

MICROWAVE DRYING OF APPLE**Nabiha Hassan Abou ElHana *****ABSTRACT**

Apple was dried in a laboratory microwave oven to evaluate the effects of microwave output power on the drying time and the dried product quality in the terms of color. The drying experiments were carried out two different levels microwave output powers ranging from 100 and 200 Watt were used in the drying experiments. The drying experiments were run on pre-treatment apple samples. Slab, dice, cylinder were the pieces shapes of apple samples. The drying process was progressed through two stages, in the first stage the samples were put in a microwave oven until drying took place mainly in constant rate period, approximately 55% of the water was removed in this period. After that the forced draft oven was used until the apple samples reached the final moisture content. The second stage, the apple samples were put in forced draft oven to reach the final moisture content. For one hour or two hours The value of the drying constant increased with increased microwave output power. The change in color values was dependent on the pre-treatment. The 45% sugar solution showed decrease drying rate than the other treatment. The increasing on the density power (W/g) the drying rate increased by 35 %.

INTRODUCTION

Fresh fruits and vegetables were dried after harvesting in order to reduce waste and spoilage and to extend their shelf life. Drying is a simple process in which the moisture in the fruit evaporates from the fruit surface and is carried away. The process is controlled by many major factors, drying techniques, the properties product and the drying time.

Evaporation of moisture requires energy, which is obtained by removal of heat from the fruit being dried. However, the moisture must be removed quickly from the fruits.

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During drying, exposure to open environment for a long time may cause contamination and spoilage of the product **Vagenas and Marinokouris(1991)**. Dried fruits are widely used as components in many food formulation such as pastry, confectionery products, ice cream, frozen desserts and yogurt. Among them, dried apples are a significant raw material for many food products **Mandala et al. (2005)**. Several experimenters have reported microwave –assisted hot-air drying experiments with foodstuffs, where considerable improvements in drying process have been evident **Huxsoll and Morgan (1968)**(apple and potato); **Garcia et al.(1988)**(banana); **Torrington et al.(1993)**(Carrot).Drying is a classical method of food preservation and it is a difficult food processing operation mainly due to undesirable changes in quality of dried product **Maskan (2000)**. There has been extensive research into microwave drying techniques. **Soysal (2004)**, carried out experiments to dry the parsley leaves by using a domestic microwave oven and to determine the effects of microwave output powers ranging from 360 to 900 W on drying time, drying rate and the dried product quality in terms of color. Increasing the microwave output power resulted in a considerable decrease in drying time and the value of the drying constant increased .No significant differences were observed between the color parameters of fresh and microwave-dried leaf materials .The change in color values was not dependent the microwave output power. By working at 900W instead of 360 W, the drying time could be reduced by 64% with a good quality product . Then a microwave drying /heating technique which reduces drying time considerably and produces a high-quality end-product could offer a promising alternative and significant contribution to the herb processing industry. **Contreras et al. (2005)**dried apple slices, both vacuum impregnated with an isotonic solution and non-vacuum impregnated at 30 and 50 °C air temperature ,with and without microwave application (0.5 W/g). Dried samples became harder when pectin solubilization increases, but become softer when dehydrated. **Funebo et al. (1998)** said that when deciding which process condition produced the best quality microwave- dried products we had to compromise between drying time and quality parameters. The drying time for apples could be reduced to

60 % of the air-drying time with the microwave process. The drying time decreased from nearly 7h to 4h to reach the final moisture content of 0.1kg/ kg.

Apples are a significant source of pectin fiber (13%) (3g per medium apple), and they provide carbohydrates (6 %), and vitamins(C 11%,A 1%) while contributing few calories and no fat , sodium, or cholesterol when a microwave oven was used to dry apples, the attempt must run carefully because the fruit requires constant attention during drying , and the oven door would have to be opened frequently to allow moisture to escape . microwave-dried apples do not dry evenly and can easily scorch or burn(Linda ,J.Harris, Publication 8229).Enhancing drying rates has been a major challenge for food engineers This approach requires identifying the rate-limiting step that may lie in the heat or mass transfer to the product (external control) or inside the piece (internal control). Diverse forms of electro-magnetic energy (infrared, microwaves, etc.) have been suggested, alone or in combination with convective heating, as source of energy to increase the drying rate **Chou et al (2001)**. Recently , pulsed electric field pre-treatments have been proposed as promising nonthermal method to induce cell membrane pre-mobilization in fruit and vegetables that improve dehydration and rehydration kinetics, **Ade-Omowaye,et al (2001)**. **Bilbao-Sainz et al (2006)** investigated the different levels of microwave incident power and different air temperatures on samples of dried apple cylinders (20mm diameter and 20mm height) dried .The results of drying food in the microwave oven were showed that weight gained and volume recovery were higher at higher levels of microwave power(0,3,5,7 and 10 W/g of initial sample weight) ,however, higher levels of microwave incident power caused a lower water holding capacity . **AI-Duri et al (1992)** , investigated the drying rate curves in terms of moisture content versus drying time for five types of foodstuff have been experimentally obtained using a convection, microwave and combined microwave/convection oven. The foodstuff studied are skimmed milk, whole milk, casein powders, butter and fresh pasta. The effects of changes in temperature and power output have been investigated, respectively. It has been found that the drying rate

increases with temperature increase in convection ovens and power outputs in microwave ovens. Furthermore, hi-speed ovens produce the fastest drying rate, yet a microwave oven causes the least damage to food. Several experimenters have reported microwave-assisted hot-air drying experiments with foodstuffs, where considerable improvements in the drying process have been evident **Huxsoll and Morgan, (1968)** (apple and potato); **Garcia et al., (1988)** (banana); **Torrington et al. (1993)** (carrot) . The improvements are described as better aroma, faster and better rehydration than hot-air drying, and much shorter drying times.

Reduction of the drying time for potato up to a factor of 60 has been reported **Bouraoui et al. (1994)**. Other results in the field of food drying indicate a drying time which is half or a third of the hot-air drying time **Riva et al.,(1991)** (mushroom); **Tulasidas et al.,(1993)** (grapes); **Prabhanjan et al., (1995)** (carrot)). A modified domestic microwave oven or a small laboratory-scale system is often used for drying experiments.

Heredia ,et al (2006), said that microwave energy can be successfully applied in several processes in food industry because the resulting volumetric heating of the material results in a slower transfer of heat from the surface to the interior of the fruit, compared to convective drying .The dielectric properties of most materials are affected by many different factors but the amount of water is generally the dominant factor. They also depend on the frequency of the electric field applied, the temperature of the material and the material density. Drying food in the Microwave Oven arrange mushrooms slices samples in a circle in a single layer again, leave the center empty. Set the microwave power on high for. 3 1/2 - 4 minutes. Rotate the mushrooms. heat them on one-third power for 4 1/2 to five minutes, cool the mushrooms and store them in an air-tight container.**(Cooperative Extension Program)**.

Wang et al (2006) carried out the drying experiments, at 150, 300, 450, and 600W and hot air pre-drying experiment was performed at 105 °C, and said that in a microwave drying system, the microwave energy has an internal heat generative capacity and can easily penetrate the interior layers to directly absorb the moisture in the sample. The quick energy

absorption causes rapid evaporation of water, creating an outward flux of rapidly escaping vapor, thus, both thermal gradient and moisture gradient are in the same direction. Theoretically, the microwave drying technique can reduce drying time and produce a high quality end-product so as to offer a promising alternative and significant contribution to the apple pomace disposal. A two-stage drying process involving an initial forced-air convective drying followed by a microwave final drying has been reported to give better product quality with saving in energy and time

Maskan (2000). It has also been suggested in drying of apple slices, mushroom **Funebo and Ohlsson (1998)** , and raisin **Kostaropoulos and Saravacos (1995)** , that microwave energy should be applied in the falling rate period or at a low moisture content to finish drying .

Van-Arsdel W.B.et al(1973), recommend that ,the time for drying apple process in the counter current tunnel the drying time is about 8 hours and more for apple slices, rings, or cubes (1/4 in)(6.35mm) thick. Temperature as high as 180° F-190°F (82-87.77°C) (hot end) have been employed in the first stage of a 2 stages dehydration, the temperature does not exceed 165 °F(73°C) in the second stage, .In recent years, dehydration of the apple have been successful producers for commercial preparation of sliced or diced dried apples.

Feng and Tang (1998), researched the combination of a spouted bed with microwave heating to improve heating uniformity was evaluated. Experiments were performed on a laboratory system in which evaporated diced apples of about 24% moisture were dried to about 5% at 70°C air temperature using four levels of microwave power density (0 to 6.1 W/g). With the combination method, temperature uniformity in diced apples was greatly improved as compared to that with a stationary bed during microwave drying Products had less discoloration and higher rehydration and the Drying time could be reduced by >80% compared with SB drying without microwave heating.

Mandala et al. (2006) investigated the difference of osmotic pre-treatments on apple air-drying kinetics and their physical characteristics during the process drying . Apple samples were immersed in glucose or sucrose solutions of 30 %, 45 % (w/w) at different times. Sugar gain (SG) and water loss (wl) were calculated and an immersion time of 12

h was selected. Samples were further air dried and the experimental data were fitted successfully using the Page model : $MR = \exp(-k t^n)$.Apple osmoses in glucose showed a large moisture decline in the early drying periods and similar drying rates to untreated samples for the same moisture change. Sample pre-treated in 45% sugar solutions had greater porosity and better color retention during drying.

Velic D., et al (2007) investigated the effect of temperatures and pre-treatment on the quality of dried apple samples was determined on the basis of color and volume changes and reconstitution characteristics. The kinetic equations were estimated using logarithmic model.

The results of the estimation have exhibited correspondence to experimental results. The best results, shorter drying time and better rehydration properties, were obtained when samples were pre-treated by blanching in hot water Osmotic dehydration (OD) of tissue foods

mostly fruits, has been the subject of many studies in later years, including concerted- action project in Ibero America and Europe **Jose Migual Aguilera, J. M. et al, (2003)**. Osmotic drying : A method of partial dehydration of fruits by osmotic in sugar or syrup has been investigated by **Ponting et al (1966)**. In this process the fruit is reduced to about 50% of its original weight by osmosis after which ,it is drained and either frozen or dried further in an air or vacuum drier. The resultant fruit retains a large percentage of the fresh fruit flavor. **Bruin (1987)**.

OBJECTIVES

1-Evaluate the influence of microwave output power on drying kinetics, and save drying time of drying process fruits (apples).

2-Describe the drying curves and the relationship between drying time process and the moisture contents of apple samples.

3-Study the different sizes and shapes of apple samples on the drying rate and drying constant.

4-Produce high quality drier fruits and safety moisture content to storage

MATERIAL AND METHODS

(1)Material :-

The apples variety ScotianGold (McIntosh),product of Canada were obtained from local market (super store, Nova scotia, Canada). Apples stored in a refrigerator at 4 °C until drying experiments. After 2 hours stabilization at ambient temperature , homogenous samples of average weights (rang between 260-280g),The average vertical and horizontal diameters were 7.605 cm and 8.52 cm respectively .The average volume was 255 cm³. The initial moisture content of the samples were found to be about 80 % to 86% wet basis .

2- Experimental apparatus

2-1- Laboratory microwave oven

Sunbeam ,microwave oven (SMW 1480),(315 Attwell drive,Etobicoke, ontario,M9W 5C 1,Canada).Outside dimension (H *W*D)are (32.06 cm* 55.56 cm * 49.05 cm) respectively and oven cavity dimension (H* W * D) (25.24 cm * 37.94 cm *40.32 cm) respectively , the oven capacity 1.4 cu. Ft.(=0.039674 m³) and net weight approximately 43.3 Ibs(19.485 kg).Figure (1) show the dimensions of microwave oven and the part names and figure (2) show the photograph microwave oven .Microwave oven have 1000W , the levels of output power are 100, 200, 300,.....),if we want to set a power level other than 100% power, touch power, then use to number pads to enter the power level . we could set the power level from 1 to 9 , number pad 1 to 10% of power ,2 to 20% of poweretc.

2-2-The samples were put on Bamboo dinner plate has square shape ,the dimension 20*20 cm and product of China (Montreal H4 N3 L4,Toronto M 4T 2 S 8 ,CALGARY T 2E 7S9,Canada).

2-3- Hand operated cutter(Cooks Quarters, mandoline, made in P.R.C.) was used to cut the samples with the shapes and thickness required.

2-4-Digital balance (Mettler PM 4600) was used to record the weight of samples ,it has 0.01g accuracy (Mettler instrument, Switzerland).

2-5-Scale has 0.01 mm accuracy ,which was used to measure the dimensions of apple samples to calculate the surface area and the volume to find the ratio between area and volume (area: volume)

SPECIFICATIONS

Power Consumption:	120V~60Hz, 1450W
Output:	1000W
Operation Frequency:	2450MHz
Outside Dimensions(H×W×D):	12 5/8"×21 7/8"×19 5/16" in.
Oven Cavity Dimensions(H×W×D):	9 15/16"×14 15/16"×15 7/8" in.
Oven Capacity:	1.4cu.ft
Cooking Uniformity:	Turntable System (Φ 13")
Net Weight:	Approx. 43.3lbs.

PART NAMES

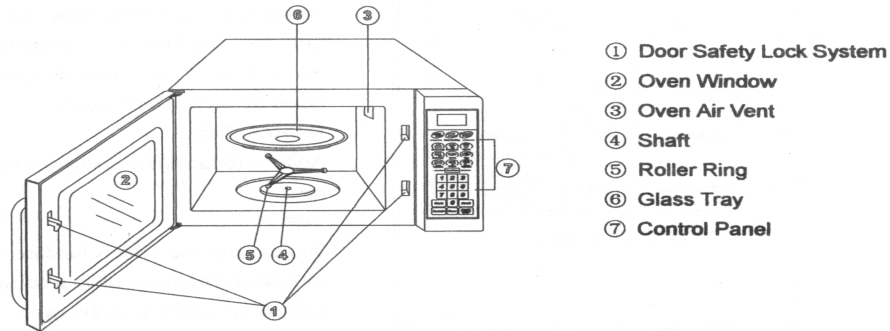


Fig.(1): Laboratory microwave oven



Fig.(2):The photograph microwave oven

2-6- Forced draft oven (Fisher Scientific Isotemp oven model 630),was used to estimate the initial moisture content of apple samples by oven method.

2-7- Shaker (Fisher Scientific , Thermix Stirrer Model 120M, made in U.S. A.) .The rang of agitation 100 or 105 shakes per minute was kept constant for 3 hours and for all combinations. It was used to agitate the sugar solution.

2-8- A Minolta Chroma Meter , was performed color measurements for the samples ,Which was model DP-30/CR-300 diffuse illumination ,0° viewing angle; specular component included, measuring area :Φ 8mm. The coordinates of the color were measurement the L* , a* and b* .a*and b* indicate two color axes , with a* the red –green axis and b* the yellow-blue .L*is measure of brightness (whit-black). The chroma C* is described by the equation

$C^* = \sqrt{a^{*2} + b^{*2}}$ so that when chrom and value axes are compared as in figure shows the above color chart rotate 90 ° with value L*extened above the line drawn from the center through chroma C* . A Delta E* (ΔE*) value is then calculated to show the color differences with other samples (These are called color differentials). To compare the color difference (ΔE) between fresh and osmotic treated apple must be estimated ΔL* , Δa*and Δb* . Color differences (ΔE) (eq.1) were estimated from the coordinates of the color by applying the following equation: ΔE value was low between the fresh apple and dried apple sample $\Delta E = \pm \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \dots\dots\dots$ (eq.1)

3- Experimental procedure :-

3-1- Preparation of pre-treated apple samples

Apples stored in a refrigerator at 4 °C until drying experiments. After 2 hours stabilization at ambient temperature.The drying process was progressed , the apple samples were washed with tap water and hand peeled, cored with a knife and then cut vertical to their axis into cylindrical shape, ((20mm high * 15 mm diameter (cy1)and 20mm high *20 mm diameter(cy2)),diced shape ((15mm side length(cu1)and 20mm side length(cu2)) and slab shape ((20mm*20mm*5 mm(sl1) and other 20*20*10mm(sl2)),(length* width* thickness) respectively using a hand operated cutter .

Table(1): The dimensions , surface area and volume of apple samples

Shape	The dimensions (mm)	Surface area(mm ²)	Volume(mm ³)
slab (sl 1)	20*20*5	1200	2000
Slab (sl 2)	20*20*10	1600	4000
cubic(cu 1)	15*15*15	1350	3375
cubic(cu 2)	20*20*20	2400	8000
cylinder(cy1)	20H*15D	1295.9	3534.29
cylinder(cy2)	20H*20D	1884.9	6283

Where: H=high & D=diameter

The apple samples were dipped in a 5% lemon solution for 5min to prevent non-enzymatic browning and drained for 5 min at room temperature , which was called treated samples (**Lind et al 1998**). In second treatment The apple samples were dipped in a hypertonic solution 30% sugar (w/w) and the third treatment 45%(w/w) sugar , the apple samples were immersed in the container for 2-3 hours at temperature 30 °C (**Bruin S.1988**),All solution were agitation for a period of three hours by shaker .The range of agitation 100 or 105 shakes per minute were kept constant for 3 hours and for all combinations. The initial moisture content of apple samples were determined using the oven method at 70°C for 24 hours (**AOAC, 1990**). These experiments were replicated thrice to obtain a reasonable average. The initial moisture content of the samples were found to be about 80 % to 86% wet basis .

3-2- Microwave drying of pre-treated apple samples

The drying process was progressed ,set the microwave oven at the output powers two levels of 100 and 200 W. Put the apple pieces on plate oven with initial load of approximately 50 ± 0.25 g and 100 g .Then after the power and the timer(30 second) requirement were controlled in order to was starte. The moisture contents were calculated by recording the change in weight of samples 30 second intervals and rotate the apple samples. . The drying procedure was continued till the moisture content of the samples were reduced of about 25-20 % wet basis (w.b.) in the first stage .Each run was performed in triplicate. At high power level, after 150 second (2.5 min)some the samples were stopped dried in microwave oven and the other samples after 210 second (3.5 min).In the

second stage the drying process was completed with using the forced draft oven at 60°C temperature for period from one and half hour to two hours. During this period three or four readings of weight were recorded each 30 minutes (1/2 hour) to reach the final moisture content of apple samples. At low power level, when the sample reached of about 25 to 20 % moisture content wet basis almost after 240 S (4min) and 270S (4.5 min). Dehydrated apples require very little storage space. Completely dried apple pieces can be stored in sealed plastic bags, (snack bags, Product of U.S.A.), (16.5 cm*8.25 cm) Lablows Inc.

4-Theoretical considerations :-

For investigation of drying characteristics of apple pieces shapes, it is important to model the drying behavior effectively . In this study, MR represents the dimensionless moisture ratio namely $MR = (M - M_e) / (M_o - M_e)$, where M is the moisture content of the product at moment, Mo is the initial moisture content of the product and Me is the equilibrium moisture content . The values of Me are relatively small compared with M or Mo for long time . Thus,

$MR = (M - M_e) / (M_o - M_e)$ can be simplified to $MR = M / M_o$ ((Akgun and Doymaz, 2005; Thakor, et al, 1999).

Modeling the drying behavior of different agricultural products often requires the statistical method of regression and correlation analysis . Linear and non-linear regression models are important tools to find the relationship between different variables, especially, for which no established empirical relationship exists. In this study, the coefficients and the drying constants were determined under the drying conditions (the power levels, the shape pieces and the pre-treatment) . The effects of these variables on the constants and coefficients of drying expression were also investigated by multiple linear regression analysis .

RESULTS AND DISCUSSION

This study indicated that the microwave oven is useful in saving the time drying of pre-treated apple pieces, the drying time of apple pieces decreases as the microwave output power increases there was just a falling rate period except a very short accelerating period at the

beginning in microwave drying processes of pre-treated different shapes apple samples .

1-Microwave drying behavior of pre-treated apple

Microwave oven was used to drying apple for varying the power levels(100-200W) at pre-treatment shapes of apple pieces .The time required to reduce the moisture content of apple samples to any given leveling microwave oven was dependent on the power level, being the highest at first level 100W and lowest at second level 200W Apple pieces have 80% to 86% wet basis average initial moisture content were dried

The moisture content versus drying time for the pre-treated apple at the selected powers are shown in figures 3 and 4, respectively. The total drying times to reach the final moisture content for the apple samples were 2.5 to 5 minutes for different the samples at 200 and 100 W. Obviously , increasing microwave output power the drying process, thus shortening the drying time . This result is similar to the results of drying apple slices (**Ramaswamy and van Nieuwenhuijzen, 2002; Wang and Chao, 2002**).The moisture content data at the different drying conditions were converted to the more useful moisture ratio expression and then curve fitting computation with drying time were carried on Page(1949)modified the logarithmic model by adding an exponent parameter to drying time (t) and Henderson (1976) was very interested in developing the thin layer drying equation between moisture content and drying time . He found that the relationship could then be setup $MR = (M - M_e) / (M_o - M_e) = ae^{-b\Delta t}$

An analysis is mad to show the effect on each factor of changes in drying power, the apple pieces, drying time and pre-treatment on moisture content of the dried apple pieces.

The linear regression analysis was resulted the straight line equation: $MC = a + bt$ and

$MC = a t^2 + b t + c$ where MC= moisture content wet basis % , t = drying time and a,b,c are constants. The best model describing the thin layer drying characteristic was chosen as the one with the highest r^2 value.

Figures 3,4,5,6 and 7 Further show the effect of the changing the process variables, namely microwave power , sample thickness pre-treatment and

the loading of sample weight on drying time and drying rate during microwave drying .It is evident that the drying time decreases with the increase in output power . When microwave power levels were changed from low level to high level at the shape pieces and the sample weight remain constant, the drying rate was greater by 33%. Similar results have been reported for the drying studies on mushroom slices (Giri et al,2007)and parsley (Soysal ,,2004).

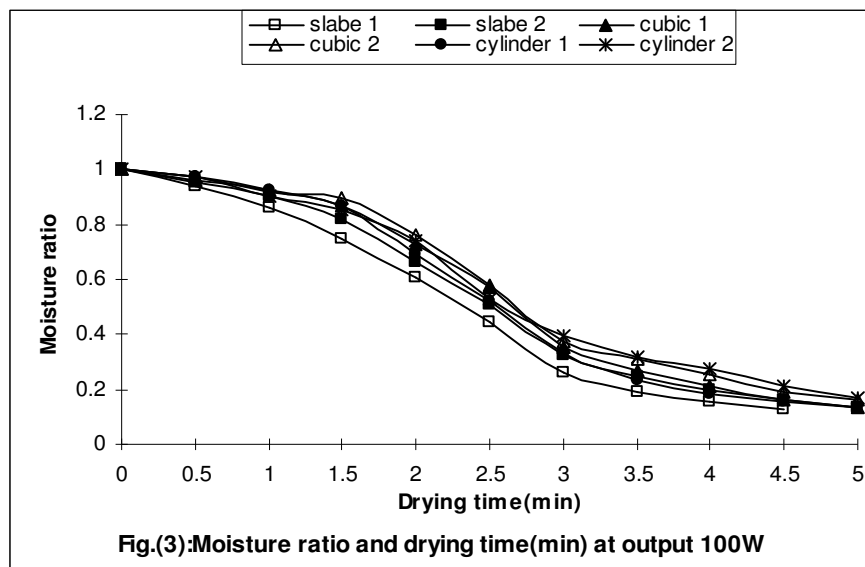
At the output power 200W , the shape was slab (sl 1)

$$MC = 1.2629\theta^2 - 23.561\theta + 111.05 \quad R^2 = 0.9846$$

$$MC = 146.77e^{-0.3778\theta} \quad R^2 = 0.9821$$

At slab (sl 2)

$$MC = .0.8932\theta^2 - 19.646\theta + 108.37 \quad R^2 = 0.9784$$



$$MC = 137.06e^{-0.3347} \quad R^2 = 0.9866$$

At dice cu1

$$MC = 0.7557\theta^2 - 18.05\theta + 0.9726 \quad R^2 = 0.9726$$

$$MC = 145.4e^{-0.3126\theta} \quad R^2 = 0.704$$

At cylinder shape cy2

$$MC = 136.61e^{-0.2753\theta} \quad R^2 = 0.9772$$

At the output power 100W , the shape was slab (sl 1)

$$MC = 0.2235\theta^2 - 11.988\theta + 102.88 \quad R^2 = 0.9708$$

$$MC = 146.03e^{-0.2562\theta} \quad R^2 = 0.9507$$

Where MC = moisture content wet basis of pre-treated apple (%)

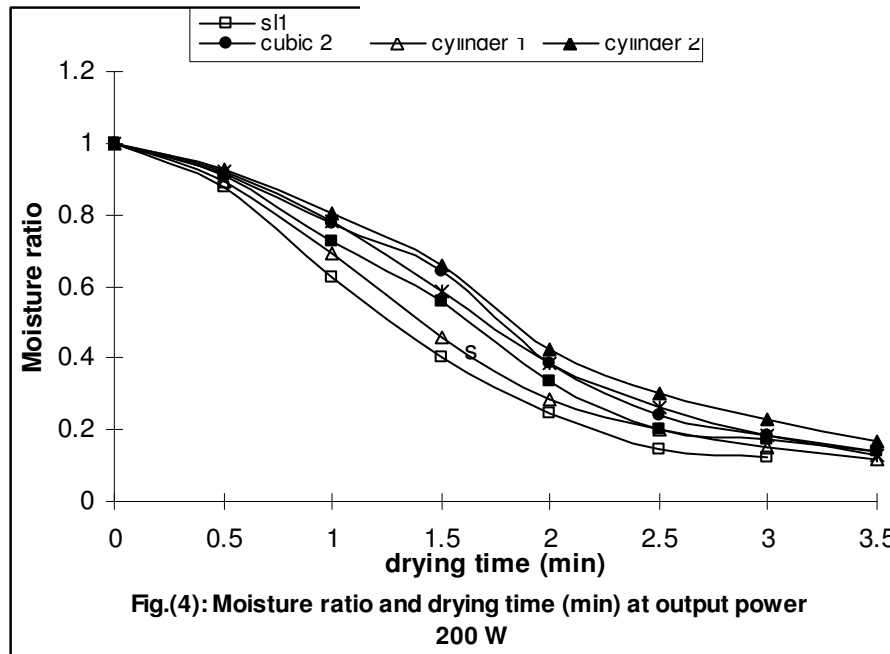


Table (2) illustrated the microwave power and the drying rate .High drying rates were obtained at higher microwave output powers .The moisture content of apple was very high during the initial phase of the drying which resulted in a higher absorption of microwave power and higher drying rates due to the higher moisture diffusion. Thus, the microwave output power had a crucial effect on the drying time and followed drying rate .Similar findings were reported in previous studies (Funebo et al, 1998; Sharma et al,2001; Maskan, 2000).

Fig (7) show experiments were performed on microwave oven , two levels of power were density 0.908 W/g and 1.736 W/g in cylinder apple shape was greatly improved as a compared to that with a stationary bed during microwave drying .The result show the increasing on the loading of samples and the power density was 0.903 W/g the drying rate was 13.26%/min after 3 minutes , the loading decreased and the power was

1.736 W/g the drying rate 20.46 %/min . The drying rate increased by 35%.

At the power density 1.736 W/g

$$MC = 0.5923\theta^2 - 15.448\theta + 106.78 \quad R^2=0.9809$$

$$MC = 130e^{-0.2355\theta} \quad R^2=0.9846$$

At the power density 0.908 W/g

$$MC = 0.0562\theta^2 - 7.9934\theta + 99.466 \quad R^2=0.9709$$

$$MC = 139.98e^{-0.1877\theta} \quad R^2=0.9709$$

Where MC= moisture content of pre-treated apple wet basis(%),

θ =drying time (min).

2-The effect of sample size and shape

This study indicated that the useful the microwave oven is useful in drying pre-treated apple pieces with saving the drying time.

Concerning the effect of the sample size on the drying time and drying rate, apple piece of smaller thickness exhibited more rapid dehydration with the same shape This can be attributed to enhanced water transport phenomena within the sample, which favor the thin samples. On the other hand, if the area ;volume ratio of a body can be increased, so that heat and vapor path ways through dried material are very short, while the heat absorbing area remains large, the drying time can be materially shortened. Table (2) illustrated the surface area :volume ratio for all shapes with different dimensions and the drying rates The shapes have high area : volume ratio the drying time was required less than the shapes have low area : volume ratio

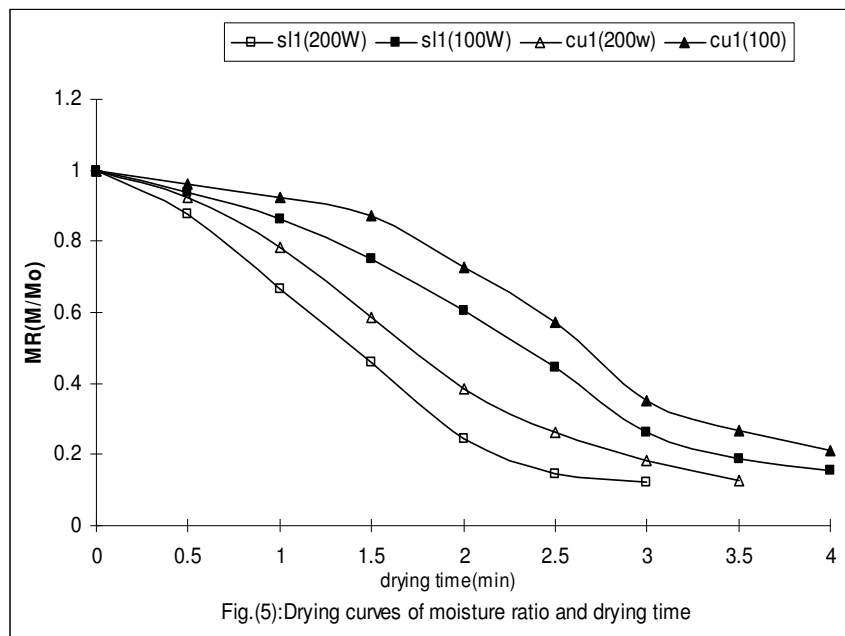
A further increase in area :volume ratio can be obtained by changing the shape of the drying material . As step hence on pointed out, spheres dry in 1/3 the time required for slabs of equal thickness heated from both sides, and cylinders dry in 1/2 the time required for slabs (Van-Arsadel et al,1973).The relationship between moisture content wet basis (MC),drying time(θ) and the ratio surface area:volume (R) were expressed as follows : At output power 200W

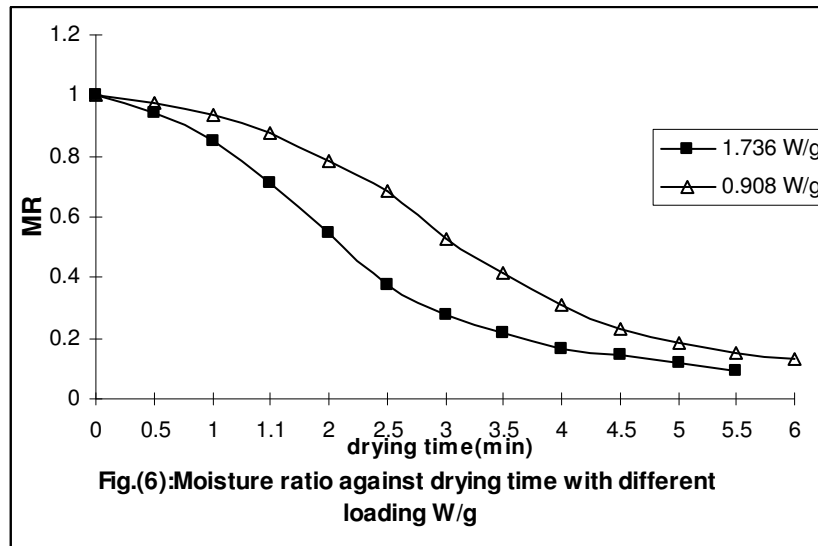
$$MC = 85.909 - 25.57\theta \quad R^2=0.95324$$

$$MC = 95.98 - 25.51\theta - 25.884R \quad R^2=0.96335$$

Table(2): Effect of interaction between the power, shape, ratio and drying rate (% /min)

Shape	surface	volume	the ratio	power (W)	
				100	200
	area	mm ³	a /v	drying time (min)	
	mm ²			at 4.5	at 3
				drying rate %/min	
slab (sl 1)	1200	2000	0.6	16.82	24.55
Slab (sl 2)	1600	4000	0.4	15.82	23.166
cubic(cu 1)	1350	3375	0.4	15.77	23.74
cubic(cu 2)	2400	8000	0.3	15.35	22.79
cylinder(cy1)	1295.9	3534.29	0.366	16.064	22.82
cylinder(cy2)	1884.9	6283	0.3	14.97	21.61





3- The pre-treatment and the color

The sensory attributes such as color ,size and shape are very important from the consumer point of view. As far as the food material is concerned the principal characteristics affecting osmosis rate are chemical composition, physical and specific area of each piece. The advantages of osmotic treatment processing drying time is reducing and the color was prevented brown. In fact, the gain of solute and the water removal give rise to a product with low free-water content.

Fig (7) show the curves moisture content wet basis against the drying duration with the different the pre-treatments (5% lemon, 30% sugar and 45% sugar) .As can be seen, a constant rate period was observed in microwave oven of the pre-treatment apple samples; the curves of both drying process presented a typical falling rate period with a very short accelerating period at the beginning.The time saving in the drying of pre-treatment apple can also be verified with the drying rate .Before the drying process was started , the weight of samples was recorded before and after immersed , caused losses of weight . When the losses were calculated approximately equal or great 5% moisture content wet basis. The osmotic dehydration can be used to reduce water content of material , the cause is imparted for normal drying methods .But the microwave technique is used to keep of the color of the apple sample is very

imparted . the results show the initial treatment of 45% sugar solution decreases the drying rate by 10 % as compared with drying rate of initial osmotic dehydration in 5% Lemon solution. From the conceptual point of view direct osmosis is a very simple process as it is based on placing foods, such as pieces of fruit or vegetables in a hypertonic solution

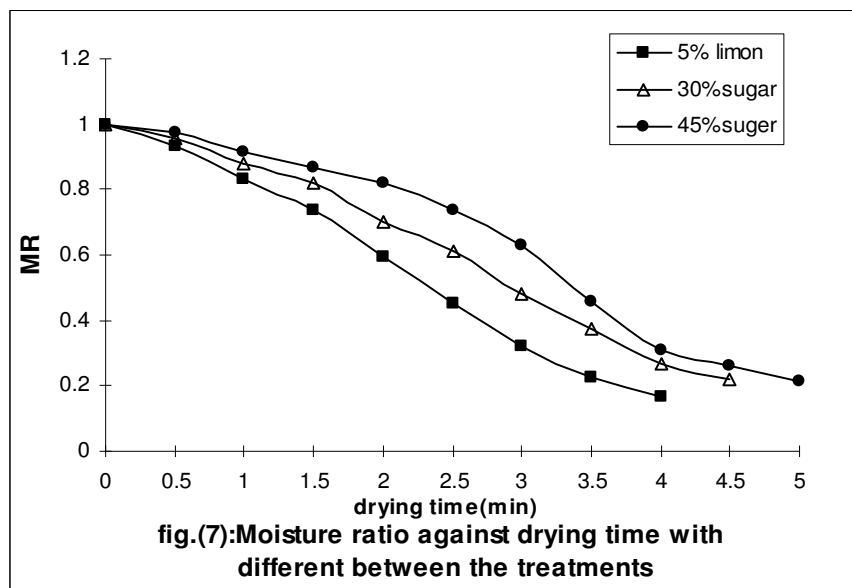
At 5% lemon solution $MR = 1.5646e^{-0.2292\theta}$ $R^2 = 0.9509$

At 45% sugar solution $MR = 1.5202 e^{-0.1615 \theta}$ $R^2 = 0.8964$

At 30% sugar solution $MR = 1.4582 e^{-0.1731 \theta}$ $R^2 = 0.9366$

Where MR=Moisture ratio

θ =Drying time (min)



CONCLUSION

This study indicated that the useful the microwave oven to dry pre-treated apple pieces with saving the time drying .The drying time of apple pieces decreases as the microwave output power increases there was just a falling rate period except a very short accelerating period at the beginning in microwave drying processes of pre-treated different shapes apple samples .

- Microwave drying of apple was faster than the other techniques for drying, the drying data showed that drying constant was highly influenced by high microwave power .

- Sample Thickness and shape (the area : volume ratio) also appeared to be factor influencing the drying rate with high ratio samples resulting in quick drying .
- The drying apple process, the apple samples could be microwave dried to 20% moisture content wet basis in few minutes (rang 3 to 5 minutes).
- The relationship between the moisture ratio ,drying time and the ratio surface area :volume could be resulted.

In order to maximize the benefits of microwave drying, further studies are required at lower power outputs with different microwave power cycles

The effect of drying parameters, such as output power of microwave oven and the particle size (area : volume ratio) on the progress of the drying process of apple was investigated .

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الملخص العربي

تجفيف التفاح باستخدام الفرن الميكرويف

نبيهة حسن أبو الهنا *

أجريت هذه الدراسة لأختبار طبيعة التجفيف باستخدام الفرن الميكرويف لتجفيف ثمار التفاح بطريقة حديثة وسريعة والآن أبحاث كثيرة توصي باستخدام الميكرويف (أو الموجات الميكرومغناطيسية) لوجود مميزات عديدة من حيث توفير الوقت حيث تتم عملية نزع كمية كبيرة من الرطوبة خلال بضع دقائق و تحافظ علي خواص المنتج المجفف ولونه وتمت إجراء التجارب في معمل بجامعة دالهاوزي بدولة كندا في فصل الشتاء لعام 2006.

1- دراسة تأثير أختلاف مستويات الطاقة على إجراء عملية التجفيف (معدلات نزع الرطوبة من عينات التفاح) ولقد تم اختيار 100 وات كمستوى أول و200 وات كمستوى ثاني من القدرة للفرن .

2- استخدامات ثلاثة أشكال مختلفة لقطع التفاح وبأبعاد مختلفة لدراسة النسبة بين المساحة السطحية والحجم لكل شكل. وقد تقطعت عينات التفاح بقطاعة والحصول على أشكال مختلفة منها الشرائح والمكعبات والأشكال الأسطوانية .

3- تمت معاملة العينات بمعاملات مختلفة قبل إجراء عملية التجفيف حيث يوصي بمعاملة التفاح قبل إجراء عملية التجفيف للمحافظة علي اللون والقوام للمنتج المجفف وتساعد في تخفيض نسبة الرطوبة وتساعد في الأسرع لعملية التجفيف والمعاملة الأولى عبارة عن محلول ليمون بنسبة 5% ويتم غمس العينات لمدة خمس دقائق في درجة حرارة الغرفة والمعاملة الثانية محلول سكري بنسبة 30% و الثالثة محلول 45% ويتم الغمس في المحاليل السكرية لمدة 3 ساعات .

4- ولقد تمت دراسة تغيير كتلة العينات عند مستويات ثابتة من القدرة لدراسة ما يسمى بتوزيع القدرة أو الحمولة.

6- ولقد تم أخذ القراءت للمحتوى الرطوبي للعينات لكل 2/1 دقيقة وربط العلاقة البيانية بين المحتوى الرطوبي والزمن .

وقد توصل الي بعض النتائج الهامة منها ان :-

- 1- زيادة القدرة تقلل من زمن التجفيف وبالتالي يزيد معدل التجفيف ويزيد معامل التجفيف.
- 2- فترة التجفيف تختلف باختلاف الأشكال والأبعاد بالأخص النسبة بين المساحة السطحية وحجم الشكل . كلما زادت هذه النسبة كلما قلل زمن التجفيف . وطبيعة الشكل تؤخذ في الاعتبار والمقصود هنا نقط ارتكاز الجسم . فالشكل الأسطواني يختلف عن المكعبات.

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- 3- اوضحت النتائج انه يجب تقدير كتلة العينات وهو ما يعرف (بالوات لكل جرام) لانه يؤثر على زمن التجفيف وبالتالي معدل التجفيف وثابت التجفيف .
- 4- معالجة التفاح بالمحاليل المختلفة والمناسبة للمحافظة على اللون والخواص الطبيعية للتفاح و أثبتت النتائج الأختلاف بين لون العينات الطازجة والمجففة أقل ما يمكن. والمعاملة الثالثة وهي 45% سكر أخذت وقت أكثر لأن وجود السكر يشكل مقاومة لنزع الرطوبة .
- 5- الوصول الى المعادلات الرياضية التى تربط بين المحتوى وزمن التجفيف والنسبة بين المساحة السطحية والحجم .
- التوصيات :-
- المزيد من هذه الدراسة مع الفاكهة والخضروات للإنتاج المحلي للمحافظة على المادة الغذائية والقدرة على تصديرها .