drying time by the conventional hot air drying (144 h). At the same time, applying MW for the drying process is a proposed method and when comparing with features obtained by using conventional drying processes, that it is effective in protecting the natural characteristics of Macadamia nuts has been indicated [2].

Shivhare, in his study called "Drying Corn with MW", studied different drying methods, and as a result of these methods, equilibrium moisture content has experimentally been determined. In the study, it has been determined that even after applying of 72 h MW to corn, the corn has completely not dried and as the air velocity increases equilibrium moisture content increases, as the power of MW increases, it decreases [3].

In their study, Hansson and Antti have dried Norway Spruce Wood with MW and conventional air, then compared the effects of these two applications on resistance of the wood. In tests done after both drying methods were completed, they have reached the conclusion that there was no difference in the resistance of the wood [4].

Kumar, in his study entitled "The Effect Drying with MW on Paper Properties", in the 400 W and 700 W power MW system, it has been tried to determine physical and visual characteristics of the paper and compared with environmental air dryings. According to other drying systems, that with MW drying system, a decrease of 5-7% in structural strength, 2-4% in density, the amount of breaking elongation was further than the amount in the same density have been seen. The result that the MW drying system realized better quality drying process has been reached [5].

The study in which drying of parsley done in a pilot-scale dryer with convection MW band, it has been investigated that the effects of the pulse rates applied in drying products with a combination of hot hair with discrete MW on energy consumption of the dryer, drying time and colour quality of dried product. In drying trials, hot air obtained via infrared heaters and discrete MW power have been applied together. MW energy has been applied as pulsating/intermittent, by adjusting start and stop times of the dryer MW generators with a special control equipment. Applied pulse rates (open, sec/off, sec) have been adjusted as 15/30, 30/30, 45/30 and 60/30, respectively. As a result of experiments, it has been mentioned that as pulse rate increased electricity consumption of the dryer increases with the same band speed, whereas, the resulting humidity achieved and the colour quality of the product in dried products decreased. In this study, it has been defined that to dry product to levels of 10%, the optimum results in terms of the time required and electrical energy consumption values of system has been obtained with MW drying method with hot air and 30 h active, 30 sec passive pulsating at 0.133 m/min band speed. According to the result of this studying method, it has been reported that the time required to dry product up to the humidity 10.48% ± 3.43 of which last value for humidity, was 41 minutes, and 3.02 kW of electrical energy consumed [6].

In the study entitled "Drying Spinach With Microwave", spinach weights has been determined as 50 g and drying studies have been carried out in the MW oven between 90 and 1000 W and with 8 different MW power levels. Drying periods varied in accordance with MW power level between 290 and 4005 seconds. It has been emphasized that the best quality, colour and ascorbic acid values have been observed at the period of 750 W MW power [7].

As a result of the study done on drying leeks, red and green peppers, eggplant, onions and potatoes with MW by selecting the appropriate power level, it has been concluded that drying was possible in a very short time with regulations preventing vegetables from reacting with MW, without loss of quality. As a result of drying, it has not been fixed that there were any adverse changes such as burn spots, colour fading, changes of typical smell and taste. Drying methods have been compared and it has been concluded that drying time with MW occurred in a short time ranged from 1/5 to 1/12 compared to convection drying [8].

In the study entitled "Drying Apple with Hot Air and MW", a system combining with hot air and MW was established for drying and studies have been done on this system. Drying experiments have been carried out at temperatures of 25, 30, 40 and 50 ^{0}C, on different scales of 3, 5, 7, and 10 W/g MW forces. It has been proposed an experimental model in terms of using fresh apples, air temperature values, estimating drying costs with MW power [9].

Güven have performed a study relating to the effect of MW oven strength and quantity of product on popping character of popcorn kernel. Corn has been popped as the amount of 5 different product (10, 15, 20, 25 and 30 g) and with three different MW oven strength (540, 720 and 900 W). In this study, the volume of the pop, the rate of popped grain, the pop size of the grain, pop material and mass index of popped grain have been examined. In the study, the highest volume of pop, with an amount of 20 g of product and900 W oven power, as to the volume of the lower pop, with 20 and 25 g of the amount of product and720 W oven strength have been obtained [10].

MW drying method is not widely used in our country, however, is commonly used in developing countries, especially in the food industry to dry in shorter periods. To determine the advantages of this method, nettle leaves of which humidity content is 4.41 % has been dried until reaching the humidity content of 0.1 % by comparing the energy consumption and colour parameters in MW, convectional and vacuum drying systems. Especially experiments, to examine respectively effect of these parameters in MW and convective drying, at 4 different levels of MW power (500, 650, 750 and 850 W) and at 4 different air temperature (50, 75, 100 and 125 ˚C) have been performed. Drying periods, for MW, convectional and vacuum drying, ranged between 4 to 6, 30 and 120 and 35 and 65 minutes respectively. In this study, as the most suitable method according to drying period, colour and energy consumption values has been determined as drying with 850 W MW [11].

The samples of fresh apple puree and the samples of pre-drying apple puree have been dried in MW drier with 150, 300, 450, 600 W, respectively. The relative humidity rate of ambient is 30%. Humidity loss of the samples in the drier have simultaneously been measured with analytical balance at 1 minute intervals and recorded. It has been continued drying process until reaching final humidity of 5%. In the study, in case of studying with 150, 300, 450 and 600 W MW, it has been detected that when the samples of fresh apple puree reached the final humidity content, the total drying times were as 77, 37, 29 and 21 minutes, respectively. Similarly, in the study conditions with 150, 300, 450 and 600 W MW , it has been appointed that when pre-treated apple puree reached the final humidity content, that the total drying times were as 23, 11.5, 8.5 and 6.5 minutes, respectively. In the study, between certain MW power ranges (in this study 150 W-600 W) that increased MW output power accelerated the drying process, thus, drying time reduced has been indicated. Researchers also has indicated, to remove the last 40% of humidity content of the fresh apple puree, the drying process performed in MW with 150, 300, 450, 600 W MW powers took 31.0,15.03,11.3, 8.6 minutes, respectively. At the same time the power consumption values have been determined as 0.078, 0.075, 0.085, and 0.086 kWh. For drying pre-treated apple puree by using the same power, that drying process performed took 23, 11.5, 8.5 and 6.5 minutes, respectively, energy consumption values were 0.058, 0.058, 0.064, 0.065 kWh have been indicated. If comparison the fresh apple puree, for drying the pre-dried apple puree, it has been indicated that the drying times and power consumption decreased by 25.80%, 23.48, 24.78, 24.42, respectively. To identify drying characteristics in the best manner, the four regression equation of drying rate was found in response to drying time and humidity of the fresh and pre-treated apple purees. These findings have facilitated the design and drying operation with MW for the apple puree [12].

In this study, for drying the egg tray, drying processes with different MGN output power (175, 250, 350, 500 and 700 W) and different band speed (0.6, 1, 1.4, 1.8, 2.2, 2.4 m / min) have been carried out and the effect of MW power on the drying time has been investigated. Studying has been performed with MW oven having prototype conveyor which was specially manufactured.

2. Experimental Study

a) Test Setup:
The experimental setup is shown in Figure 1 [13].

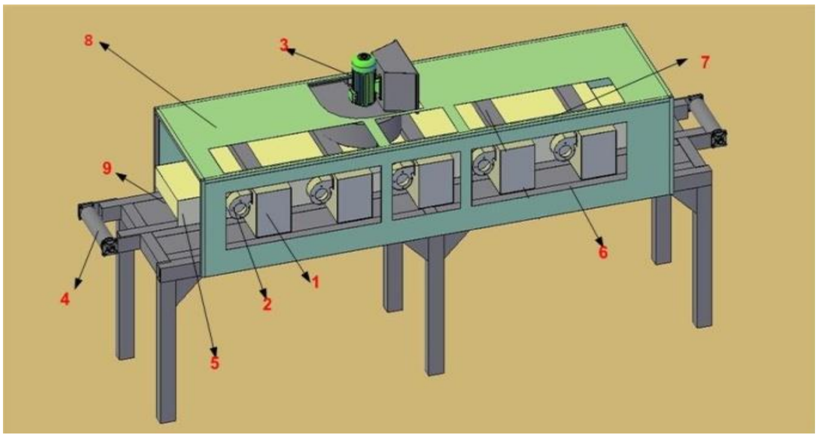

Figure 1. Specially manufactured MW oven with prototype conveyor. 1.Mikrowave generator (MGN, high voltage transformer and temperature control device), 2.MGN cooling fan, fan 3.Circulaton fan, 4.Bant system 5.Stainless interior cabin, 6.Side shuttings 7.Top shuttings, 8.Stainless outer cabinet, 9.Entery point.

Drying experiments with microwave have been performed in MW oven system with prototype conveyor which has been set up in the Heat/Energy Laboratory of the Department of Automotive Engineering, of Faculty of Technology, Pamukkale University. Band motion engine is 0.75 kW, as to cycle number is 1370 rev/min. Reducer ratio has been chosen as 1/39. 5 pieces of MGN having 700 W power with 2450 MHz with have been cooled with 5 pieces of MGN cooling fan having 18 W. To take the moisture out of the oven, 1 piece of suction fan having 1950 m^3/h capacity, running at 2735 rev/min with 380 W has been used.

With the automation created on prototype MW oven system;5 pieces of MGN with 700 W power having the same technical features can be adjusted to different output powers and depending on the location of the sample, it is provided MGNs' to start-up and cut out circuit. In this way, it is prevented from continuously running with MGNs'.

Drying experiments have been performed with different MGN power and different band speeds in MW drying system with prototype conveyor system with automation. Before and after drying, egg tray weight has been determined. Three sets of experiments have been conducted. A total of 42 models have been created.

Set 1; Drying process has been performed with 6 different band speeds (0.6, 1, 1.4, 1.8, 2.2, 2.4 m/min) and 5 equal magnetron (MGN) powers (5x175 = 875 W, 5x250= 1250 W, 5x350 = 1750, W 5x500= 2500 W, 5x700 = 3500 W). 30 models have been created in the experiments.

Set 2; According to increasing order from the entrance, the outputs power have been adjusted as 1st MGN the output power 175W, 2nd MGN's output power 250W, 3rd MGN 's output power 350W, 4th MGN 's output power 500W and 5th MGN's output power 700W. Keeping stable each of MGNs' at output power adjusted, drying experiments have been performed with different 6 band speeds (0.6, 1, 1.4, 1.8, 2.2, 2.4 m/min). 6 models have been created in the experiments.

Set 3; According to increasing ordering from the entrance, the outputs power have been adjusted as 1st MGN's output power 700W, 2nd MGN's output power 500W, 3rd MGN's output power 350W, 4th MGN's output power 250W and 5th MGN's output power 175W. Keeping stable each of MGNs' at output power adjusted, drying experiments have been performed with 6 different band speeds (0.6, 1, 1.4, 1.8, 2.2, 2.4 m / min). 6 models have been created in the experiments.

3. Results And Discussion

To be able to conduct the experiments, MW oven with prototype conveyor system has been specifically designed and manufactured. On the system, 5 pieces of magnetrons with air-cooled with 700 W output power having the same technical specifications have been used. Owing to the automation created, MGN power and band speeds can be adjusted. Experiments have been performed with MGN different powers (175 W, 250 W, 350W, 500W and 700W) and different band speeds (0.6 m/min, 1 m/min, 1.4 m/min, 1.8 m/min, 2.2 m/min and 2.4 m/min). Egg trays used in the experiments have the same size and the same properties and before drying, it's weight is 190 g. As for its temperature is18 ^{0}C'dir

In microwave drying systems, MGN power, band speed, exposure time to microwave, product type, geometry of product, and the initial humidity content of the product are important factors affecting the quality of drying.

With different band speeds, depending on the strength of MGN, the change in the rate of the humidity removed through the egg tray is shown in Figure 2 (Theory 1).

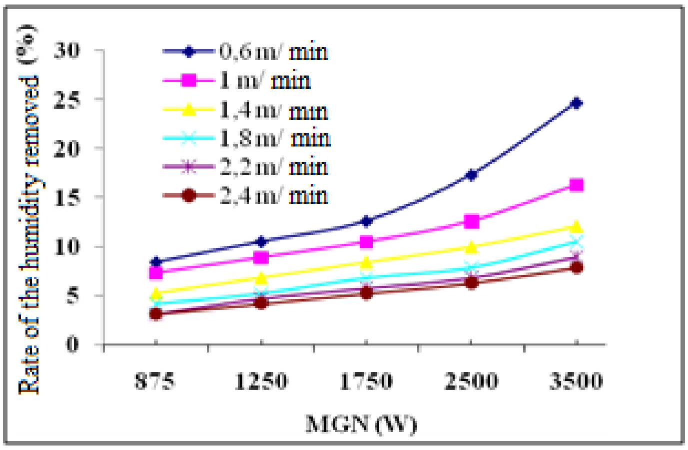

Figure 2. With different band speeds, depending on the strength of MGN, the change in humidity rate.

When examining Figure 2, as MGN output power increases the rate of the humidity removed from the egg tray increases, with increasing the band speed the rate of the humidity removed through the egg tray decreases. With 0.6 m/min band speed, minimum (5x175 = 875 W) and maximum (5x700 = 3500 W) output power of MGN, the rates of humidity removed have been obtained as 8.42% and 24.74%, respectively.

The maximum rate of humidity removed has been obtained with minimum band-speed (0.6 m/min) and MGN maximum output power (3500W).

According to increasing (Theory 2) and decreasing (Theory 3) MGN output power, with different band speeds, the change of the humidity removed from the egg tray are shown in Figure 3.

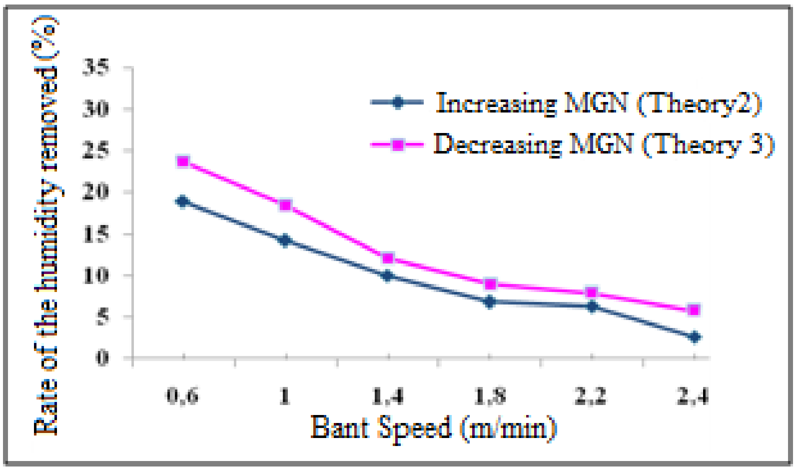

Figure 3. The change of the humidity removed according to the band speed with increasing and decreasing magnetron output power.

As can be seen from Figure 3, drying rates in the microwave oven with the same band speed and the same power in total (Theory 2, Theory 3; 1975W) are different. The rate of the humidity removed with 0.6 m/min band; while according to Theory 2 is 18.95%, according to Theory 3; it has been calculated to be 23.68%.

4. Results

Experiments have been conducted on a total of 42 models.

1) In the 1st Theory separately, the total; 5x175 = 875 W = 1250 W 5x250, 5x350 = 1750 W = 2500 W 5x500, 5x700 = 3500 W power has been applied. With different magnetron output power and different band speed (0.6, 1, 1.4, 1.8, 2.2, and 2.4 m / min), drying experiments have been performed and, 30 patterns have been created in the experiments.

With 0.6 m/min band speed, the minimum (5x175 = 875 W) and maximum (5x700 = 3500 W) output power of MGN, the rates of humidity removed have been obtained as 8.42% and 24.74%, respectively. A maximum rate of the humidity removed has been obtained with minimum band speed (0.6 m/min) and maximum MGN output power (3500W).

2) In the 2nd Theory and 3rd Theory; for each step, 175 W+250 W+350 W+500 W+700 W=1975 W power has been applied. In a total, this power in the 2nd Theory and 3rd Theory is fixed. With increasing and decreasing MGN output power and different band speeds (0.6, 1, 1.4, 1.8, 2.2, and 2.4 m/min), drying experiments have been conducted and 12 patterns have been created.

The rate of the humidity removed from the egg tray; while according to increasing magnetron powers is 18.95 %, according to decreasing magnetron powers, it has been calculated as 23.68 %. The reason of being more efficiently of drying with decreasing MGN power (Theory 3) can be considered as a sudden penetrating of microwaves to the material.

3) 190 g of wet egg tray has been exposed to 540 s microwave energy with 0.6 m/min of band speed and energy consumption has been calculated. Accordingly;

In Set 1, the drying experiments done with the maximum MGN output power (3500 W), while 47 g of the moisture has been removed, a total of 525 Wh of energy has spent.

In Set 2 and 3, a total of MGN output power is 1975 W, and in the drying experiments done with increasing MGN output power, 36 g humidity, as to with decreasing MGN output power, 45 g humidity has been removed from the egg tray and a total of 296.25 Wh of energy has spent.

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