EFFECT OF DIFFERENT DRYING METHODS ON MINT LEAVES PHYSICAL AND QUALITY PROPERTIES

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ABSTRACT

Three drying methods were used for drying mint leaves, oven drying (40, 50, 60 and 70 ^oC), microwave drying (180, 360, 540, 720 and 900 Watt) and direct solar drying with three levels of load (0.5, 1.25 and 5kg/m^2).The drying characteristics and the quality aspects of the dried mint leaves were studied. From initial moisture content (7.65 g.w/g.d.m.) to achieve the equilibrium moisture content the drying time was 5 minutes by microwave drier at use powers 900 and 720 Watt with loading level 0.5 kg/m^2, while the highest time took for drying mint was 20 hours to achieve equilibrium moisture content when use oven drier at 40 ^oC. Meanwhile, the solar drier required 8 hr. to achieve the final moisture content of mint leaves (0.11 g. w./g. d .m) at both 1.25 and 0.5 kg/m^2 loading levels. The results showed that drying of the mint leaves at temperature 50 ^oC with loading rate 1.25 kg/m^2 was the best treatment from all treatments were studied in this work to getting the highest amount of essential oil. Midili - kucuk, model adequately described the oven and solar drying behaviors and logarithmic model adequately described the microwave drying behaviors.

Key wards: mint leaves, microwave, oven drying, solar drying,

1-INTRODUCTION

Drying is one of the oldest methods of food preservation technique and it represents a very important aspect of food processing. The basic essence of drying is to reduce the moisture content of the product to a level that prevents deterioration within a certain period of time (Ekechukwu, 1999). Mint *(Mentha piperita)*,is one of the most important and common flavor in the world coming after vanilla and citrus flavors. Fresh or dried leaves of mentha species are used as a condiment and also their essential oils are produced (Doymaz, 2006).

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Fresh herbs are most often sun dried and minced for flavoring several dishes. Sun drying permits one to produce a product with a rich color and a translucent appearance, but has many disadvantages such as slowness of the process, to exposure to environmental contamination, the dependency on weather and the hand labor requirement (Maskan, 2001).The drying method also had a significant effect on the proportion of the various components (Omidbaigi et al., 2004). Radünz (2004), after working with drying of mint common (*Mentha villosaHuds*), at temperatures between 50 and 70°C, concluded that the air temperature of 50°C is recommended for drying mint-common in order to obtain the highest essential oil content and higher concentration of the main active constituents. Therdthai and Zhou (2009) determined the characteristics of microwave assisted vacuum drying of mint leaves in comparison with conventional hot air drying and their effects on the color and structure of the dried leaves required 13, 12 and 10 min, respectively for reducing the moisture content to less than 0.1 kg water/kg dry sample.

The main objective of this experiment was to investigate the effect of different drying types (oven drying, solar drying and microwave drying) as well as different loading levels on drying characteristics and quality of mint leaves.

2-MATERIALS AND METHODS

Plant material

Fresh peppermint leaves (*Mentha piperita*.) was brought from locale market in El-Kom, Egypt.

Microwave oven drier

Microwave oven (KOR-9G2B) with maximum output of 900W and 2450 MHz was used for drying experiments. The Outside dimensions of the microwave were 465*280*282 mm. cavity dimensions (W*H*D) 314*235*346 mm, and cavity volume 26 L. glass plate with diameter 30 cm use to put the mint leaves on it.

Oven drier:-

Oven drier (Rumo-10878, Germany made) was used for drying experiments. The Outside dimensions of the oven drier (W*H*D) were 80*70*60 cm. and cavity dimensions (W*H*D) 50*60*50 cm.

Solar drying system

The solar drier used in this study was designed and manufactured in the College of Agricultural Minofiya University Shibin El-kom and installed on the roof of Agricultural Engineering Department at (latitude 30.5° N, longitude 31.3° E, and altitude 16.2 meters from mean sea level) as shown in Fig (1). The solar drier consists of the following parts:-

Solar collector (air heater)

The solar collector was made of wooden box having gross dimensions of 1.0 m long, 0.75 m wide and 0.20 m deep. The walls and bottom was constructed of two layer of plywood (0.003 m thick) and the space between the two layer are insulated by foam layer (0.03 m thick), this box painted from inside and outside by a blackboard paint mixed with 50 % by weight of a talc powder . A corrugated absorber plate of surface area was (0.62 m^2) made of galvanized iron sheet 0.5 mm thick. The solar collector was covered with one layer of an ordinary glass, 0.003 m thick. The solar collector was attached with the drying chamber by an air duct. The solar collector was oriented to face the south direction and tilted with an optimum tilt angle at noon.

Drying chamber

The side walls and bottom of drying chamber were constructed of two layer of plywood (0.003 m thick) and the space between the two layer are insulated by foam layer (0.03m thick). The drying chamber was equipped by two drying trays which were made of wooden frame (0.35 m × 0.65 m) and stainless steel screen mesh in the bottom, Fig. (1).

Methods:

Experimental procedure

The fresh mint leaves were washed with water and then excess water on the surface of leaves was drained. The moisture content of the fresh mint leaves was measured at70 ºC in an oven drier for 24 hours. Then the sample was divided into 3 parts each of them dried using different **method as follow:**

Solar drying

Peppermint leaves were distributed on three steel trays of size 0.1 * 0.1, 0.2*0.2 and 0.3*0.3 m , as samples to be weighted with three levels of loading, 5 , 1.25 and 0.5 kg/m^2, and put it on the trays of solar drier.

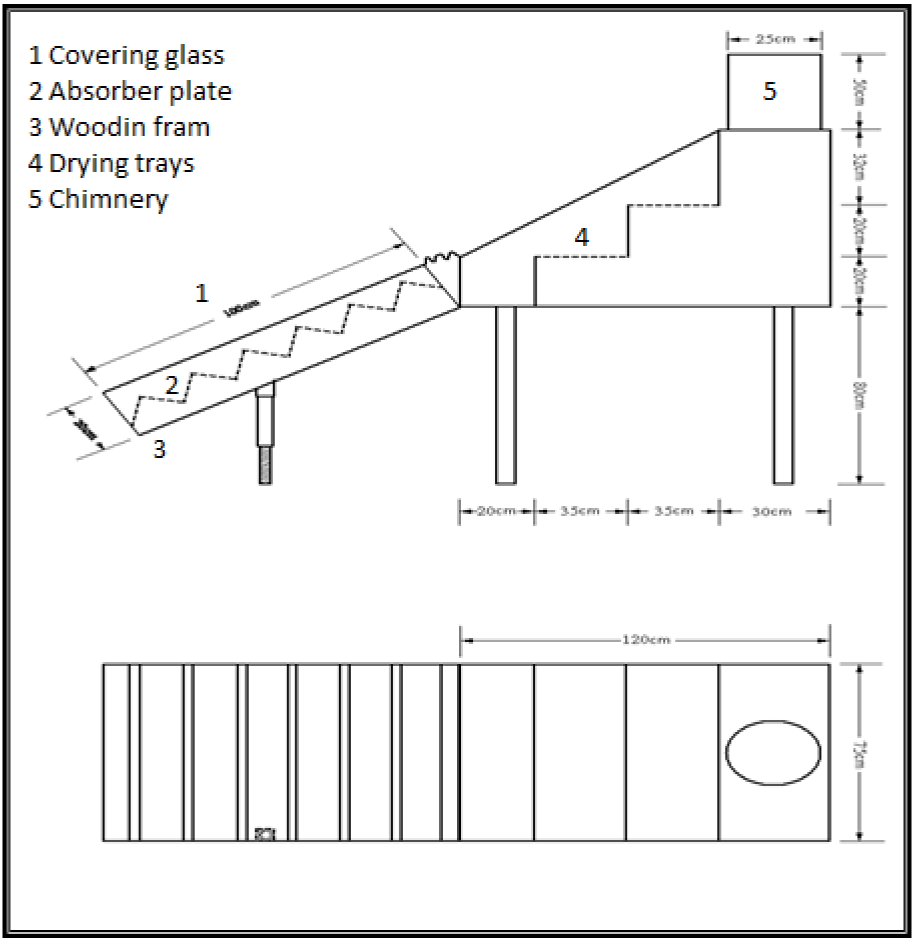


Fig. (1): Schematic diagram of solar drier.

The remaining free space of solar drier trays were used to put on it amount of mint with the same loading rates.

Microwave drying

Peppermint leaves were distributed uniformly in three levels of loading 0.5, 1.25 and 5 kg/m^2 on to the glass Microwave oven plate (dish) diameter 30 cm, and the Microwave operated by different powers (180, 360, 540, 720 and 900 Watt).

Oven drying

Peppermint leaves were distributed on three steel trays of size 0.1 * 0.1, 0.2*0.2 and 0.3*0.3 m , as samples to be weighted with three levels of loading, 5 , 1.25 and 0.5 kg/m^2, and put it on the trays of oven drier. The remaining free space of oven drier trays were used to put on it amount of mint with the same loading rates.

Taking data

Drying data were obtained using three samples for peppermint which were weighted and positioned at the center and the two ends of each tray. The mass of the sample was measured every 1 hour during oven and solar drying and every 1 minute during microwave oven drying for mint leaves.

Measurements:

Moisture content.

The moisture content of fresh mint was determined according to El-Awady *et al*. (1993).

The moisture content of a material expressed on the dry basis (M_{db}) by using the following equation:

$$M_{db} = \frac{w_o - w_d}{w_d} x100 \quad \% \qquad (2.1)$$

Where:

w_o= initial weight of fresh product (kg)

W_d= weight of dry product (kg)

The Drying Efficiency

The drying efficiency η_D is the ratio of the energy required to evaporate the moisture from the crop to available energy.

solar Drier efficiency:

Available energy was solar radiation falling on the area of the drying chamber only.

$$\eta_{Ds} = \frac{Wr * Lv}{I * A} * 100 \qquad (2.2)$$

Where :-

W_r = water removal, (kg/s)

L = latent heat of vaporization, $2256.7*10^3$ (J/kg).

I = solar intensity on horizontal surface (W/m^2)

A = surface area of dying chamber (m^2)

t = desired time period (s)

Oven drier efficiency:

$$\eta_{Dm} = W_r * \frac{LHV}{P} * 100 \qquad (2.3)$$

Where :

W_r = water removal (kg/s)

LHV = Latent heat of vaporization $2256.7*10^3$ (J/Kg)

P = Power consumed(W)

$$P = V*I*COS\varphi = 1.159 \text{ KW.} \qquad (2.4)$$

Where :-

V =Voltage electrical, 230V

I = The intensity of electric current, 6.3 by clamp meter

COS φ = 0.8

Microwave drier efficiency:

$$\eta_{Dm} = W_r * \frac{LHV}{P} * 100 \qquad (2.5)$$

Where :

W_r = water removal (kg/s)

LHV = Latent heat of vaporization $2256.7*10^3$ (J/Kg)

P = Power consumed, 1350 (Watts)

Temperature: temperatures (˚C) were measured using a Rotronic Instruments UK ltd.

Essential oil determination: Fifty gram of the fresh and dried mint were placed in the distillation apparatus then let boil for 3 hours (Board ,2003) and the yielded oil was collected as the amount of oil per 100 g dry weight.

Chlorophylls measurement: The contents of total chlorophylls were calculated using the following equations according to El-Yateem (1995),

Chlorophyll A = (9.78×E 644)-(0.99×E 644) ,mg/liter (2.6)

Chlorophyll B = (21.426×E 644)-(4.65×E 662) ,mg/liter (2.7)

where : E = sample optical density at the indicated wave length.

Modeling the drying characteristics

Mathematical models of drying curves

The methods drying curves were fitted with eleven different moisture ratio equations given by several researchers and cited by Idlimam *et al.*, 2007, as listed in table 2.1.

Fitting the mathematical models:

The regression analysis was performed using the statistical computer program, (Data fit 9.0). The goodness fit between the predicted and experimental values of the tested mathematical models was evaluated from the coefficient of determination R^2 and the reduced chi-square χ^2. The higher of R^2 values and the lower of χ2 values, the better is the goodness of fit Ertekin and Yaldiz, (2004). The reduced chi-square can be calculated as follow:-

$$MBE = \frac{1}{N}\sum_{i=1}^{N}(MR_{pre,i} - MR_{\exp,i}) \quad (2.8)$$

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{\exp,i} - MR_{pre,i})^2}{N-n} \quad (2.9)$$

Where:-

$MR_{exp,i}$: the experimental moisture ratio.

$MR_{pre,i}$: the predicted moisture ratio.

N : number of observations

n : number of constants.

MBE: mean bias error was used to determine the quality of the fit.

Table (1) Mathematical models applied to the drying curves Idlimam et al. (2007).

Model number	Model name	Model expression
1	Newton	$MR = \exp(-k.t) = e^{-k.t}$
2	Page	$MR = \exp(-k.t^{n}) = e^{-k.tn}$
3	Henderson and Pabis	$MR = a.\exp(-k.t) = a.e^{-k.t}$
4	Logarithmic	$MR = a.\exp(-k.t)+c = a.e^{-k.t+c}$
5	Two term	$MR = a.\exp(-k_{0}.t) + b\exp(-k_{1}\,t)$ $=a.e^{-k0.t} + b\,e^{-k1\,t}$
6	Two term exponential	$MR = a.\exp(-k.t) + (1-a)\exp(-k.a.t)$ $= a.e^{-k.t} + (1-a)\,e^{-k.a.t}$
7	Wang and Singh	$MR = 1+ a.t+bt^{2} =1+ a.t+bt^{2}$
8	Approximation of diffusion	$MR = a\exp(-k.t) + (1-a)\exp(-k.b.t)$ $= a\,e^{-k.t}+ (1-a)\,e^{-k.b.t}$
9	Modified Henderson and Pabis	$MR = a\exp(-k.t)+b.\exp(-g.t)+c.\exp(-h.t)$ $=a\,e^{-k.t}+b.e^{-g.t}+c.e^{-h.t}$
10	Verma	$MR = a\exp(-k.t) + (1-a)\exp(-g.t)$ $= a\,e^{-k.t} + (1-a)\,e^{-g.t}$
11	Midilli–Kucuk	$MR = a\exp(-k.t^{n}) +b.t$ $= a\,e^{-k.tn} +b.t$

Where

MR : moisture ratio, T : time, h and A,b,c,g,h,k,n : constant

3. RESULTS AND DISCUSSION

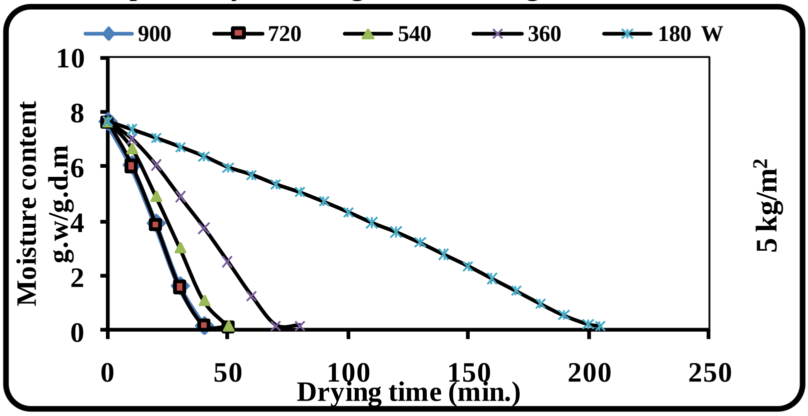
Effect of Drying Methods on drying Characteristics of Peppermint leaves

Mint leaves with initial moisture content (7.65) g.w./g.d.m. was dried by different drying methods (oven drying, solar drying and microwave drying) at different loading levels (5,1.25and 0.5kg /m^{2}). The drying characteristics (moisture content, drying time, drying efficiency and energy consumption) were determined as the quality aspects of the dried mint leaves were evaluated.

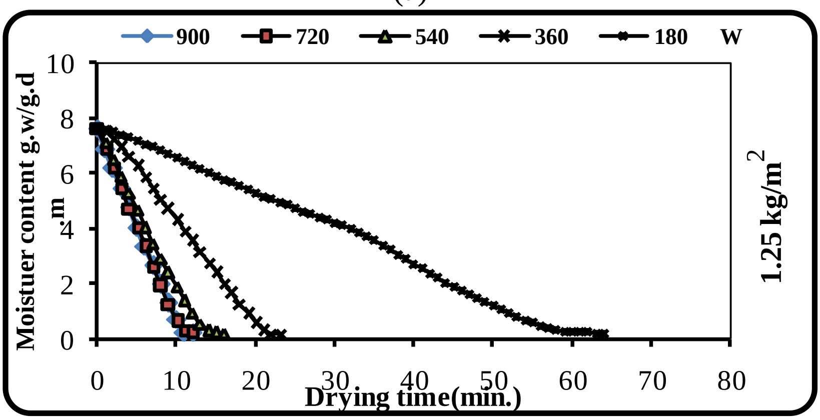
Effect of different drying methods on moisture content:-

Microwave drying:

Fig. 2 (a, b and c) describe the microwave drying curves of moisture content versus drying time the microwave powers and the three loading levels. These figures show the equilibrium moisture content (0.08) g. w./g. d. m. for mint leaves using microwave drying required a range between 205 and 5 min at five radiation powers (180, 360, 540, 720 and 900W) with three loading levels (5, 1.25 and 0.5 kg/m2).). Where it required 205, 71, 48, 45 and 40 min, respectively at loading leave 5 kg/m^2; 64, 23, 16, 12 and 12 min, respectively at 1.25 kg/m^2 and 16, 9, 6, 5 and 5 min respectively at 0.5 kg/m^{2}of loading leave.



(a)



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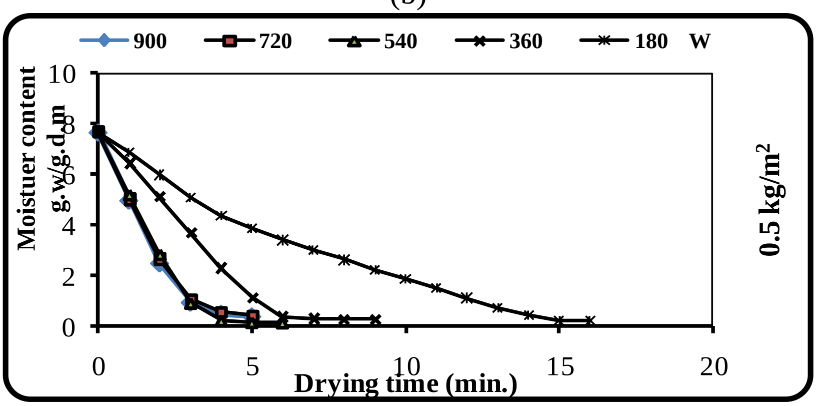
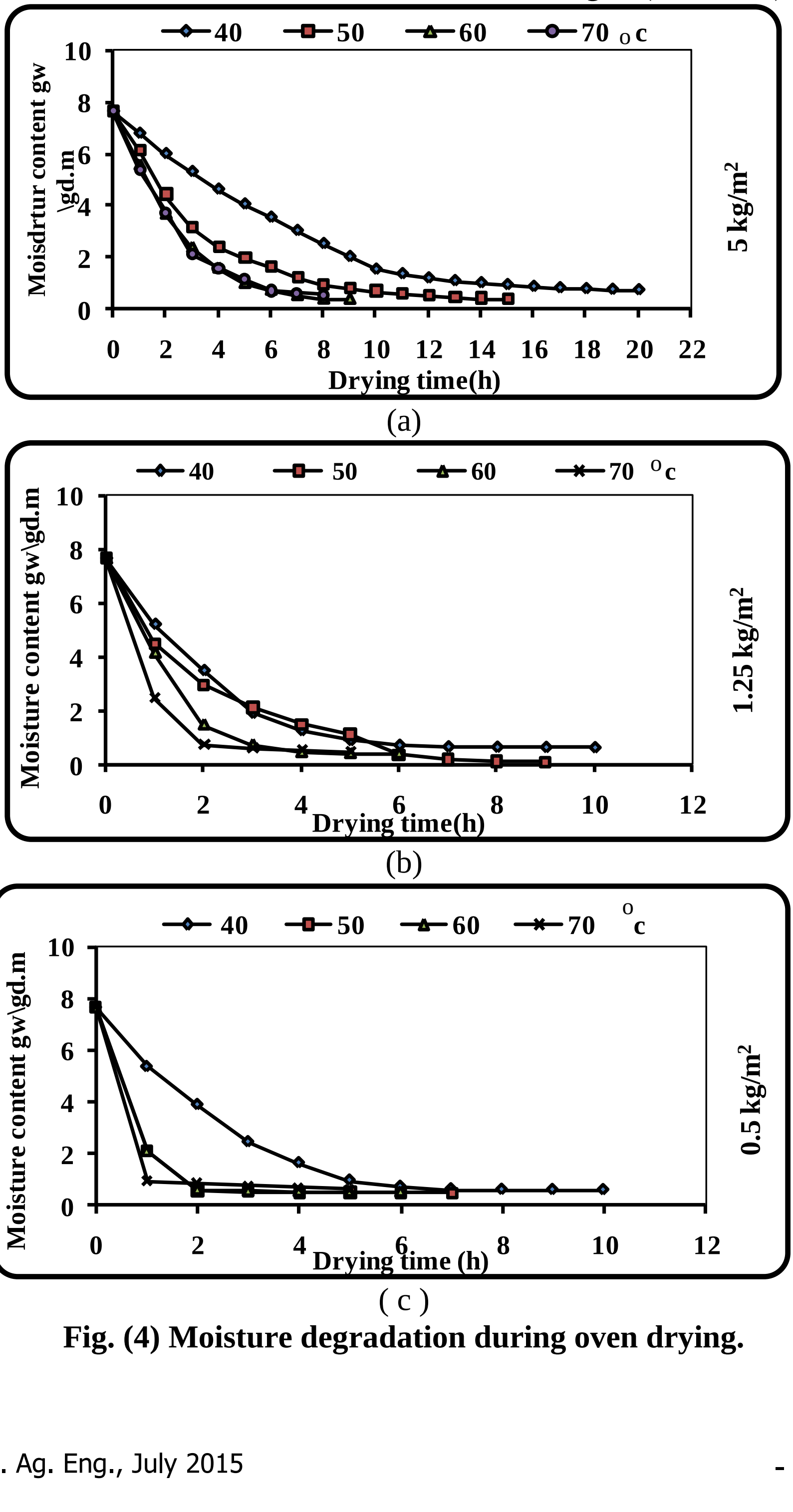


(c)

Fig. (3) Moisture degradation during microwave drying.

Oven drying:

The effect of oven drying condition (temperature and loading) on moisture content of mint leaves are illustrated in Fig. 4 (a, b and c).



(c)

Fig. (4) Moisture degradation during oven drying.

The moisture content of mint leaves was decreased with increasing drying time under the various drying conditions. achieving the equilibrium moisture content for mint leaves using different oven temperature (40, 50, 60 and 70 °C) with loading level 5 kg/m^2. While it required 10, 9, 6, 5, and 10, 7, 6, 5hours at loading levels 1.25 and 0.5 kg/m^2, respectively. Remarkable difference in drying time was observed between drying at 40 °C and both 60 and 70 °C. The drying time at 70 °C was about 60, 50 and 50% shorter as compared with the drying time at 40°C with the levels 5, 1.25 and 0.5 kg/m^2, respectively. Meanwhile no remarkable difference in drying time among 50, 60 and 70 °C with loading levels 0.5, 1.25kg/m^2.

Solar drying:

Fig (5) describe the solar drying curves of moisture content versus drying time at three levels of loading. To achieve the save storage moisture content for mint leaves using solar drying it required 14, 8 and 8 hours, at three loading 5, 1.25 and 0.5 kg/m^2,respectively. The result clearly maintained that no difference in drying time between loading levels 0.5, 1.25kg/m^2 which represent a drying time 43% shorter than the drying time at 5kg/m^2 and it means that the loading 1.25 kg/m^2 was the better.

Drying time of mint leaves could be shortened by 42.8 and 35.7 % by using oven driers at 70 ^{o}C and 60 ^{o}C, respectively compared to solar drying (at 5 kg/m^2 loading). While Microwave drying shortened the drying time over than 95 and (83-98.5%) when compared to the solar and oven drying methods.

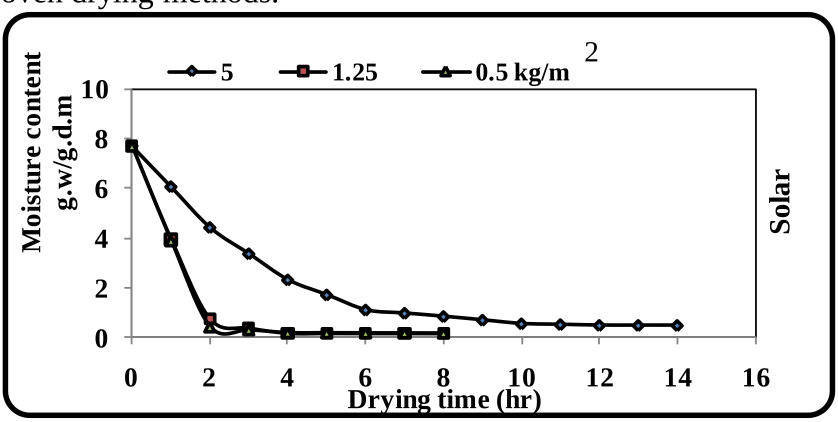
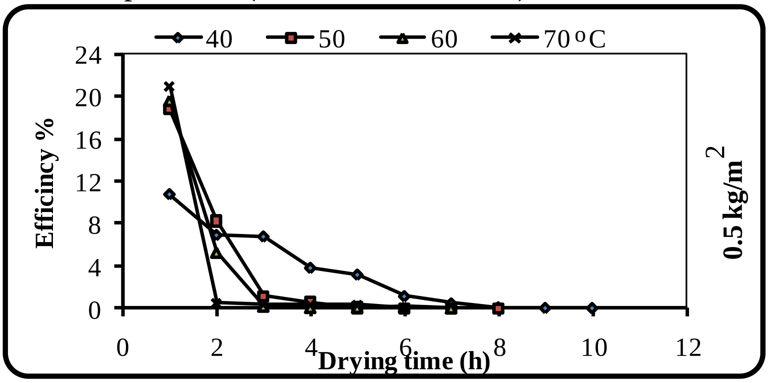


Fig. (5) Moisture degradation during solar drying.

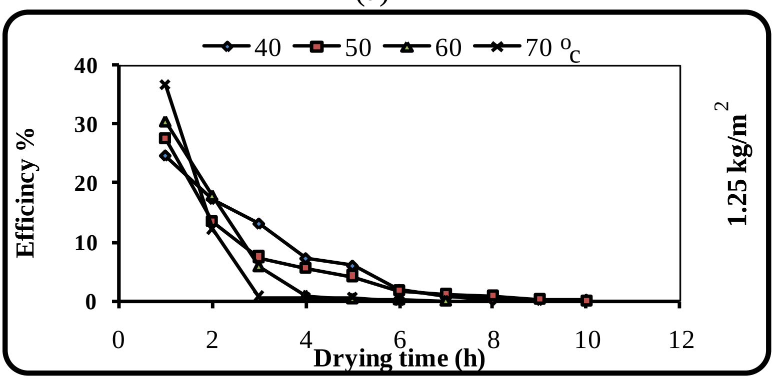
Effect of drying methods on drying efficiency:-

Oven drying:

Fig. 6 (a, b, and c) describe the relation between the drying efficiency and oven drying time with three levels of loading 5, 1.25, and 0.5 kg / m^2 and different temperature (40, 50, 60 and 70 ^{o}C).



(a)



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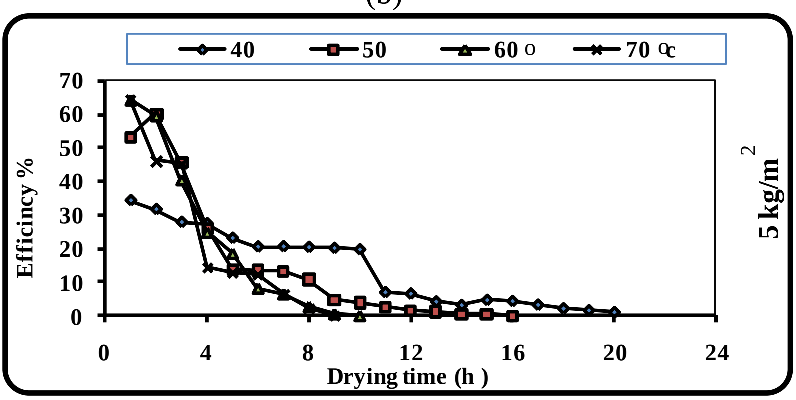


(c)

Fig. (6) relation shape between the drying efficiency and oven drying time

The drying efficiency was always relative high at the beginning of the drying due to increase in drying rate. And wherever it could be noticed that the efficiency increased with increasing loading rate, where the highest efficiency was 64% at loading 5 kg/m^2 and 70 ^{o}C. The lowest was 10% at 0.5kg / m^2 and 40 ^{o}C. On the other side, increasing loading rate to 5kg/m^2 takes the longest period time this means more energy consumption.

Solar drying:

Fig. (7) describe the relation between the drying efficiency and solar drying time, the highest efficiency was 50 % at levels 5, 1.25, and 0.5 kg / m^2 of loading . Meanwhile the lowest was 25% which recorded at 0.5 kg/m^2. The drying efficiency was always relative high at the beginning of the drying due to increase in drying rate.

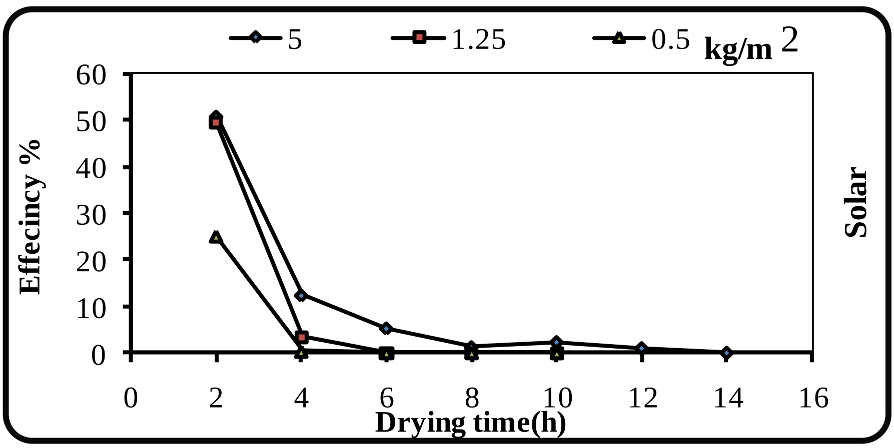
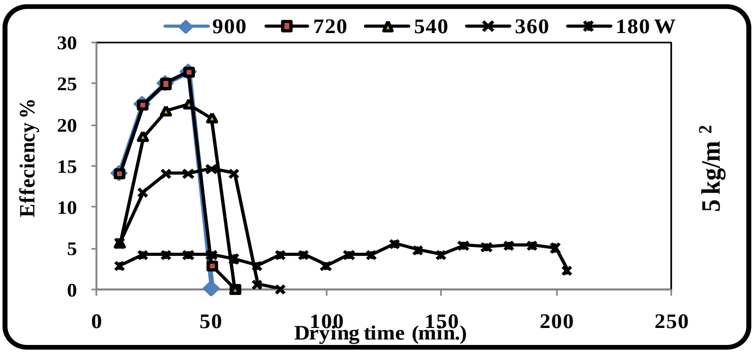


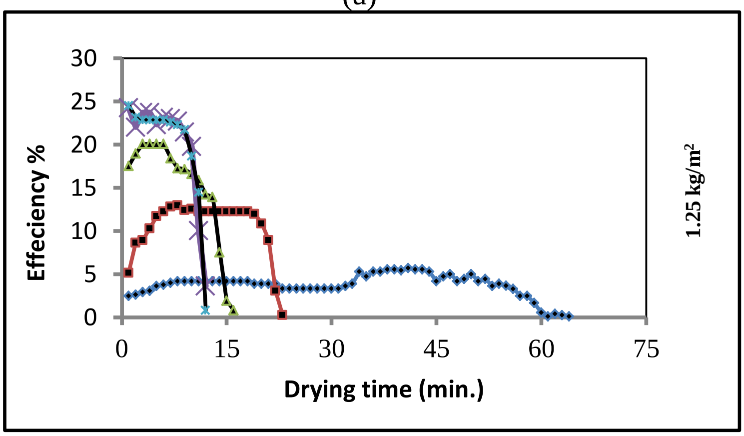
Fig. (7) relation shape between the drying efficiency and solar drying time

Microwave drying:

Fig. 8 (a, b and c) describes the relation between the drying efficiency and drying time with varies microwave power 180, 360, 540, 720 and 900 W, at three levels of loading 0.5, 1.25 and 5 kg/m^2. The drying efficiency was always relative high at the beginning of the drying time due to increase in drying rate. The Figures show that the efficiency decreased with increasing loading rate, and it decreased with decreasing of microwave power. However the highest efficiency was 31 % at loading level 0.5 kg / m^2 with 900 W, and the lowest was 5 % at loading level 5kg /m^2 with 180 W. Furthermore increasing of loading rate (5kg/m^2) takes the longest period time, this means more energy consumption.



(a)



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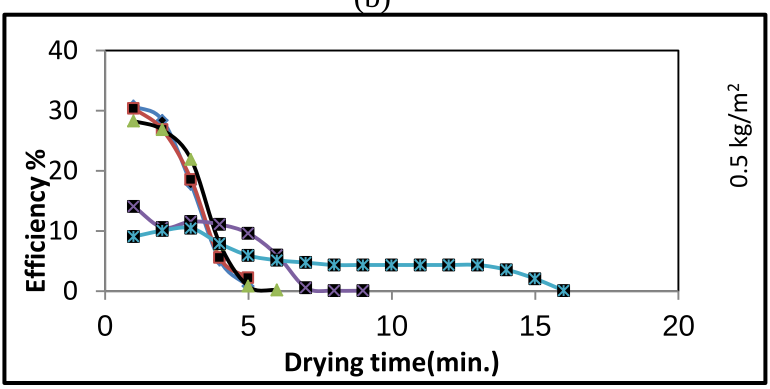

(c)

Fig. (8) relation shape between the drying efficiency (%) and microwave drying time(min)

Effect of drying methods on energy consumption:

Table (1) shows consumed energy by different drying methods (oven drying, microwave drying and solar drying) during peppermint drying process. The highest value of energy consumption was 48.7 MJ when used 40 ^{o}C with 5 kg/m^2 loading rate in oven drying, while the lowest value was 0.405 MJ when used the microwave power 900 and 720 W at 0.5 kg/m^2 loading rate.

Table (1) Total energy consumption during drying peppermint by different Drying methods (MJ)

Loading (kg/m^2)	Drying methods									
	Oven temperature (^{o}C)				Solar drying	Microwave power (W)				
	40	50	60	70		180	360	540	720	900
5	48.7	41.7	28.2	27.8	17.5	16.6	5.7	3.9	3645	3.240
1.25	24.3	25034	18775	17.4	11.09	5.184	1.8	1.2	972	0.972
0.5	20.8	17.03	16.7	15.6	11.09	1.296	0.729	0.486	0.405	0.405

Effect of drying methods on the essential oil yield:

The effect of drying methods on the essential oil yield of mint leaves is illustrated in table (2). The essential oil yield of mint leaves remarkably affected by using the different drying methods (microwave drying, oven drying and solar drying) at the three loading levels (5, 1.25 and 0.5 kg/m^2). Generally, drying the plant material before distillation might be resulted in increasing or reducing the essential oil yield depending on time of drying and temperature Hamrouni-Sellami et al. (2011).

The highest oil yield (1.116 ml /100 g. dry weight) was obtained from fresh sample plant. Drying the mint leaves by electric oven (50^{o}C and 1.25 kg/m^2 loading level) reduced the yield to 0.68 ml/100g d. w., meanwhile increasing the drying temperature and loading to 70 ^{o}C and 5kg/m^2 decreased the oil yield to 0.08 ml/ 100g d. w. With using direct solar drying, the highest yield was 0.60 (ml/100g. d. m.)at 1.25 and 0.5 kg/m^2 loading. The essential oil content of mint leaves was completely lost when the leaves dried at various microwave powers (except leaves dried at 360 W and 1.25 kg/m2 loading which contained only 0.04 ml/100g). The samples dried in the oven at 40, 50 ^{o}C and solar drying retained 0.62, 0.68 and 0.60 ml/100g (.d. b.) of essential oil yields, respectively. No clear differences was observed among the obvious three treatments. On the other side, oven drying at 60 and 70 ^{o}C retained 0.20 and 0.14 ml/100g (d.b.), respectively, At all loading levels, the highest essential oil yields were obtained through oven drying method at 50^{o}C.In microwave drying, the high temperature resulting from microwave energy which used in drying decreased the essential oil yield. This may be due to at high temperatures, the biological structure of the oil glands of medicinal and aromatic plants can be affected and the epithelial cells in the dried samples of some sensible plants can be observed to have been collapsed.

Table (2) Effect of drying methods on the essential oil yield (ml/100g. dry matar)

loading	fresh	Hot air temperature (C)				Solar drying	Microwave power (W)				
		40	50	60	70		180	360	540	720	900
5kg/m^2	1.116	0.44	0.48	0.12	0.08	0.4	0	0	0	0	0
1.25k g/m^2	1.116	0.62	0.68	0.2	0.14	0.6	0	0	0	0	0
0.5kg/m^2	1.116	0.6	0.66	0.2	0.15	0.6	0	0	0	0	0

Effect of drying methods on Total chlorophyll content:

Table (3) shows The degree of color change as affected by drying methods and loading levels. High temperature could lead to the replacement of magnesium in the chlorophyll by hydrogen, thereby converting chlorophylls to pheophytins (Rudra et *a*l. 2008).

The impact on color change of oven dried mint leaves was increased when temperature increased from 40– 50 ^{o}C to 60–70 ^{o}C.This result agreed with (Maharaj and Sankat, 1996) in which slower rate of chlorophyll degradation was found with shorter drying process. From table (3) the chlorophyll a, b of dried mint leaves by varies microwave power was higher than other drying methods in this study. This could be due to shorter drying time of the microwave drying. Insignificant impact of drying temperature in this range on the color of hot air dried products was observed in a previous study of drying dasheen leaves.

Comparing to the microwave drying, the hot air drying yielded dried mint leaves being darker, less green and more yellow.

Table (3) Chlorophyll (a, b) content in mint leaves mg/ L

Loading (kg/m^2)	Chlorophyll a, b	Fresh	Drying methods									
			Temperature				Solar	Microwave drying (W)				
			40	50	60	70		180	360	540	720	900
5	Ch. a	42	9	10	7	6	8	21	16	14	13	13
	Ch. b	24.6	3	4	2	2	3	7.8	5	4	3	3
1.25	Ch. a	42	14	15	11	10	11	26	27	24	22	21
	Ch. b	24.6	4	5	3	2	5	12	11	10	8	8
0.5	Ch. a	42	13	14	10	9	12	25	26	23	20	20
	Ch. b	24.6	4	5	3	3	5.6	11	10	10	7	7.5

Mathematical model of drying curves:

Drying curves were simulated using empirical models of reduced moisture content. These empirical models coming from the fundamental diffusion models are generally suitable for fruits.

The drying data as the moisture ratio (MR) versus drying time were fitted to the eleven drying models. The predicted (MR) of the mint were obtained using the Data fit computer program. Tables (4), (5) and (6) show the drying model coefficients and the comparison criteria used to evaluate goodness of fit, namely the coefficient of determination (R^2), the reduced Chi-square (χ^2), and mean bias error (MBE) for oven drier, solar drier and microwave drier. The values of R^2, χ^2 and MBE for models range from 0.99782 to 0.9999964, 2.97257E-9 to 2.46666E-4, and -5.08333E-5 to 0.18236036, respectively. For oven and solar drying According to table (4) the Midili-kucuk model showed good agreement with the experimental data and gave the best result for mint samples For solar and oven drying at 70 ^oC with 0.5 kg/m^2 of loading rate. The values of R^2, χ^2, and MBE for microwave drying was 0.992399 to 0.99992, 3.964E-9 to, 0.00673 and - 0.003233 to 0.0117096, respectively, According to table (6) the logarithmic model showed good agreement with the experimental data and gave the best result for mint samples at 900 of microwave power and 5 kg/m^2 loading.

Table (4) Modeling of moisture ratio according to drying time for mint by oven drier.

Load	T	model	Model parameters (Coefficients)				R^2	χ^2	MBE
			A	b	k	n			
5kg/m^2	40	Midili-kucuk	0.989	-1.1E-03	0.162	1.063	0.999	2.72E-7	1.0233E-4
	50	page	-	-	0.293	1.058	0.998	2.97E-9	1.275E-5
	60	Midili-kucuk	1.002	- 3.E-03	0.335	1.141	0.998	1.89E-8	3.37E-5
	70	Midili-kucuk	0.997	-3.8E-03	0.406	1.070	0.999	3.69E-7	1. 51E-4
1.25kg/m^2	40	Midili-kucuk	0.996	-9.2E-04	0.461	1.149	0.998	5.08E-6	0.182360
	50	Midili-kucuk	0.998	-2.8E-04	0.752	1.179	0.998	7.84E-6	6.701E-4
	60	Midili-kucuk	1.000	2.7E-04	1.439	1.120	0.999	2.46E-4	-1.057E-4
	70	Midili-kucuk	1.000	2.5E-04	1.432	1.734	0.999	3.02E-7	-1.295E-4
0.5kg/m^2	40	Midili-kucuk	0.993	-6.9E-04	0.368	1.196	0.997	4.96E-6	5.3609E-4
	50	Midili-kucuk	1.000	4.2E-04	0.919	2.290	0.999	3.31E-6	- 4.55E-4
	60	Midili-kucuk	1.000	2.1E-04	1.545	1.579	0.999	1.19E-6	-2.708E-4
	70	Midili-kucuk	1.000	4.2E-05	3.670	0.611	0.999	4.65E-8	-5.083E-5

Table (5) Modeling of moisture ratio according to drying time for mint by solar drier.

Load	Model	Model parameters (Coefficients)					R^2	χ^2	MBE
		a	B	C	k	N			
5k/gm^2	Two term exponential	1.64			0.4238		0.998	1.9e-4	3.39e-3
1.25kg/m^2	Midili-kucuk	1.00	3.2E-3		0.6828	1.7956	0.998	5.429e-5	-1.83e-3
0.5kg/m^2	Midili-kucuk	1.00	3.2E-3		0.6963	2.1702	0.999	5.8e-5	-1.9e-3

Table (6) Modeling of moisture ratio according to drying time for mint by Microwave drier.

Load	Power (W)	model	Model parameters (Coefficients)					R^2	χ^2	MBE
			A	b	C	k	n			
$5kg/m^2$	900	L	3.791	-	-2.8006	7.603	-	0.999	2.06E-6	-0.00369
	540	L	19.530	-	-18.448	1.214	-	0.993	2.22E-8	2.0612E-5
	720	P	-	-	-	1.261	2.091	0.992	0.00673	0.011709
	360	W	-1.019	-6.397	-		-	0.997	8020E-4	-0.003233
	180	W	-3.908	-5.316	-		-	0.999	3.10E-5	3.8641E-4
$1.25kg/m^2$	900	W	-0.106	1.646	-		-	0.997	6.12E-5	-0.001996
	720	W	-0.109	1.885	-		-	0.996	1.06E-4	-0.002629
	540	L	1.8153	-	-0.783	5.673	-	0.995	2.06E-5	-0.003629
	360	L	11.262	-	-10.219	4.471	-	0.996	1.68E-7	1.7916E-5
	180	L	20.166	-	-19.13	8.710	-	0.995	1.65E-6	1.5584E-4
$0.5kg/m^2$	900	M	0.999	-2.475	-	0.434	1.440	0.999	3.86E-8	4.633E-5
	720	M	0.999	-3.285	-	0.425	1.384	0.999	2.31E-9	1.133E-5
	540	M	0.995	-2.169	-	0.366	1.576	0.997	4.86E-6	5.457E-4
	180	M	1.008	-1.320	-	0.128	0.918	0.998	3.96E-9	-1.335E-5
	360	P	-	-	-	0.123	1.715	0.995	0.0008	0.0081513

CONCLUSION

Microwave drying resulted in a high temperature so it is not advisable to use for drying of medicinal and aromatic plants in order to obtain aromatic oils, including due to the sensitivity of aromatic oils to heat whereat works to removed them entirely. Solar drying is more suitable for drying medicinal plants because it maintains much of the oil, furthermore its low cost. Oven drying (at 50 ^{o}C and load level 1.25kg/m^{2}) could be a potent drying method of mint leaves since it maintain much of it' s essential oil.

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الملخص العربى

الخواص الفزيائية وخواص الجودة لأوراق النعناع المجففة بطرق التجفيف المختلفة

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استخدمت ثلاث طرق لتجفيف اوراق النعناع وهي التجفيف بالفرن الكهربائى عند درجات الحرارة (٤٠, ٥٠, ٦٠ و ٧٠م^{o}) , التجفيف بالميكروويف عند (١٨٠, ٣٦٠, ٥٤٠, ٧٢٠ و٩٠٠ وات) والتجفيف الشمسي المباشر , تم تجفيف أوراق النعناع بثلاثة مستويات تحميل (٥ , ١,٢٥ , ٠,٥ كجم/م^{2}) وقد تم فى هذا البحث دراسة بعض خواص التجفيف (المحتوى الرطوبي، زمن التجفيف ، معدل التجفيف و كفاءة التجفيف) بالإضافة الى دراسة تأثير طرق التجفيف على كمية الزيت الطيار في النعناع ، وكمية الكلوروفيل b, a، كما تم حساب كفاءات طرق التجفيف، وكذلك أهتمت الدراسة بحساب كمية الطاقة المستهلكة لكل طريقة من طرق التجفيف المستخدمة في البحث وأيضا إستنتاج النماذج الرياضية المناسبة لوصف سلوك ومنحنيات التجفيف لنبات النعناع .

***قسم الهندسة الزراعية - كلية الزراعة - جامعة المنوفية**

وكانت اهم النتائج المتحصل عليها كما يلي:

- اقل زمن لتجفيف النعناع من المحتوى الرطوبي الابتدائي٧,٦٥ جم ماء/ جم مادة جافة على أساس جاف إلى المحتوى الرطوبي المتوازن كان ٥ دقائق اثناء التجفيف بالميكروويف عند الطاقة ٩٠٠ و٧٢٠ وات والتحميل ٠,٥ كجم/م٢ وأعلى زمن استغرق في تجفيف النعناع كان ٢٠ ساعة عند درجة الحرارة ٤٠ مْ ومعدل التحميل٥ كجم /م٢. بينما كان زمن التجفيف الشمسي ١٤ ساعة عند معدل التحميل ٥ كجم/ م٢ و ٨ ساعات عند معدل التحميل ١,٢٥ و٠,٥ كجم/م٢.
- بينت النتائج إن المعاملة عند درجة الحرارة ٥٠مْ ومعدل التحميل ١,٢٥ كجم /م٢ هي الأفضل في الحصول على اعلي كمية من الزيت مقارنة بدرجات الحرارة ومعدلات التحميل الأخرى.
- كما بينت النتائج أن التجفيف بالميكروويف يعمل على تبخير الزيت العطري بالكامل الا انه يحافظ على قدر كبير من الكلوروفيل أ، ب.
- وقد كانت أعلى كفاءة ٦٤٪ وذلك عند ٧٠ درجة مئوية والتحميل ٥ كجم /م٢ ، أما أدنى كفاءة فقد كانت أقل من ١٠٪ عند التحميل ٠,٥ كجم /م2 و الطاقة ١٨٠وات.
- أوضحت النتائج أن أكبر قيمة للطاقة المستهلكة كانت ٤٨,٧ ميجا جول عند درجة الحرارة ٤٠ درجة مئوية والتحميل ٥كجم/م٢ وأقل طاقة مستهلكة كانت ٠,٤٠٥ ميجا جول عند استخدام القدرة ٩٠٠ و ٧٢٠ وات والتحميل ٠,٥ كجم /م٢.