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POST- BAKING DRYING SIIRT TANDIR BREAD BY MICROWAVE OVEN

MASTER DEGREE THESIS

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THESIS ACCEPTANCE AND APPROVAL

This thesis entitled **"POST- BAKING DRYING SIIRT TANDIR BREAD BY MICROWAVE OVEN"** prepared by Huda Jamal Mhamad under supervision of Asst. Prof. Dr. RAHMI UYAR , Prof. Dr. ÖMER ŞAHIN and Dr. EMRE BAKKALBAŞI has been accepted thesis study on the date 28/05/2018, was accepted as a Master's degree in the Department of Food Engineering at Siirt University, with majority votes by the jury below.

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LIST OF ABBREVIATIONS

Abbreviations	Explanation
^{0}C	Celsius
WHO	World Health Organization
RF	Radio frequency
MW	Microwave
IR	Infrared radiation
mm	Micrometer
m	Meter
D_P	Penetration depth
WC	Water content
wb	Wet base
db	Dry base
g	Gram
kg	Kilogram
d	Dimension
m/s	Meter/second
m^3/h	Cubic meters per hour
mm	Micrometer
W	Watt
R_2	Correlation coefficient
h	Hour
MC	Moisture content
l/h	Liter/hour
mm/s	Millimeter/second
a_w	Water activity
MR	Moisture ratio

ÖZET

YÜKSEK LİSANS TEZİ

POST- BAKING DRYING SIIRT TANDIR BREAD BY MICROWAVE OVEN

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Siirt Üniversitesi Fen Bilimleri Enstitüsü

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Siirt Tandir ekmeği Siirt ili ve çevresinde yaygın olarak tüketilen, normal ekmeğe göre raf ömrü uzun olan geleneksel kurutulmuş bir ekmek çeşididir. Geleneksel Tandır Ekmeği genellikle ıslatılarak veya çorbaya ilave edilerek tüketilir. Geleneksel Siirt Tandır ekmeği, kırsal yörelerde, tandır fırınında 6 ila 8 saat arası bir sürede hazırlanmaktadır. Pide fırınlarında ise pişirim sonrası kurutma süresi 2-3 saat almaktadır. Bu çalışmada Siirt Tandır ekmeğinin pişirim sonrası kurutma karakteristikleri mikrodalga kurutma sistemi ve sıcaklık kontrollü fırın kullanılarak incelenmiştir Ayrıca hava akışı ve mikrodalga sisteminin beraber kurutma etkisi incelenmiştir. Öncelikle fırındaki sıcaklık seviyelerinin 120 ^{o}C, 130 ^{o}C, 140 ^{o}C, 150 ^{o}C gıda örneğinin kütlesinin nem içeriğine ve kuruma süresine etkileri sıcaklık kontrollü fırın kullanılarak araştırılmıştır. En düşük sıcaklıkta 120^{o} C kurutma için 0.345 'dan 0.159 g su/g katı madde gerekli süre 115 dakika, en yüksek sıcaklıkta 150 ^{o}C kurutma için 0.310 'dan 0.131 g su/ g katı madde nem içeriğine gerekli süre 65 dakika olduğu belirlenmiştir. Mikrodalga kurutma sisteminde ise 700 W güç seviyesinde kurutma 0.330 den 0.184 g su/g katı madde nem içeriğine için 3 dakika, aynı güç seviyesinde mikrodalga kurutma sistemi ile birlikte hava akışı 25 Litre/saat kullanıldığında ise 0.265 den 0.130 g su/g katı madde nem içeriğin 2 dakika gerekmektedir. Mikrodalga kurutma sisteminde farklı güç seviyelerinde, 300 W, 400 W, 500 W, 600 W, 700 W denemeler yapılmış ve en uygun güç seviyesi 600 W olarak belirlenmiştir. Mikrodalga sistem ile beraber hava akışı kullanılması kurutma süresini kısalttığı görülmektedir. Tandır ekmeğinin pişirim sonrası kurutma süresi Mikrodalga kurutma ile 3-5 dakika gibi kısa sürede ürün istenilen nem içeriğine getirilebilmekte, sıcaklık kontrollü fırın ile süre 1-2 saat arasında daha uzun bir süre gerektiği belirlenmiştir. Kısa süreli uygulanan ısıl işlem ürün kalitesin korunmasına ve verimliliğin artırılmasına katkısı olduğu düşünülmektedir.

Anahtar kelimeler: Düzenli fırın, mikrodalga kurutma, ekmek, nem içeriği, kuruma süresi, hava akımı, güç seviyeleri

ABSTRACT

MS THESIS

POST- BAKING DRYING SIIRT TANDIR BREAD BY MICROWAVE OVEN

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In Food Engineering Department
The Degree of Master of Science

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Siirt Tandir is popular, traditional and special dried bread with a long shelf life comparing with the ordinary in Siirt province, consumed by local people in this region. Traditional Tandır Bread is usually consumed by soaking or adding to soup. Siirt Tandir bread is made in rural areas in the traditional oven which takes 6 to 8 hours to prepare. With different types of oven, it takes 2-3 hour to dry the bread after baking. In this study, drying characteristic of Siirt Tandir bread is investigated by two methods. Microwave drying with different power levels, 400 W,500 W,600 W,700 W and regular oven with different temperatures 120 ^{o}C,130 ^{o}C,140 ^{o}C,150 ^{o}C used to compare the two methods. The effects of temperature levels in regular oven with different temperatures 120 ^{o}C, 130 ^{o}C, 140 ^{o}C, 150 ^{o}C, sample mass on moisture content, and drying time of bread were investigated. Drying bread at 120ºC to remove moisture content from 0.345 g water/g solid to 0.159 g water/g solid needed 115 min but drying bread at 150ºC for reaching moisture content from 0.310 g water/g solid to 0.131 g water/g solid needed 65 minutes. When the microwave power level 700 W used, it needed 3 minutes to reach moisture content from 0.330 g water/g solid to 0.184 g water/g solid. If the same MW power level used with 25 l/h airflow, it needed 2 minutes to reach moister content from 0.265 g water/g solid to 0.130 g water/g solid. Different MW power levels were studied 400 W, 500 W, 600 W, 700 W. At the level of 400 W the drying process was too slow and at level of 700 W the process is too fast to control and caused sometimes burned products. As a result, in the MW system 600 W power selected as an optimum power level in the drying process. Drying time of post baking bread by microwave system that the product can be brought to desired moisture content in a short time like 3-5 minutes and it takes longer time between 1-2 hours with regular oven. It is thought that the short-term heat treatment contributes to the preservation of product quality and to the improvement of productivity.

Key words: Regular oven, microwave drying, bread, moisture content, drying time, airflow, power levels

1. INTRODUCTION

Siirt Tandir is popular, traditional and special dried bread in Siirt consumed by local people in this region. This is a popular dried bread with a long shelf-life (more than six months) comparing the ordinary bread. Usually consumed by soaking or adding to soup. Siirt Tandir bread is made in rural areas in the traditional oven consuming a lot of time which takes 6-8 hours. Some of the bakers use 3-4 hours to dry the Tandir bread. Traditionally drying methods need longer times because heat and mass transfer mechanism is slow during drying.

For the first time, bread was baked 12000 years ago and it is known that Greeks, Romans, and Babylonians made bread BC. (Karizaki, 2017).

Bread is the most important food which is consumed widely all around the world. Bread is freshly prepared and has attractive brownish, crispy and crunchy shell next to enjoyable aroma. It has consisted of two parts crumb and crust. The crust is forming during baking surface of the bread and the density of the crust is higher than crumb (Altamirano-Fortoul et al., 2012).

Bread is an important source of vitamins, dietary fibers, proteins, antioxidants and common product used all around the world (Karizaki, 2017).

The WHO advises consumer can consume daily 250 g of the bread per individual and relying on the country, bread baked is one of the foods widely consumed around the world, the worldwide consumed over 9 billion kg (Pico et al., 2015).

Bread is consumed widely around the world and manufacturing of bread is automated. The key step of the bread production is baking. The method of baking dough is a complicated process included the chemical and physical changes occur in the oven (Khatir and Paton, 2013).

During baking, some chemical, physical and biochemical changes were occurring such as browning reactions, evaporation of water and expansion (Mondal and Datta, 2008).

Dehydration reduces water activity and extends shelf-life preserving foods in a stable and safe condition. Airflow drying, vacuum drying, and freeze-drying, have less drying rates in the falling rate period of dehydrating. The long drying times at high temperatures often results quality degradation of the last products. MW drying decrease the drying time and improves the last quality of the dehydrated food (Zhang et al., 2006).

The main objectives of this research are drying bread faster with microwave system, and determine drying parameters (time, temperature and power) with two methods, traditional drying method, and microwave drying method.

2. LITRITURE REVIEW

2.1. Bread

Bread has been prepared in various shapes, in different size of the volume and has wide range properties such as colors, textures. The property of bread relies on the forming of gluten structure which is a major compound of bread processing. The gluten quality relies on proteins in the flour (Cauvain, 2012).

2.2. Ingredients of Bread

Bread ingredients are flour, salt, yeast, and water for enriching nutritional value of bread can be added some optional ingredients like wheat barley and oats which are sources of biotin. Barley, oats, and rye are rich in source folic acid, the different cereal oils contain vitamin D and K. Barley is considered the source of potassium and sodium. The potassium levels are high in wheat (rye, barley). Wheat-rye, barley, and oats are classified as sources of calcium, magnesium iron, and copper (Dewettinck et al., 2008).

2.2.1. Wheat flour

Whole wheat flour has been indicated by many investigators to be a rich source of these functional components such as fiber, phytochemicals, minerals and essential amino acids that are existed in the bran and fat-soluble vitamins contained in the germ of the whole wheat grain (Ngozi, 2014).

2.2.2. Yeast

Saccharomyces cerevisiae is a popular yeast in bread processing. Fermentable sugars yeast cells metabolize and produce carbon dioxide under anaerobic conditions and improving dough size. Yeast supports aroma compound and gluten network. Active cells of yeast are available in dehydrated form. It should be stored in refrigerator. Active dry yeast is produced and dried to low moisture content. Instant yeast is made from active strains of yeast and dried lower level of moisture. Active dry yeast has a long shelf-life at room temperature but it must be hydrated before it is used. Instant yeast must store in refrigerator and can be used without hydration (Giannou et al., 2003).

2.2.3. Water

Water is essential for the dough making and it is used to mix the ingredients like salt and sugars and helps distribute the yeast cells into dough. Water transports food to the yeast. It is necessary for starch gelatinization during baking. The water activates enzymes, forms new bonds among the macromolecules in the flour and changes the rheological characteristics of dough also, the amount of water need to bread making depends on the moisture content and the physicochemical properties of the flour (Giannou et al., 2003).

2.2.4. Salt

Salt is one of the bread ingredients. It makes the gluten stronger and controls the bread size, however, salt slows the process of fermentation (Giannou et al., 2003).

2.2.5. Lipids

Lipids may be used in bread baking in shape of fats and oils. Lipids are an optional component in bread making to develop dough treatment, crumb appearance, product flavor and developing the quality of moistness and softness (Giannou et al., 2003).

2.3. Dough

Dough as a mixture of starch, proteins, water, fibers, fat, salt, and small amount of other components. In bread producing, the first step is blending the ingredients of dough. The ingredients are added and dispersed, the number of changes occur and then dough improves (Belz et al., 2012). These changes are related to the formation of gluten, that requires both the hydration of the proteins in the flour and the application of energy through the process of kneading. The bread making changes physical characteristics of the dough and improves its ability to retain the carbon dioxide gas which is generated by yeast fermentation. This improvement in gas retention ability is important during baking. In the early stages of baking, large quantities of carbon dioxide gas are generated and released from the dough since activity of yeast is maximum. The gas production and gas retention in a fermented dough is different. Gas production refers to the generation of carbon dioxide gas produced by yeast fermentation. The gas production will continue if the yeast cells in the dough viable and if there is sufficient substrate. The proportion that will be retained relies on the development of gluten. Gas retention in the dough is therefore closely linked with the degree of dough development. The factors are related to the protein component of flour; the dough will be impacted by a huge number of ingredients and method of parameters (Cauvain, 2012).

2.4. Drying

Drying is an oldest processes of food preserving according Wang and Xi (2005), based on reducing the water content to decrease water activity to a level when the development of the microorganism, enzymatic reactions, and other deteriorative reactions are prevented to prolong shelf life (Susanti et al., 2016).

The size of food product is reduced by dehydration and decrease packaging requirements. Hence the product can be handled easily and the cost of transportation reduced (Doymaz, 2005).

Dehydrating is a complicated method because is affected by some exterior (air velocity and relative humidity) and interior parameters (density, permeability, porosity, sorption-desorption attribute and thermophysical characteristic) of food being dehydrated (Kaya et al., 2007).

2.4.1. Sun drying

Sun dehydrating process is widely applied to dehydrate the food products and vegetables. Solar radiation immediately impacts the surface of the foods and the heat results in evaporation of water from the surface of the food.

Sun dehydrating is a popular process with the less cost but has some disadvantages. Sun dehydrating is not uniform, the method cannot be controlled because it relies on weather conditions, has long dehydrating periods and possibility of contamination by molds, bacteria, animals and insects. This results from some quality problems on the final product such as nutrition loss, contamination and color change (Aydoğdu, 2014).

2.4.2. Convective drying

In convective dehydrating, hot and dry air is applied to produce heat for evaporation of water in food. There are two base mass transfers in drying, move of water in the food to the surface and the removal of water vapor from the surface. In conventional dehydrating, dehydrating food consists of three parts. In the initial part dehydrating rate is steady. At high water contents, water flows because of capillary forces to the surface inside the food. The water on the surface has been removed, the water is transferred from inside to the surface of the food. During dehydration, that water moves the distance evaporate from the surface becomes longer. Therefore, this stage is called as first falling drying period rate, in the second stage there is only diffusion (Aydoğdu, 2014).

Initial stage of dehydrating, convective dehydrating is an efficient process. However, as the method continues, slows down so it requires more energy. During dehydrating method, the rate of water movement to the surface is lower than the rate of evaporation. So, the surface becoming dehydrate and hard, it is a problem in vegetable dehydrate. During convectional dehydrating, food is dried for long time that reasons quality loss (color, flavor, texture, sensory properties, loss of nutrients, shrinkage, reduction in bulk density and rehydration capacity) (Aydoğdu, 2014).

2.4.3. IR drying

While IR dehydrating, the energy of radiation absorbed on the food surface, changed to heat and moved to the inside the food. The importance of IR dehydrating is a medium for transmission of energy from the source to food is not required, getting better dehydrating capacity, high rate of energy absorption and moving it inside to the food is necessary. The efficiency for dehydrating rate is depending on the food characteristics and thickness (Aydoğdu, 2014).

2.4.4. Microwave drying

Microwave heating food caucused by friction dipole molecules in the oscillating electrical field. Water has a dipole structure component in the food product and the other parts such as (salt, fats, and proteins) are dielectric portion. Microwave ovens have fast heating rates and high yield, while the reason is food compounds have different dielectric properties such as fats and proteins and can results in non-uniform heating of foods (Fakhouri and Ramaswamy, 1993). For industrial applications, 2.45 GHz or 915 MHz are applied but local microwave ovens use at 2.45 GHz. The microwave heating system consist of a generator and an applicator. The generator is converting the alternating current to the high-frequency microwave energy. The produced microwave energy focused over the sample using waveguides. The heat produced can be calculated by this equation (Aydoğdu, 2014).

$$Q = 2\pi\varepsilon_0\varepsilon'' f E^2 \quad (1)$$

Where: ε_0 is the free space (8.85×10^{-12} F/M), f is the microwave frequency (Hz) and E is the electrical field strength (V/M) in the materials.

The position of MW among radio frequency and infrared wave as shown on the electromagnetic spectrum (Figure 2.1.). The microwave wavelengths are between 1mm-1m, (Pappas et al., 1999).

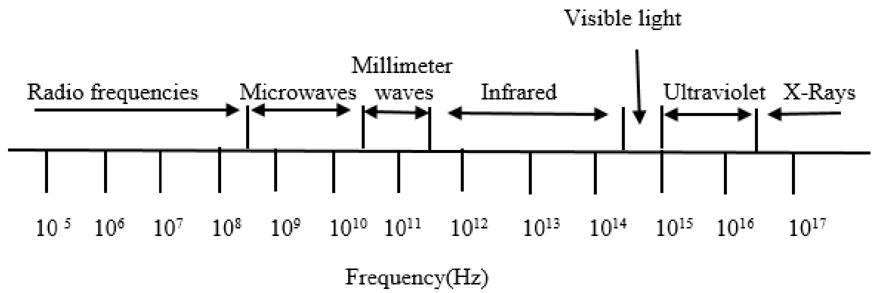


Figure 2.1. Electromagnetic spectrum

In general, MW drying has three dehydrating parts. In the binging MW energy is used to heating sample and increase the temperature of the product. In the fast dehydrating part, the temperature is constant and the heat is used to remove water. When the water content is decreased at falling drying rate MW energy cause to overheating of food samples (Zhang et al., 2006).

Penetration depth (D_P) is a measure of distance that microwave radiation can penetrate inside of food. In the MW system design penetration depth is important and depends on frequency and dielectric properties microwave (Tripathi et al., 2015).

MW Drying

Microwave heating uses in food processing are baking, dehydrating, pasteurization. The microwave dehydrating methods are microwave drying with hot air, microwave dehydrating with vacuum, and microwave freeze drying. Microwave dehydrating mixed with other conventional processes can enhances the dehydration process (Chandrasekaran et al., 2013).

Studies about MW drying of food products

Balbay and Şahin (2012) studied MW drying kinetics by using various power levels 250 W,500 W and 750 W and various temperatures 40 ºC,45 ºC,50, ºC and 55 ºC for dehydrating Liquorice root. Dehydrating kinetics of Liquorice root with initial moisture content 49.5 % (wb) and reduced to 4-10 % (wb) were experimentally studied in microwave dehydrating system.

Dadalı and Kılıç (2007) studied the moisture content, moisture ratio and dehydrating rate of turkey okra by applied different MW power levels between 180 W and 900 W. Also, the impact of power level and mass of sample on water content, moisture proportion, dehydration average and dehydration period of okra studied.

Hazevazife et al., (2012) studied designing, manufacturing and evaluating microwave hot-air combination, to evaluate the processes of the manufactured apple pieces were dehydrated to 20% water content by applied MW and hot air. The results indicated that raise microwaves power level caused the dehydrating time to decrease and drying rate to rise.

Sumnu et al., (2005) investigated MW, halogen-lamp-MW combination and hot air was used for dehydrating pieces of carrot. When used MW and halogen lamp-MW combination the carrots dehydrated to 0.47 kg moisture/kg dry solid by applying hot air dehydrating. Sumnu et al., (2005) reported that carrots dehydrated in halogen lamp–microwave combination oven had better color and rehydration ratio.

Sharma and Prasad (2001) studied hot air and combined MW-hot air for drying garlic cloves in the experimental dryer. The temperatures applied at 40 ºC,50 ºC,60 ºC and 70 ºC, power level 40 W and air velocities range from 1.0 m/s and 2.0 m/s. The result showed that moisture content of garlic cloves nearly 1.89 g water/g dry solid to 1.85 g water/g dry solid dehydrated to the moisture content of 0.06 g water/g dehydrate solid. Increasing temperature of the air, the garlic samples color was becoming darker and brown.

Balbay and Sahin (2013) investigated the dehydrating kinetics by applied different temperatures 36°C, 40°C and 48°C, air flow rates 0.2 $m^3 h^{-1}$, 0.4 $m^3 h^{-1}$and 0.7 $m^3 h^{-1}$ and microwave power levels 250 W, 500 W and 750 W for dehydrating two kinds of Turkey pistachios (Antep- (MC) 32.01% (db) and Siirt-WC 41.92% (db)). The good quality of drying pistachio provided with moisture content 5-7% (db) and for determining the quality mathematical models the modified Henderson and Pabis mathematical model was found fitting model for dehydrating of Antep pistachio and Siirt pistachios.

Maskan (2000) studied MW and convection drying banana, the power levels of MW 350 W, 490 W and 700 W and convection 60°C at 1.45 m/s. The result showed that MW the color of dehydrated banana was brighter and rehydration value was highest.

Ozkan et al., (2007) studied with different MW power levels, to dehydrate spinach leaves. The dehydrating spinach leaves completed among 290 s and 4005 s and relies on MW power levels and the humidity fell down to 0.1 on a dry basis. However, drying at 500 Wand 850 W produced the best brightness, redness, and yellowness parameters. The optimum microwave power level was 750 W for the dehydrating of spinach with drying time.

Arslan and Özcan (2010) investigated MW oven, sun and oven, the power levels of MW 210 W to 700 W and the temperatures range from 50 ^{0}C to 70 ^{0}C used for dehydrating onion pieces. The moisture content of onion at temperatures 50 ^{0}C and 70 ^{0}C dehydrating with the oven is 36.68 g/100 g - 1.81 g/100 g since the moisture content by the sun and microwave dehydrating were 48.86 g/100 g wet weight basis and 2.19% g/100 g wet weight basis for onion. Onion slices dehydrated with oven were darker in color compared to sun and microwave dehydrated samples.

Maskan (2001) studied dehydrating rate and shrinkage of kiwi fruits by using the microwave and hot air-microwave. The drier used an air velocity of 1.29 m/s to the drying surface and the temperatures are 60°C and 27°C, the microwave power levels are 210 W, 350 W, and 490 W. The MW drying kiwi pieces showed less rehydration ability and faster water absorption rate.

3. MATERIAL AND METHOD

3.1. Material

The ingredients used in this study were obtained from the supermarket such as Wholemeal wheat flour, salt, sunflower oil, wet yeast. Also, in experimental part oven (WTB binder), electric balance (Shimadzu-D435301276), sensitive balance (Shimadzu D310030301), distill water machine (Mini pure 1, MDM-0170), desiccator, Temperature meter (HIC-2), Cylinder, beaker, Petri dish, Tray metal, microwave digestion system (START D), electric balance (AND GF-600), Drying cap, Texture analyser (TA. XT-PLUS-stable Micro Systems), computer (HANNS.G-HW173A). Data input unite, air compressor (KULETAŞ OTS7502-50), humidity meter (TES 1360), flow meter, electrical heater and water activity meter used (LabTouch-aw novasin3).

A special modified MW and regular oven setup used for this research.

3.2. Method

Since we are studying post baking drying of Siirt Tandır Bread, the dough prepared and baked according the recipe of traditional bread making. After prepared the baked breads drying with MW oven with different power levels and regular oven with different temperatures were studied. MW drying combined with air flow with different volumetric flow rates also studied. Besides the time and the temperature, power levels of MW and airflow rates, some parameters also were studied such as, texture, rehydration. Between MW dried bread and regular oven dried bread sensory analysis conducted if there is a difference between two products, statistical analysis has performed a paired t-test where each panelist tasted both products.

3.2.1. Dough making

The dough was prepared from Wholemeal wheat flour 500 g, water 354.291 g, instant yeast 10 g, salt 7 g and oil (sunflower)15g as showed on (Figure 3.1.) The ingredients were mixed in a bowl then put water gradually at the room temperature and knead by hand for 30 minutes, the dough was prepared and covered with plastic film for one hour at room temperature for fermentation. The dough was divided into 4 samples every sample 160 g and prepared a circle shape by hand and put it on the tray.

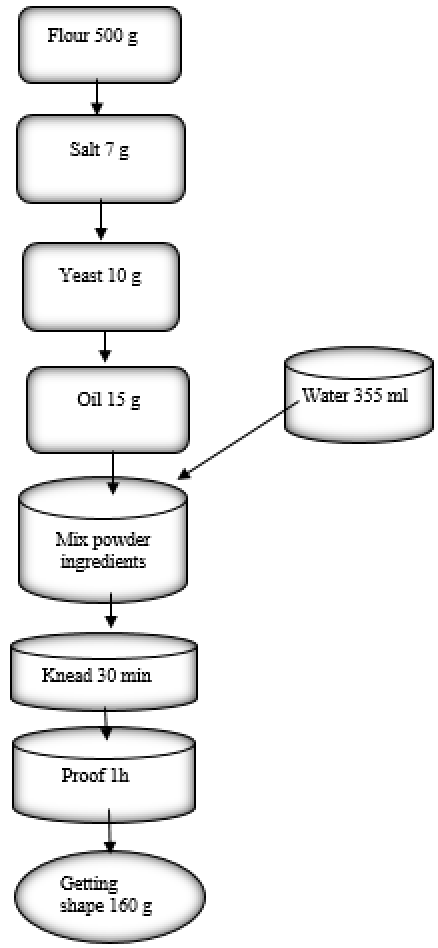


Figure 3.1. Dough preparing flow chart

3.2.2. Baking bread

The sample of dough in the tray was put in the oven for baking. Bread was baked for 1 hour at the stable temperature regular oven 200ºC. After baking, bread was allowed to cool down at room temperature for one hour and was measured the dimensions (the width, height, and radius) of the bread as shown on (Figure 3.2.).

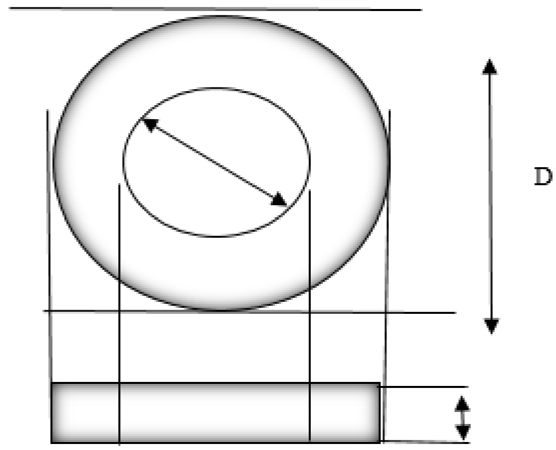


Figure 3.2. Bread shape

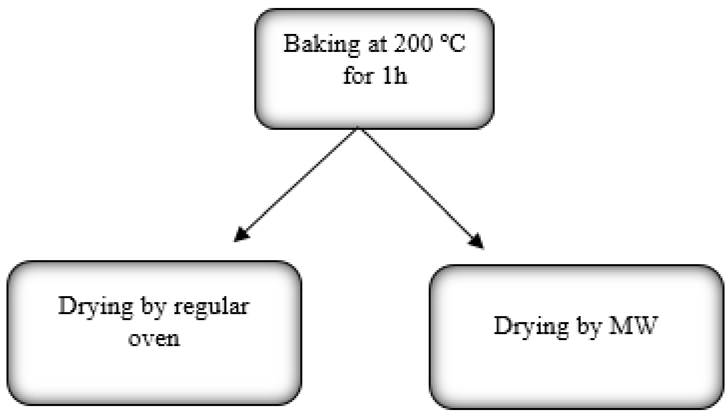
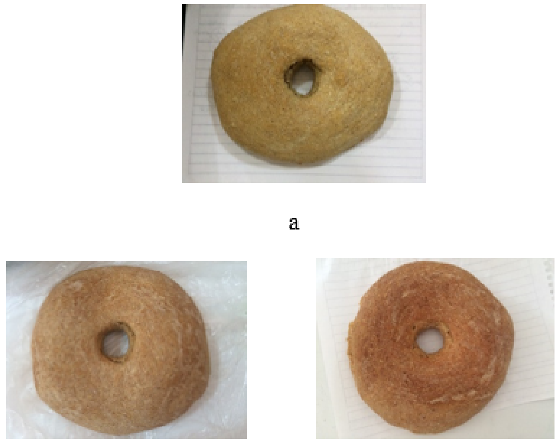


Figure 3.3. Baking and drying process



a

b c

Figure 3.4. Baking and drying process in the images. a) bread after baking, b) drying bread with regular oven, c) drying bread with microwave

3.2.3. Drying

This study was included two kinds of drying process MW drying and regular oven drying of bread as shown on (Figure 3.3-3.4.). Drying bread with the regular oven was applied different temperatures and with MW was used different power levels to removing moisture from the samples. In addition, air flow combined with MW system drying system with different airflow rates were studied.

3.2.3.1. Drying bread by regular oven

Bread was dried by using the regular oven. A modified balancer was put over the oven as shown on (Figure 3.5.), to measure simultaneously the weight of bread during the drying process. The 120ºC, 130ºC, 140ºC and 150ºC temperatures were used in the regular oven to dry the samples. When the moisture content was reached around 11 % - 15%, it was desired to get a proper final product. The moisture ratio of drying bread calculated by this equation (Balbay and Sahin, 2013).

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad (1)$$

where: MR is the moisture ratio, M_e equilibrium moisture content (g water/g dry matter), M_t is the moisture content at time t, (g water/g dry matter), M_0 is initial moisture content (g water/g dry matter).

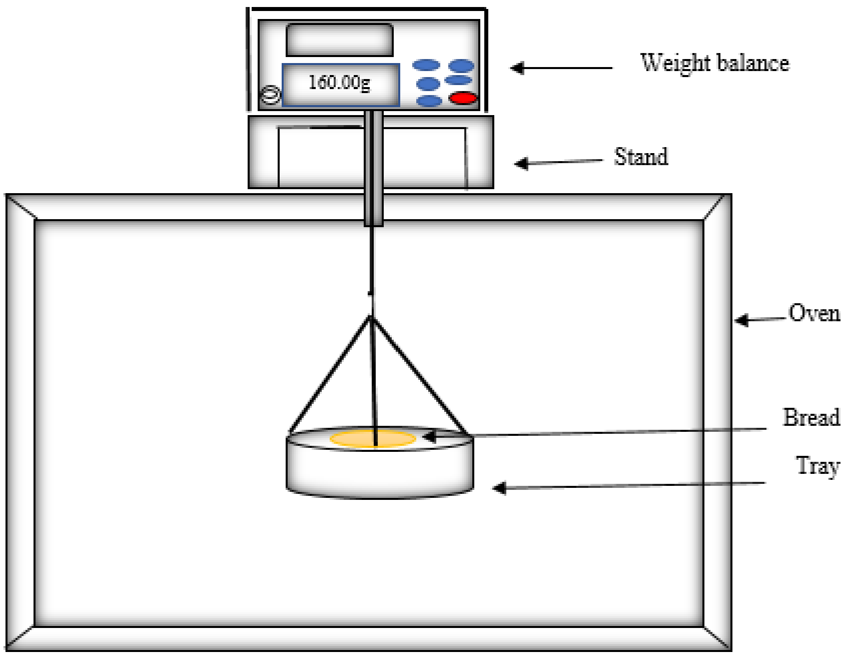


Figure 3.5. Regular oven

3.2.3.2. Drying bread by microwave oven

The experimental setup includes a compressor, humidity meter and flow meter connected to MW system as shown in. Figure 3.6. Air was supplied from the compressor was adjusted to the desired flow rates. The samples were prepared 114 g to 119 g of bread after baking, it was put on the glass tray. The MW power levels 400 W ,500 W, 600 W and 700 W and the time was required 2 minutes to 9 minutes, weight loss was recorded at some minute's intervals during drying by weighing the bread samples inside the drying cap connected to a digital balance, the results were recorded. The MW heating was applied until around 11-15% moisture content percent satisfied. The temperature and relative humidity of airflow during this process were 20 ºC - 25 ºC and 21 %-35% respectively.

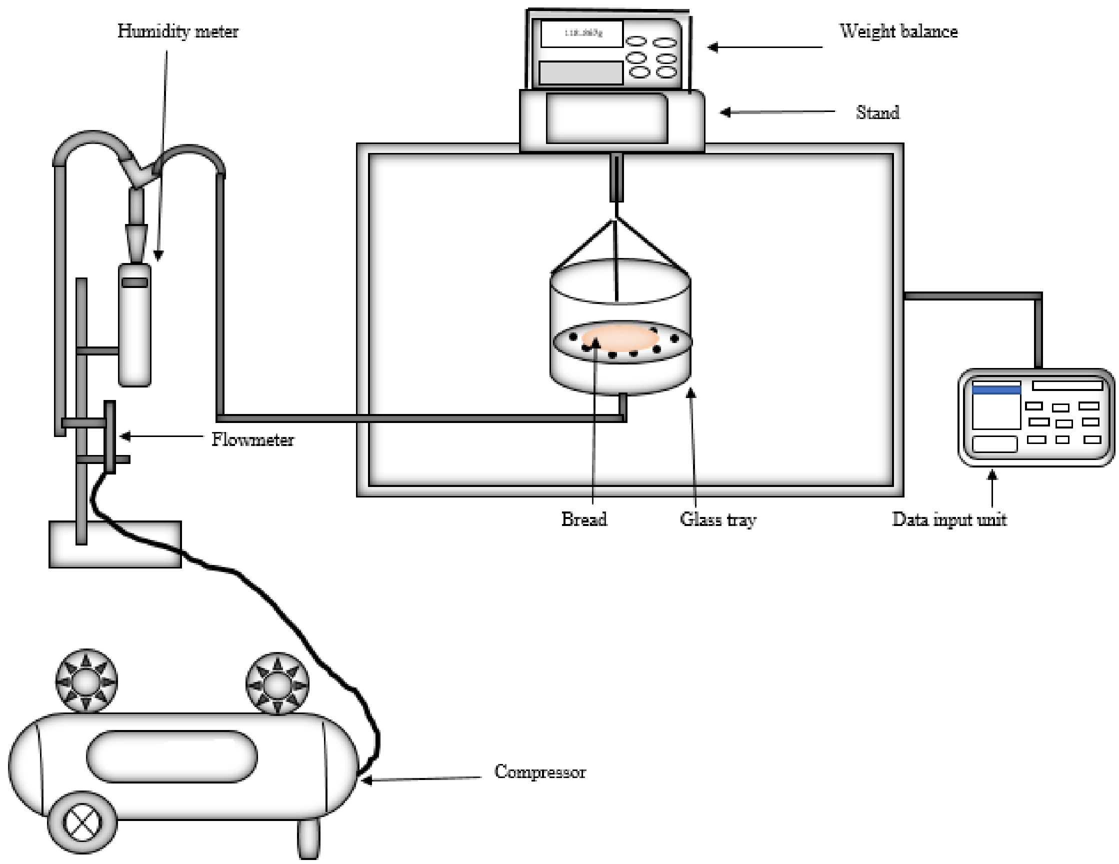


Figure 3.6. Microwave system

3.2.4. Moisture content

Moisture content was determined by taking 10 g of bread samples, cut bread into small slices, spread slices into the petri dish then the samples put to the oven at 130 ºC and dried until the constant weight was obtained.

3.2.5. Water activity

Water activity is a ratio of the water vapour pressure of the food material to the vapour pressure of the pure water at the same temperature. Water activity has a great impact to the growth of microorganisms, when the water activity is lower than 0.7 bacterial growth is not possible (Ayub et al., 2003). The method of this study was that calibrate the water activity meter and put a little of bread sample, the sample was analyzed and the result also recorded.

3.2.6. Texture analysis

The texture parameters were obtained (peak force, distance and time) the texture analysis conducted after 2 hours when drying process was completed. For estimating texture characteristics was used a texture analyzer (TA. XT-PLUS- stable Micro Systems), for each measurement was needed a slice of soaked bread. The pre-test speed 1.0 mm/s, the test speed was 0.5 mm/s, post-test speed 10.0 mm/s, the distance was (5) mm, the trigger force Auto-5g, probe (p/3) the data acquisition rate 400 pps.

3.2.7. Rehydration test

Rehydration ability of dehydrated bread was decided by immersing 10 g of samples in 400 ml distilled water at room temperature. The rehydration ratio was explained as percentage water, and considered from the sample weight difference prior and after the rehydration as in the following equation. (Aydoğdu, 2014).

$$\text{Rehydration rate} = \frac{W_t - W_d}{W_t} \quad (2)$$

where W_t is the weight of rehydrated sample (g) when stable weight was obtained and W_d is the weight of the dried sample.

3.2.8. Sensory evaluation

The sensory quality of bread is an important parameter for determining the last product quality. It is a significant process used to describe food products, sensory evaluation was registered by the human senses of appearance, aroma, texture mouthfeel, flavor and taste, it was done for bread to estimate if there is a significant difference of MW dried bread samples and regular oven dried samples for 20 panelists at Siirt University in Turkey. Two dried products were rated by each panelist on a 5-point scale for appearance, aroma, flavour, texture. The general explanation of evaluated of the degrees were (1= very bad), (2=bad), (3=medium), (4=good), (5= very good).

4. RESULT AND DISCUSSION

The results of drying bread by different methods, drying by regular oven and MW drying system were obtained but each of baked breads have different the moisture content. The four bread samples baked in the temperature controlled regular oven have different moisture content since it's not possible control every parameter in heat and mass transfer during the baking process. Also the dimensions of the breads of four samples were not identical because of hand shaped bread making. Each time four samples were baked in the same oven and the baked bread have moisture content (w) between the range of 0.300 g water/g solid - 0.345 g water/g solid. In both drying systems the process controlled by weight of the product, if the last products reached a desired weight the process were ended. The moisture content of dried breads in the temperature controlled oven were obtained in the range of (11 to15%) and water activity (a_w) 0.685 to 0.742. The water activity under 0.7 thought to be safe considering bacteriological growth. The samples have taken from the market the water activity have found in the range of 0.5-0.8 which is depending strongly about the storage conditions since the dried bread kept open to the air.

4.1. Drying of bread with regular oven

In this study, bread was dried for an hour at various temperature 120ºC, 130ºC, 140ºC and 150ºC. Drying bread at 120ºC was needed 115 min for reaching moisture content from 0.345 g water/g solid to 0.159 g water/g solid. The drying bread at 130ºC was needed 80 minutes for reducing moisture content from 0.301 g water/g solid to 0.141 g water/g solid, drying bread at 140ºC was needed 70 min for reaching the moisture content from 0.335 g water/g solid to 0.145 g water/g solid but drying bread at 150ºC was needed 65 min for reducing moisture content dry base bread from 0.310 g water/g solid to 0.131 g water/g solid, as shown on (Table 4.1.). In the regular oven drying process had a bottleneck when the increasing temperature levels. Heat and mass transfer rate were increasing with higher temperatures but at a certain level because of crust formation and narrowing of capillary structure water cannot move to the surface results with slowing down the mass transfer rate.

Table 4.1. Moisture content (db) and moisture ratio of bread samples with regular oven at different temperature

	120ºC		130ºC		140ºC		150ºC	
Time (min)	db (g water/g solid)	MR	db (g water/g solid)	MR	db (g water/g solid)	MR	db (g water/g solid)	MR
0	0.345	0.257	0.301	0.231	0.335	0.251	0.310	0.237
5	0.342	0.255	0.296	0.228	0.331	0.249	0.306	0.234
10	0.339	0.253	0.291	0.226	0.324	0.245	0.299	0.230
15	0.334	0.250	0.286	0.222	0.312	0.238	0.289	0.224
20	0.327	0.246	0.276	0.216	0.299	0.230	0.274	0.215
25	0.319	0.242	0.266	0.210	0.282	0.220	0.256	0.204
30	0.310	0.237	0.254	0.202	0.265	0.209	0.239	0.193
35	0.301	0.231	0.241	0.194	0.247	0.198	0.221	0.181
40	0.291	0.225	0.228	0.186	0.232	0.189	0.203	0.169
45	0.281	0.220	0.218	0.179	0.216	0.178	0.187	0.158
50	0.271	0.213	0.205	0.170	0.200	0.166	0.172	0.147
55	0.261	0.207	0.193	0.162	0.185	0.156	0.157	0.136
60	0.253	0.202	0.182	0.154	0.173	0.147	0.144	0.126
65	0.243	0.195	0.171	0.146	0.158	0.137	0.131	0.116
70	0.234	0.189	0.162	0.139	0.145	0.127		
75	0.224	0.183	0.151	0.131				
80	0.215	0.177	0.141	0.123				
85	0.207	0.171						
90	0.198	0.165						
95	0.190	0.160						
100	0.182	0.154						
105	0.175	0.149						
110	0.166	0.143						
115	0.159	0.137						

MR= Moisture ratio, Time(min)=Time(minutes)

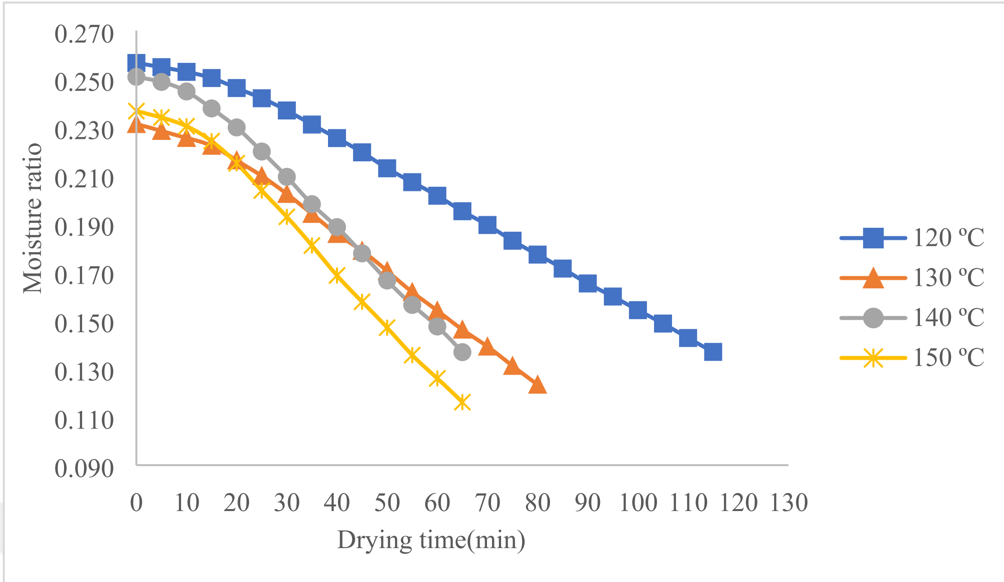


Figure 4.1. The effect of different temperature on moisture ratio for drying bread samples

As shown on (Figure 4.1-4.2.), the lower-temperature of drying the bread 120ºC was needed a long time 115 minutes to reduce moisture content but the temperature of 150ºC was needed 65 minutes to remove the moisture content. The drying process in the regular oven there couldn't see a significant difference between 140 ºC -150 ºC temperatures may be because of crust formation. The crust prevents the water moving to the surface so that slowing down the mass transfer rate of moisture. For comparing with MW drying the 140ºC temperature selected for regular oven temperature.

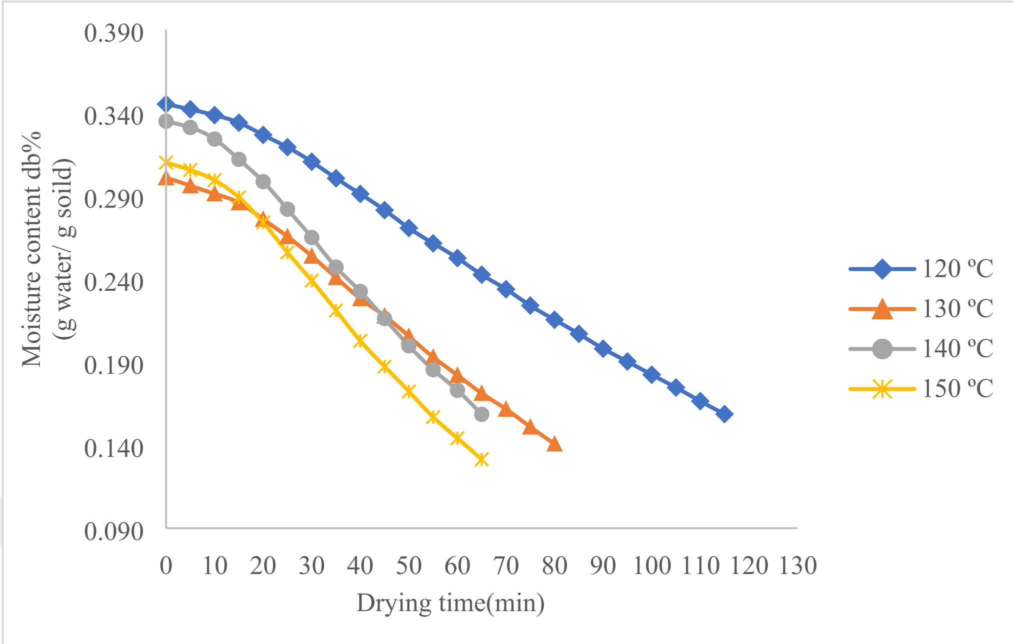


Figure 4.2. Moisture content (db) at different temperature for drying bread with regular oven

4.2. Microwave drying bread with different power levels

Drying bread with microwave at different power levels as shown on (Table 4.2.), the effect of power on bread samples, the moisture content reducing depends on the power levels, in the power of 400 W moisture content reduced from 0.331 g water/g solid to 0.169 g water/g solid and needed 9 minutes, the moisture content at the power level of 500 W was needed 5 minutes for reducing moisture content from 0.347 g water/g solid to 0.181 g water/g solid, at the power level 600 W dry bread was needed 4 minutes to reach moisture content 0.306 g water/g solid to 0.145 g water/g solid but for removing moisture content dry base from 0.330 g water/g solid to 0.184 g water/g solid needed 3 minutes at 700 W, dried bread with microwave higher power level was faster compared with lower power level .

Table 4.2. Moisture ratio and moisture content (db) with drying time by using microwave at different power levels

Time (min)	400 w db (g water/g solid)	400 w MR	500 w db (g water/g solid)	500 w MR	600 w db (g water/g solid)	600 w MR	700 w db (g water/g solid)	700 w MR
0	0.331	0.249	0.347	0.258	0.306	0.234	0.330	0.248
1	0.330	0.248	0.347	0.258	0.302	0.232	0.318	0.241
2	0.329	0.248	0.323	0.244	0.263	0.208	0.258	0.205
3	0.303	0.233	0.274	0.215	0.186	0.157	0.184	0.156
4	0.276	0.216	0.222	0.182	0.145	0.126		
5	0.243	0.196	0.181	0.154				
6	0.222	0.182						
7	0.203	0.169						
8	0.182	0.154						
9	0.169	0.145						

MR= Moisture ratio

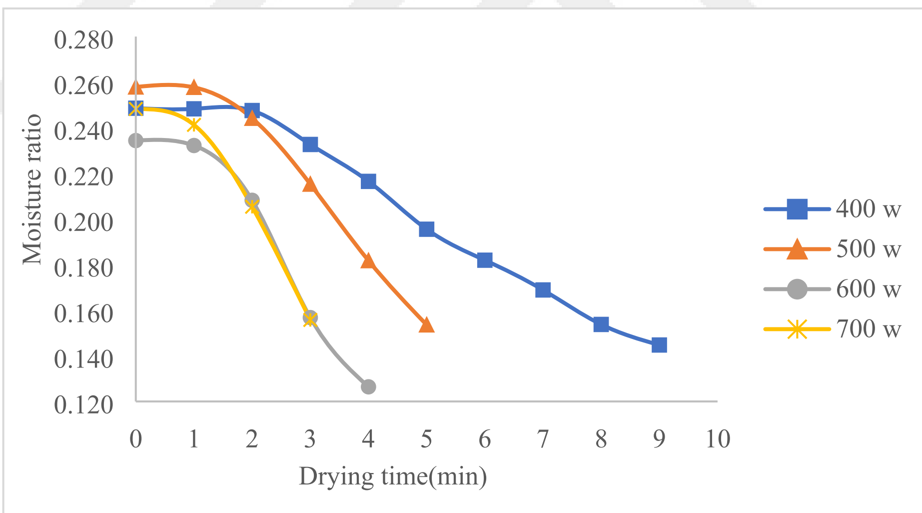


Figure 4.3. Moisture ratios curve for drying bread at different power levels

As shown in Figure 4.3-4.4. The effect of microwave power levels 400 W, 500 W, 600 W, and 700 W, increasing power levels from 400 W to 700 W speed up the drying process, shortening drying time. In MW drying with the higher power level over 700 W were tested but were resulted some burned parts in the bread sample and it was happening to fast and hard to control the process. Even in 700 W power level after 3 minutes of drying process should end immediately to prevent burning damage in the sample. As a result, the 500 W selected as an optimal drying process in MW drying.

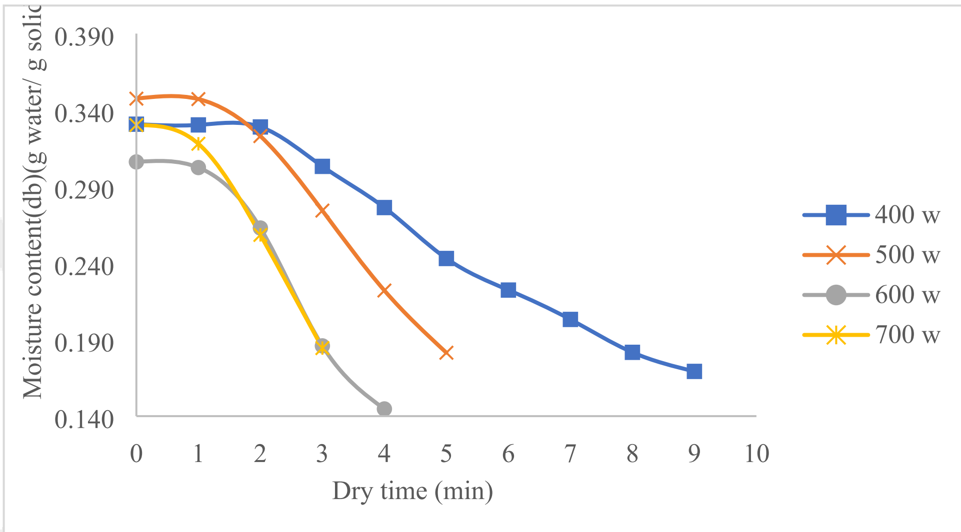


Figure 4.4. Moisture content at different power levels of drying bread

4.1.3. Drying with microwave at 600 W and different airflow

Drying bread with microwave at constant power level and different air velocity were affected to reduce drying time as shown on (Table 4.3.), drying bread without airflow was needed 3 minutes at 600 power level to reach moisture content from 0.312 g water/g solid to 0.127 g water/g solid, drying bread at 5 l/h airflow was needed 2 minutes for reducing moisture content from 0.344 g water/g solid to 0.222 g water/g solid, but the moisture content at 15 l/h airflow needed 2 minutes to reach moisture content from 0.341 g water/g solid to 0.209 g water/g solid and for removing moisture content from 0.289 g water/g solid to 0.151 g water/g solid was needed 2 minutes at 25 l/h airflow , the lower airflow rates was not affected the drying rate.

Table 4.3. Drying bread with microwave at stable power level 600 W and different airflow

	Without airflow		5 l/h airflow		15 l/h airflow		25 l/h airflow	
Time (min)	db (g water/g solid)	MR	db (g water/g solid)	MR	db (g water/g solid)	MR	db (g water/g solid)	MR
0	0.312	0.238	0.344	0.256	0.341	0.254	0.289	0.224
1	0.307	0.235	0.335	0.251	0.321	0.243	0.265	0.209
2	0.222	0.182	0.222	0.182	0.209	0.173	0.151	0.131
3	0.127	0.113						

MR= Moisture ratio

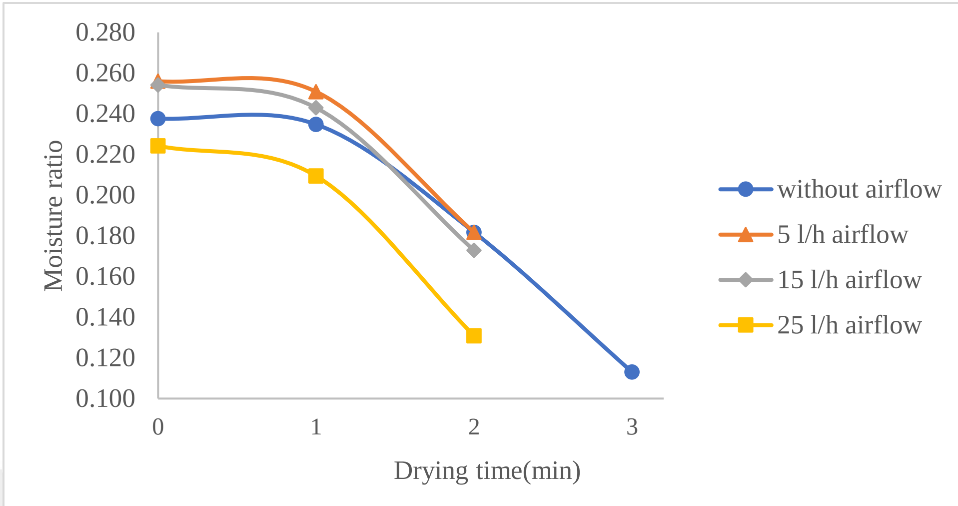


Figure 4.5. Moisture ratio for dry bread at 600 power level and different airflow

As shown on (Figure 4.5-4.6.), the moisture content changed during the time of drying bread processing in different air flow.

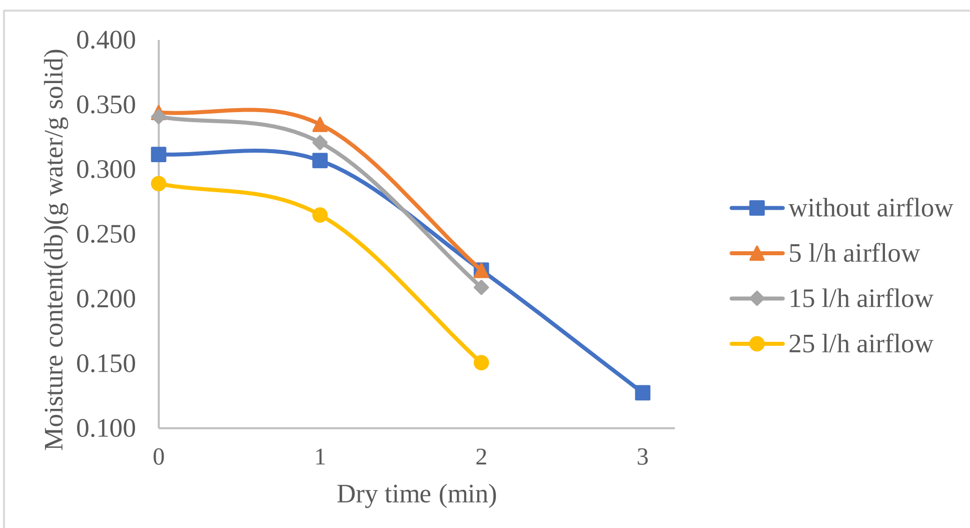


Figure 4.6. Moisture content (db) for drying bread at 600 power levels and different airflow

4.1. 2. Drying with microwave at different power levels and 25 l/h airflow

Drying with microwave at different power level and stable airflow 25 l/h were affected to reduce drying time as shown on (Table 4.4.), drying bread at 400 W was needed 4 minutes to reach moisture content from 0.312 g water/g solid to 0.132 g water/g solid, drying bread at 500 W was needed 2 minutes to reach moisture content from 0.251 g water/g solid to 0.165 g water/g solid, but at 600 W the moisture content needed 2 minutes to reach 0.290 g water/g solid -0.153 g water/g solid and moisture content was reduced from 0.265 g water/g solid to 0.130 g water/g solid at 700 W by 2 minutes respectively. Dried bread with microwave higher power level was faster compared with lower power level.

Table 4.4. Drying bread with microwave at different power levels and 25 l/h airflow

	400 w		500 w		600 w		700 w	
Time (min)	db (g water/g solid)	MR	db (g water/g solid)	MR	db (g water/g solid)	MR	db (g water/g solid)	MR
0	0.312	0.238	0.251	0.200	0.290	0.242	0.265	0.209
1	0.317	0.240	0.249	0.199	0.262	0.237	0.238	0.192
2	0.281	0.219	0.165	0.141	0.153	0.161	0.130	0.115
3	0.205	0.170						
4	0.132	0.117						

MR= Moisture ratio

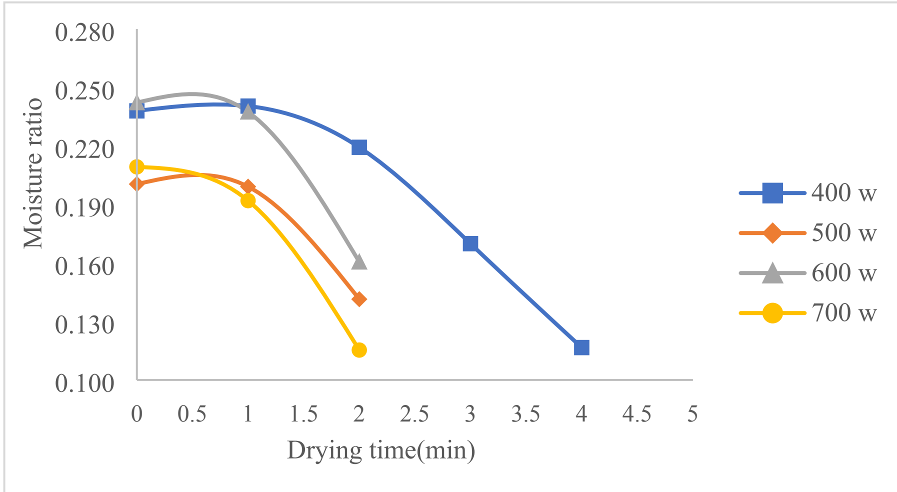


Figure 4.7. Moisture ratios curve for drying bread at different powers and 25l/h airflow

Increasing the microwave power levels had less effect on the moisture content as shown in Figure 4.7-4.8.

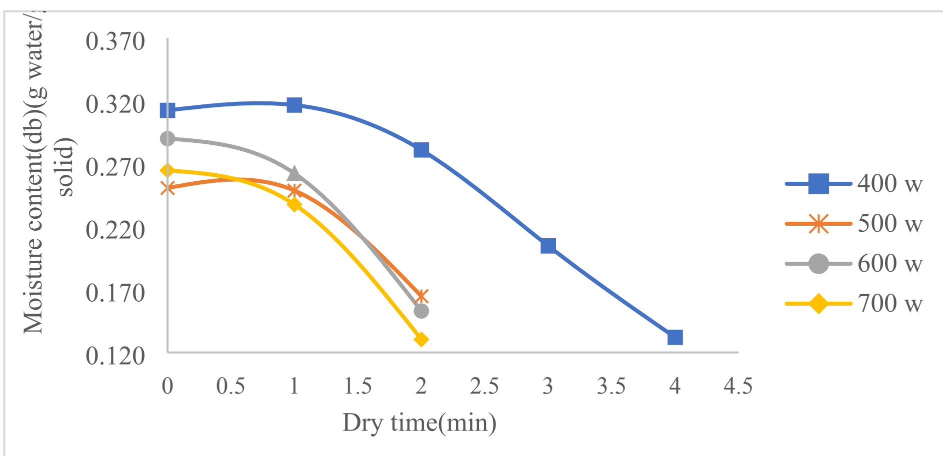


Figure 4.8. Moisture content at different powers of drying bread at 25l/h airflow

4.1.4. Compare between regular oven and MW

As seen in the Table 4.5. Reduced moisture content dry base from 0.335 g water/g solid to 0.145 g water/g solid at 140˚C was needed 70 min due to the mechanism of regular oven very slow compared with microwave. Reduced moisture content from 0.347 g water/g solid to 0.181 g water/g solid at 500 W and needed 5 minutes, dried bread at 500 W with 25 l/h airflow needed 2 min to reach moisture content from 0.251 g water/g solid to 0.165 g water/g solid.

When the effect of microwave power and regular oven on dried bread were studied, as shown on (Figures 4.9-4.10.). The effect of microwave powers on dried bread at the lower time, it was generated more heat because of the higher power and airflow was effected the molecular of water, it was assisted the bread dried in a shorter time but dried bread by regular oven was needed the longest time due to regular oven system slower than the microwave. Because electromagnetic waves can penetrate directly into the material, heating is volumetric and provides fast and uniform heating throughout the product (Kouchakzadeh and Shafeei, 2010). The drying method is caused by water vapor pressure differences among interior and surface regions which provide a driving force for moisture transfer. Microwave drying suggested as most effective at product moisture contents below 20%. Therefore, considering productivity, microwave energy should be applied in the falling rate period or at a less moisture content (where conventional drying takes a long time) to finish drying (Maskan, 2001). The results of conventional drying process indicate that at by the nature of drying process is very slow comparing with the MW drying process. Especially considering that baked products have moisture contents were around 25% MW drying process is convenient for this kind of product. In addition to reduce the time and energy needed during drying, high quality products could be obtained with the use of microwave drying, because it minimizes the quality loss and provides rapid heating and better homogenous heat distribution in the food product (Ozkan et al., 2007). The results show that MW drying method is obviously faster process comparing with the conventional method. The airflow combined with MW system reducing the drying process time to the desired moisture ratio. The airflow removes the moisture on the surface of the product this concluded a faster mass transfer.

Table 4.5. Compering the drying bread with regular oven at 140 ºC, microwave at 500 W with airflow 25 l/h and without airflow

140ºC			500 w			500 w,25 l/h a. f		
Time (min)	db (g water/g solid)	MR	Time (min)	db (g water/g solid)	MR	Time (min)	db (g water/g solid)	MR
0	0.335	0.251	0	0.347	0.258	0	0.251	0.200
5	0.331	0.249	1	0.347	0.258	1	0.249	0.199
10	0.324	0.245	2	0.323	0.244	2	0.165	0.141
15	0.312	0.238	3	0.274	0.215			
20	0.299	0.230	4	0.222	0.182			
25	0.282	0.220	5	0.181	0.154			
30	0.265	0.209						
35	0.247	0.198						
40	0.232	0.189						
45	0.216	0.178						
50	0.200	0.166						
55	0.185	0.156						
60	0.173	0.147						
65	0.158	0.137						
70	0.145	0.127						

MR= Moisture ratio, w=watt, a. f= airflow

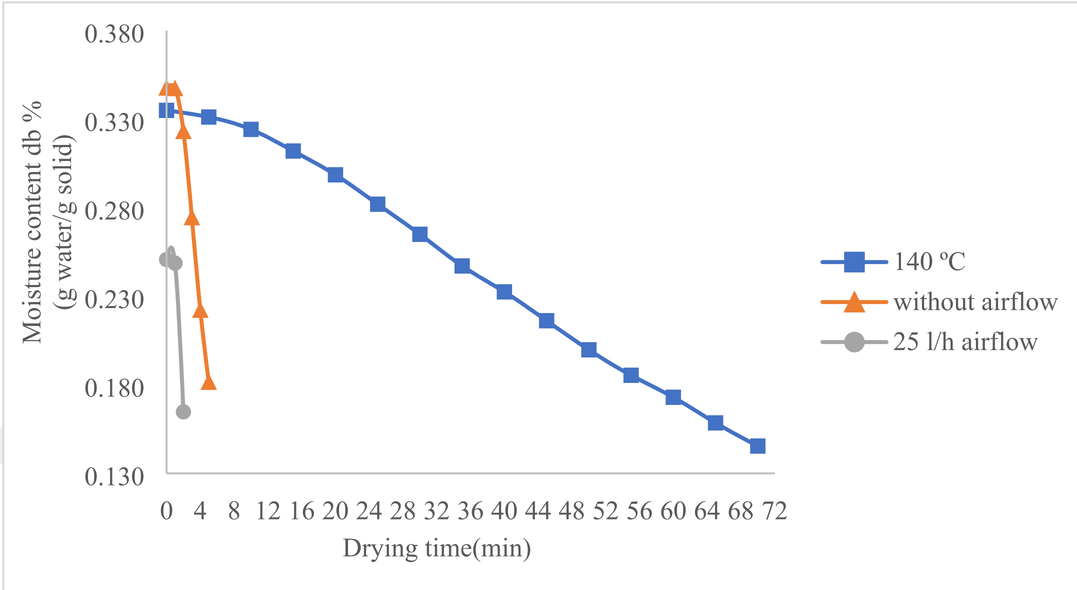


Figure 4.9. Compering the moisture content with regular oven at 140 ºC, microwave at 500 W with airflow 25 l/h and without airflow

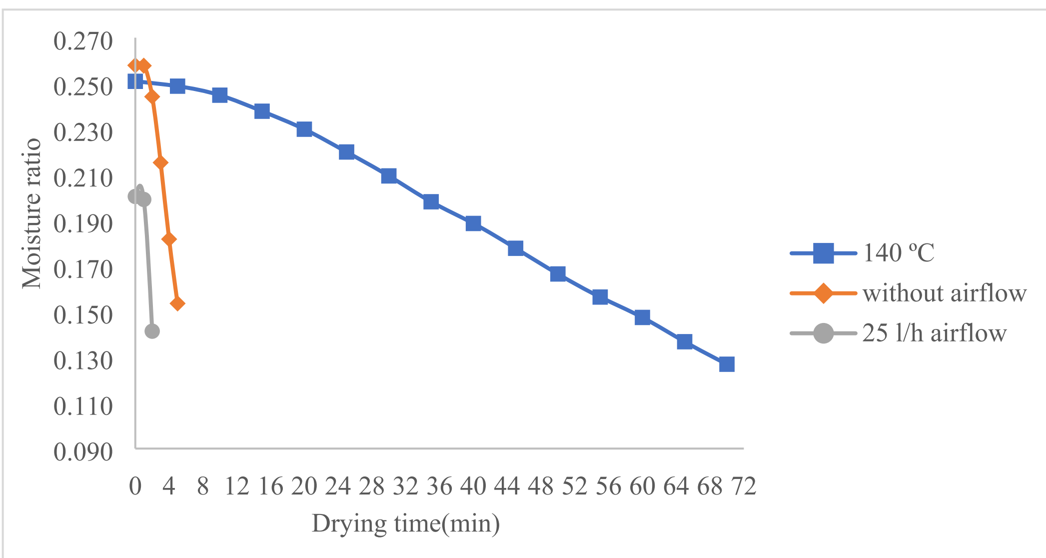


Figure 4.10. Compering the moisture ratio with regular oven at 140 ºC, microwave at 500 W with airflow 25 l/h and without airflow

4.2. Texture analysis for regular oven and microwave

Crispness is a desired textural property for dehydrate foods. It is a highly demanded textural property for snacks. Crispness is a sophisticated texture parameter and while eating it is especially appetizing and stimulating. Crispness indicates that food cooked well and is related with freshness (Jackson et. al., 1996).

Describing objective processes for crispy foods, its recommending that satisfactory process of measuring this textural characteristic calculating slope of the steepness of the force-distance graph in a snapping test. Because crispy foods break on first bite giving sharp force peaks and steep force-distance graphs (Jackson et al., 1996).

The result of texture characteristics of bread was showed on (Figure 4.11.) for the regular oven and MW after immersing the bread for 10 second in water, the result of the measurement bread samples was taken from the various place of the bread, the force necessary to completely compress the slices on a bread surface. As showed on (Figure 4.12.) were noted that the microwave oven-dried samples had more crispness compared to the regular oven of bread had softness.

Some texture parameters of bread were important because they strongly affect bread properties, such as bread hardness, softness, and crispness the curves showed that those characters were the most used descriptors in studied to evaluate the texture. Force was necessary to attain given deformation applied to the teeth to compress the food, relates to the ability to bread into pieces.

Texture analysis conducted after dried samples immersed in water because the traditional dried product consumed after immersing in water. Crispy texture demanded even after immersing in water by the consumers. Texture analysis results show that MW dried breads have crispier structure than regular oven dried bread. Because in the force time graphs the applied force have more ups and downs. More rounded force time graph shows softness of the texture.

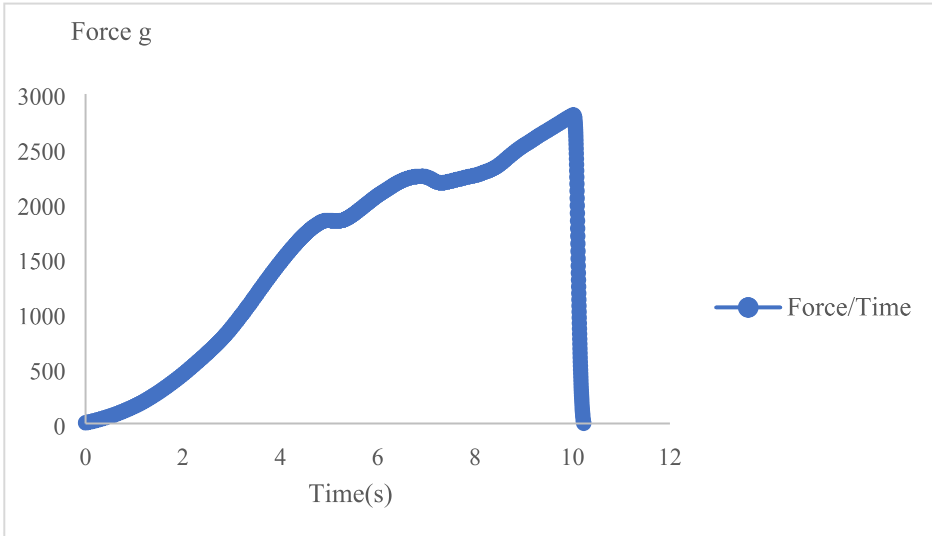


Figure 4.11. Typical texture analyser for a sliced dried bread with regular oven

The steepness of the slope shows in 5 seconds and in 7 seconds the resistance of the chip to bending. A crisp chip has a steep slope and is more resistant to bending than a less crisp chip. As seen in Figure 4.11. The regular oven dried sample indicates the force has no fracture points like MW dried sample. Obviously the regular dried bread sample has less crispy property than MW dried sample.

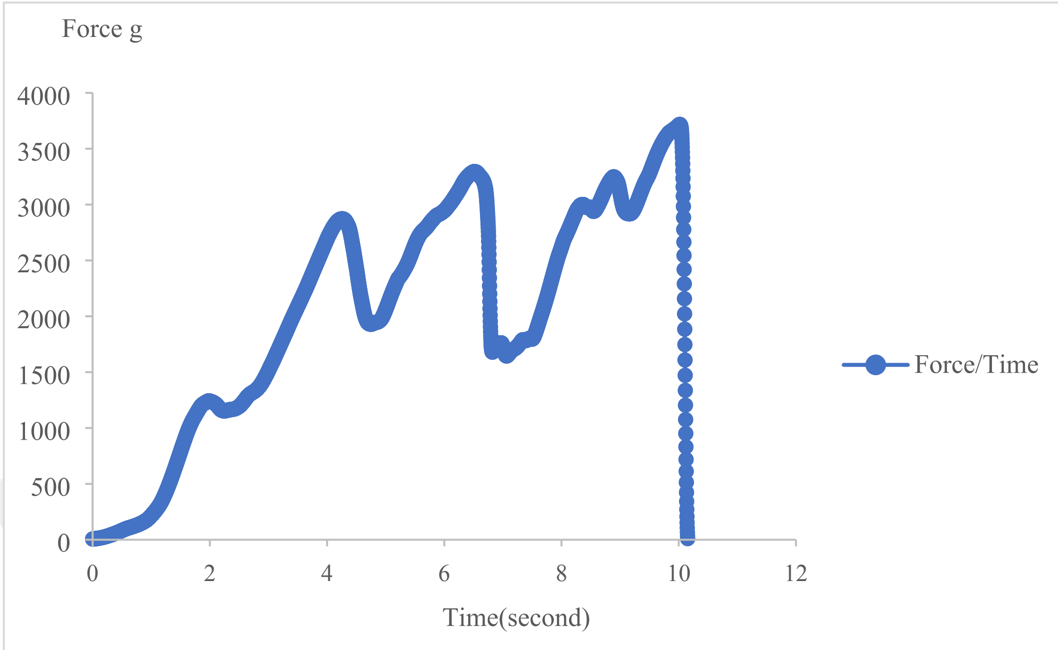


Figure 4.12. Typical texture analyser for a sliced dried bread with microwave

A typical force deformation curve for a crispy food is shown on (Figure 4.12.). In the first 1 second the graph shows the force to bring the probe into contact with the sample. The next 4 second indicates a steep, linear raise in force, the slope of force was defined as crispness. A minor fracture is seen after 2 seconds, but the slope before and after was nearly constant. At about 7 seconds there was a sharp reduce in force when the sample suddenly braked, followed by multiple peaks which denote further fracture events. The vertical line at the end of shows complete fracture and snapping of the sample. This graph shows properties of a typical crispy food.

4.3. Rehydration

The rehydration graph of dehydrated bread as showed on (Figure 4.13.), rehydration of bread dried with the microwave method had the higher value compared to the regular oven. In this experimental part was three samples used in rehydration test as showed on (Table 4.6.).

Rehydration is considered as a measure of the injury to the product caused by dehydrating. It is generally accepted that the degree of rehydration is relies on the degree of cellular and structural disruption. During dehydrating, irreversible cellular rupture and dislocation is observed resulting in collapsed capillaries as reflected by the inability to absorb water to rehydrate (Krokida and Marinos-Kouris, 2003).

Bread rehydration was affected significantly by the drying methods, rehydration of bread drier with MW had higher ability to absorbed water from 0.424±0.497 g, 1.449±0.506 g, 1.885±0.822 g and 2.281±1.175 g but the rehydration with regular oven raised from (0.138±0.00 g,1.228±0.191 g,1.701±0.252 g and 2.029±0.308 g. The higher rehydration properties were showed the high quality of bread drier.

The higher RR at higher microwave power can be attributed to the development of greater internal stresses during dehydrating in MW system. The quick microwave energy absorption causes rapid evaporation of water, creating a flux of rapidly escaping vapour which helps in preventing the shrinkage and case hardening, thus improving the rehydration characteristics. Maskan (2001), investigated that microwave dehydrated kiwifruit samples had faster water absorption rate than hot air dehydrating. Durance and Wang (2002) reported that samples dried using microwave vacuum system has faster rehydration than batch convection air dryer. El-Din and Shouk (1999) also concluded a raised rehydration ratio in okra samples dehydrated using microwave system. These studies are consistent with this study that MW dried bread samples has better rehydration properties than convectional dried bread samples.

Table 4.6. The effect of drying with microwave and regular oven on rehydration bread

Time(min)	Regular oven at 140 ºC (g)	MW 600 W(g)
0	0.138±0.00	0.424±0.497
1	1.228±0.191	1.449±0.506
2	1.701±0.252	1.885±0.822
3	2.029±0.308	2.281±1.175

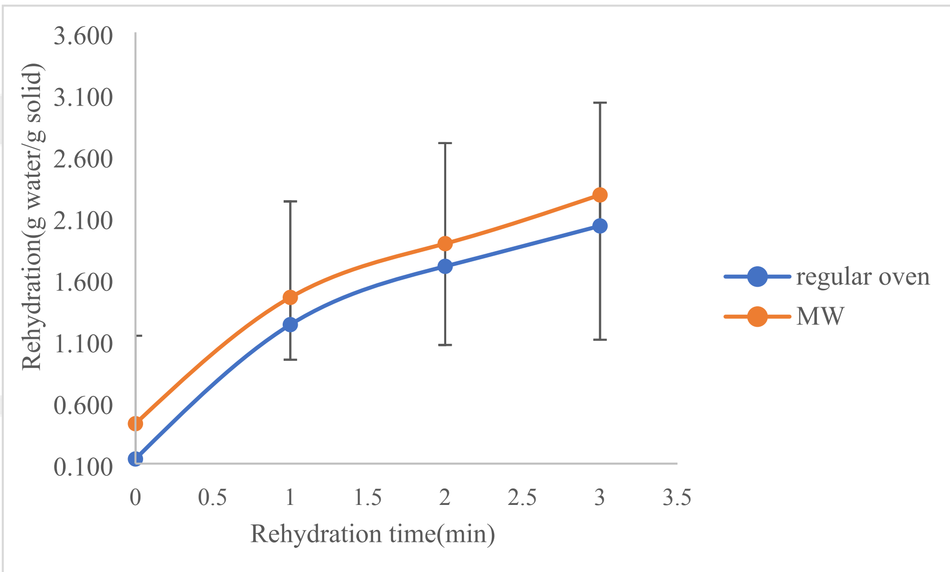


Figure 4.13. The effect of drying by microwave and regular oven on rehydration bread

4.4. Sensor analysis

The product was tested by 20 panelists and apply paired T-test with spreadsheet software. The results of paired T-test are (appearance, aroma, texture mouthfeel, flavor and test) for the last product samples (microwave and regular oven dried bread) showed that there is no significant difference between the drying bread, microwave dried bread and regular oven dried bread, the differences among samples were considered not significant at P >0.05.

5. CONCLUSION AND RECOMENDATION

5.1. Conclusion

The experiments on the microwave and regular drying were achieved at different temperatures 120 ºC, 130 ºC, 140 ºC, and 150 ºC regular oven and microwave power levels 400 W, 500 W, 600 W and 700 W. The carried-out results were summarized as follows:

Drying bread with the regular oven at different temperature 120 ºC, 130 ºC,140 ºC and 150 ºC play an important role in properties the drying bread. The drying bread was gradually increased by raising the temperature. A higher temperature of regular oven produces a higher drying rate at the beginning of a drying time and thus decreased with drying time. Drying bread at 120ºC to reach moisture content from 0.345 g water/g solid to 0.159 g water/g solid needed 115 min but drying bread at 150ºC to reach moisture content from 0.310 g water/g solid to 0.131 g water/g solid needed 65 min.

The drying bread by MW at different power levels and without airflows was decreased the drying bread gradually and needed less time. Drying bread with the MW oven at 700 w was needed 3 minutes to remove the moisture content dry base from 0.330 g water/g solid to 0.184 g water/g solid.

The drying bread by MW at the 600 W and different airflows 0,5 l/h,15 l/h and 25 l/h, the moisture content gradually decreasing with increasing the airflow. In this experimental was shown the effect airflow on drying rate and drying time to remove moisture content, the drying bread with MW 25 l/h airflow was needed 2 minutes to reach moisture content from 0.289 g water/g solid to 0.151 g water/g solid compared to 5 l/h airflow to reach moisture content from 0.344 g water/g solid to 0.222 g water/g solid needed 2 minutes.

The drying bread with MW at the different power levels and 25 l/h airflows, for removing moisture from 0.265 g water/g solid to 0.130 g water/g dry solid at power level 700 w needed 2 minutes also, drying bread needed 4 minutes at power level 400 w to reach moisture content from 0.312 g water/g solid to 0.132 g water/g solid. Dried bread with the regular oven at 140˚C needed 70 minutes, reduced moisture content from 0.335 g water/g solid to 0.145 g water/g solid, dried bread with regular oven was needed a long time for reducing moisture content than MW. Comparing MW and regular oven, the dried bread with microwave was needed 5 minutes at power level 500 W to reduce moisture content from 0.347 g water/g solid to 0.181 g water/g solid but remove moister content from 0.251 g water/g solid to 0.165 g water/g solid needed 2 min at power level 500 w and 25 l/h airflow with high quality.

The texture of drying bread by MW was crispy but drying bread by regular oven was softer.

Rehydration of drying bread by MW absorbed more water than rehydration by regular oven.

The bread was evaluated by sensory analysis and calculated by using paired t-test was given the no significant deference between dried bread by regular oven and microwave oven.

5.2. Recommendation

For benefits of MW drying it can be studied the nutritional value of the samples which were dried by MW and conventional drying methods. Automation of bread making process needed especially dough making stage should be automatic. Last product of dried samples texture analysis could be studied without immersing in water.

The traditional Siirt Tandır Bread cannot consume without immersing in water. The dried last product is too hard to be consumed as a snack or similar product. Based on traditional recipe a smaller snack style more consumer acceptable dried bread product can be developed and this product could be consumed without immersing in water.

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7. APPENDICES

APPENDIX A

Table A.1. The thickness of bread after baking

The thickness of some bread samples after baking	
Bread samples	Thickness mm
1	24.85±1.90
2	27.28±1.55
3	26.37±4.44
4	27.38±1.55
5	27.45±1.10
6	28.99±1.42
7	24.68±5.28
8	28.15±1.37
9	28.097±2.35
10	27.37±0.62
11	26.75±1.95
12	27±1.03
13	23.53±1.85
14	24.13±2.30
15	22.96±1.23
16	22.57±0.50

APPENDIX B
STATISTICAL ANALYSIS (T-TEST).

Table B.1. Data of paired *t*-test for drying by microwave at 600 Wand regular oven at 140 ˚C

	600 W	140^{o}C		
Panelist	Appearance	Appearance	Different	(Different)^2
1	3	4	-1	1
2	4	5	-1	1
3	3	3	0	0
4	5	5	0	0
5	5	4	1	1
6	5	3	2	4
7	3	4	-1	1
8	4	4	0	0
9	4	4	0	0
10	4	4	0	0
11	4	4	0	0
12	5	5	0	0
13	4	3	1	1
14	4	4	0	0
15	5	3	2	4
16	4	2	2	4
17	3	5	-2	4
18	4	4	0	0
19	4	5	-1	1
20	5	3	2	4

Calculations:

Sum of different	4
Sum of $(different)^2$	26
Mean of different	0.2
Standard diffusion	1.151
Tdifferent	0.776
Ttable	2.093

Table B.2. Data of paired *t*-test for drying by microwave at 600 Wand regular oven at 140 ˚C

	600 W	140 ˚C		
Panelist	Aroma	Aroma	Different	$(Different)^2$
1	4	3	1	1
2	5	5	0	0
3	5	5	0	0
4	4	4	0	0
5	5	5	0	0
6	5	4	1	1
7	3	3	0	0
8	3	4	-1	1
9	4	4	0	0
10	5	5	0	0
11	5	5	0	0
12	4	5	-1	1
13	4	3	1	1
14	5	4	1	1
15	5	4	1	1
16	3	1	2	4
17	4	3	1	1
18	3	3	0	0
19	4	4	0	0
20	3	4	-1	1

Calculations:

Sum of different	5
Sum of $(\text{different})^2$	25
Mean of different	0.476
Standard diffusion	1.118
Tdifferent	1.904
Ttable	2.093

Table B.3. Data of paired *t*-test for drying by microwave at 600 Wand regular oven at 140 ˚C

	600 W	140 ˚C		
Panelist	Flavor and test	Flavor and taste	Different	$(\text{Different})^2$
1	3	3	0	0
2	4	4	0	0
3	4	4	0	0
4	3	4	-1	1
5	5	5	0	0
6	5	4	1	1
7	3	3	0	0
8	3	4	-1	1
9	4	4	0	0
10	3	3	0	0
11	3	3	0	0
12	4	4	0	0
13	4	3	1	1
14	5	3	2	4
15	5	3	2	4
16	4	3	1	1
17	5	3	2	4
18	2	2	0	0
19	5	4	1	1
20	3	4	-1	1

Calculations:

Sum of different	7
Sum of (different)^2	49
Mean of different	0.666
Standard diffusion	1.565
Tdifferent	1.904
Ttable	2.093

Table B.3. Data of paired *t*-test for drying by microwave at 600 Wand regular oven at 140 ˚C

	600 W	140 ˚C		
Panelist	texture mouthfeel	texture mouthfeel	Different	(Different)^2
1	2	4	-2	4
2	4	5	-1	1
3	4	3	1	1
4	4	5	-1	1
5	4	4	0	0
6	5	5	0	0
7	3	4	-1	1
8	3	4	-1	1
9	4	2	2	4
10	3	3	0	0
11	3	5	-2	4
12	4	4	0	0
13	4	3	1	1
14	5	4	1	1
15	4	3	1	1
16	4	2	2	4
17	5	5	0	0
18	3	3	0	0
19	5	5	0	0
20	3	5	-2	4

Calculations:

Sum of different	-2
Sum of $(different)^2$	4
Mean of different	-0.1
Standard diffusion	0.447
Tdifferent	-1
Ttable	2.093

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