EFFECT OF DIFFERENT DRYING METHODS ON THE PHYSICAL PROPERTIES AND QUALITY OF SOME FRUIT PEELS

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ABSTRACT

Fruit peel represents approximately 30-40 g/100g of the fresh fruit mass and could be used to develop value-added products rather than causing pollution of the environment. Fruit peels of orange, lemon, pomegranate and grapefruit were dried using two different drying methods (oven and microwave) under different fruit peels masses of 50, 100, 150 and 200g in order to study the drying behavior in terms of specific energy, drying efficiency and product quality. Mathematical models of the oven and microwave dryers were investigated based on the experimental data in order to predict their performance. The obtained data revealed that the use of a microwave was accompanied with higher drying rates of fruit peels, higher drying efficiency and lower specific energy compared with electric oven. The best product quality was achieved in the case of using fruit peels of 50g in the microwave and 200g in the oven comparing with other peels masses. In oven, Newton and Henderson and Pabis models showed good agreement with orange and lemon, while Page and Modified Page (I) were the best descriptive models for pomegranate peels. Regard to the drying in microwave, Page and Modified Page (I) models showed good agreement with all fruit peels (orange, lemon, pomegranate and grapefruit).

INTRODUCTION

Wastes of the peels contribute to pollution of the environment. Recently food industries are being forced by governments to develop productions without secondary residues. Therefore, there is a considerable emphasis on the recovery, recycling and upgrading their by-products. Since these by-products antioxidant activities **(Bauer *et al*., 2012)** and could be converted into a range of commercial products **(Martínez *et al*., 2012)**. For these reasons, different researches have

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assayed different methods in order to obtain new raw materials products from fruit and vegetable processing by-products **(Calín-Sánchez *et al*., 2012)**. Large scale consumption as fresh fruits, the *Citrus* fruits are mainly processed to produce juice. The waste of *Citrus* processing industry left after juice extraction, such as peels, seeds and pulps, corresponding to about 50% of the raw processed fruit can be used as a potential source of valuable by-products **(El-Adawy *et al*., 1999)**. In Egypt and in many Mediterranean countries, major quantities of the peel are not further processed. If not processed further, it becomes waste produce odor, soil pollution, harborage for insects and can give rise to serious environmental pollution **(Mandalari *et al*., 2006).** Some attempts were made to use these residues as livestock feed, although their low nutritional value allowed only limited success **(Bampidis and Robinson, 2006).**

Specifically, the *Citrus* peels, commonly treated as agro-industrial waste, are a potential source of valuable secondary plant metabolites and essential oils **(Andrea *et al*., 2003)**. Citrus fruit peels contain carbohydrates, fat and pectin that contribute to good functional properties. Thus, they can be acceptable as a food ingredient in food industries and at home level.

The pomegranate peels have high moisture contents which can reduced to extraction higher added value products. It is the main waste fraction of pomegranate fruits, which had been widely studied because they contain numerous biologically active compounds including natural antioxidants such as phenolic acids and flavonoids **(Singh *et al*., 2002 and Li *et al*., 2006). Bejar *et al.* (2011)** determined the effect of microwave power on color, total phenols and water and oil holding capacities. By increasing microwave powers (100–850W), drying time decreased from 6960 to 420 seconds for orange peel and from 4800 to 210 seconds for leaves. Page model successfully described the drying kinetics. The applied microwave powers affect significantly all color parameters of peel and leaves compared to the fresh state, functional properties of peel and leaves decreased after microwave drying except the water holding capacity of peel that increased. For both dried peel and leaves and at each applied microwave power, water holding capacity values were higher than oil holding capacity values. Microwave drying decreased total phenols of the dried leaves compared to the fresh ones.

Talens *et al.* (2013) studied the effect of different microwave power densities (0, 2, 4 and 6W/g) combined with 55ºC air drying on drying kinetics, dielectric properties and microstructure of orange peel. Mass variation, water activity and dielectric properties were measured at time points of 0, 5, 15, 40, 60 and 120min for each drying experiment. Results showed that higher microwave power levels resulted in higher amounts of water evaporated in the same time and faster drying rates. However, desorption isotherms did not show differences among power density, while microstructure microscopy showed the opposite.

Sorour *et al.* (2014) dried samples of pomegranate peels and seeds in laboratory dryer at different temperatures of 70, 80, 90 and 100°C and 50, 60, 70 and 80°C, respectively. The results indicated that drying took place in the falling rate period at all temperatures studied for all samples. Moisture transfer from pomegranate peels and seeds was described by applying the Fick's diffusion model, and the effective diffusivity was calculated. Effective diffusivity increased with increasing temperature. An Arrhenius relation with an activation energy value of 7189.282 kJ/mol for pomegranate seeds and 11223.9 kJ/mol for pomegranate peels.

The drying kinetics of food is a complex phenomenon and requires dependable models to predict drying behavior **(Sharma *et al*., 2003)**.

So, the objectives of this study are to:

- Compare the performance of microwave and electric oven for drying some fruit peels (orange, pomegranate, grapefruit and lemon peels)
- Optimize some different parameters (two drying methods, different fruit peels, peels mass) affecting the product quality.
- Determine the specific energy and drying efficiency through drying process of peels.
- Predict the drying behavior dependable on a mathematical model.

MATERIALS AND METHODS

Experiments were carried out during the season of 2016 at Faculty of Agriculture, Zagazig University, Egypt in order to select the proper conditions for drying some fruits peels in a microwave and electric oven which affect some physical properties and product quality (vitamin C, Fiber content, essential oil and phenolic content) and predict their performance dependable on mathematical models.

1. Materials

1.1. Sample preparation

Four different types of fruits [Navel orange (*Citrus sinensis* L.), Lemon (*Citrus limon*), Pomegranate (*Punica granatum*) and Grapefruit (*Citrus paradise*)] were bought from a local supermarket, washed with tap water and stored two days at 8^{o}C until processing. All used peels were separated manually to be dried at different masses, cut into strips approximately 10mm wide, 1mm thickness and then, weighted by using a digital balance (Ming Heng K_1 model) with an accuracy of ± 0.01g.

1.2 Drying equipment

The drying experiments were conducted using two drying equipment as follows:

- **Microwave**, model KOC-185V, Daewoo type, 50MHz, 1000W power and made in Egypt.
- **Electric oven**, model WO-05ASS, White Whale type, 220/240V, 50/60HZ, 1600W power and made in Egypt.

The temperature controller of the two used dryers was adjusted at 80^{o}C and air velocity in the case of using microwave was adjusted at 0.5m/s.

2. Methods

2.1. Experimental procedure

The performance of the drying process was experimentally measured under the following parameters:

- Four different fruit peels (Navel orange, Lemon, Pomegranate and Grapefruit).
- Two different drying equipment (Microwave and Electric oven).
- Four different fruit peels masses (50, 100, 150 and 200g).

Different mathematical models were applied in order to predict the drying behavior and select the proper model for drying fruit peels.

2.2. Measurements and Determinations

Evaluation of the performance of drying process was based on the following indicators:

2.2.1. Moisture content

The average moisture content of fresh samples was determined by drying samples in a vacuum oven at 105ºC until constant weight was reached

(AOAC, 2000). Moisture content of fresh peel samples were 75.88, 83.56, 71.78 and 76.90% (w.b.) for navel orange, lemon, pomegranate and grapefruit samples, respectively.

The moisture losses of samples were recorded at every 1min intervals during the drying process.

Drying process was carried out until the equilibrium moisture content (no weight change) reaches to a level about 10% (wb) according to **(Gölükcü, 2015)**.

2.2.2. Drying rate

Drying rate (g/min) was calculated as following:

$$\text{Drying rate} = \frac{(M_{t+dt} - M_t)}{(dt)}$$

Where: M_t : Moisture content (g water/g dry matter) at time (t); M_{t+dt} : Moisture content (g water/g dry matter) at time (t+dt).

2.2.3. Specific energy and drying efficiency

Energy consumption in drying (Q_t, W.min) was calculated as following:

$$Q_t = p \times t$$

Where: *P*: Required power, W; *t*: Drying time, min.

The specific energy (Q_s, MJ/kg_{water}) was calculated as the energy needed to evaporate a unit mass of water **(Mousa and Farid, 2002 and Soysal *et al*., 2006).**

$$Q_s = \frac{60 \times Q_t}{1000 \times m_w}$$

The drying efficiency (η, %) was calculated as the ratio of the heat energy utilized for evaporating water from the sample to the heat supplied **(Yongsawatdigul and Gunasekaran, 1996; Soysal, 2004).**

$$\eta = \frac{m_w \times \lambda_w}{Q_t \times 60} \times 100$$

Where: m_w: Mass of evaporated water, g; λ_w: Latent heat of vaporization of water, kJ/kg.

The latent heat of vaporization of water at the evaporating temperature of 100^oC was taken as 2257kJ/kg **(Hayes, 1987).**

2.2.4. Product quality

The product quality was tested by the following indicators:

- **Vitamin C (Ascorbic Acid)**

Samples were prepared according to the method described by **(Meléndez *et al.*, 2004)**. The chromatographic procedure used was based on the isocratic method reported by **(Lee, 1993**).

- **Fiber Content**

Total dietary fiber (TDF) fractions were obtained as indigestible residues after enzymatic digestion, the insoluble residues were isolated by filtration and soluble fiber was precipitated with ethanol. Dried residues corresponded to insoluble dietary fiber (IDF) and soluble dietary fiber (SDF), respectively.

- **Essential oil**

The essential oil was extracted by hydrodistillation using a Clevenger device, adapted to a round-bottomed two liter flask as described by **(Skrubis, 1982 and Ming *et al.*, 1996)**.

- **Phenols content**

Total phenols content of the fresh and dried fruit peels extracts was measured using the colorimetric Folin-Ciocalteu method according to **(Singleton and Rossi, 1965)**.

2.2.5. Moisture ratio and mathematical modeling

The moisture ratio (MR) was calculated using the equation:

$$MR = \frac{M_t - M_e}{M_o - M_e}$$

Where: M_t: Moisture content at t, db; M_e: the equilibrium moisture content, db; M_o: the initial moisture content, db.

The value of M_e is relatively small compared with M_t or M_o. Therefore, the moisture ratio (MR) was simplified to (M_t / M_o).

Five semi-empirical models were applied to fit the experimental moisture data because they are widely used in drying agriculture products and they are equalities that explain the characteristic of the drying method in a safe way, as listed in Table 1.

The terms used to evaluate the goodness of the fit of the tested models to the various statistical parameters such as; coefficient of determination (R^2), reduced chi-square (X^2), mean bias error (MBE) and root mean square error (RMSE).

These parameters can be calculated as follows:

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

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

$$RMSE = \left[\frac{1}{N} \sum_{i=1}^{n} (MR_{pre,i} - MR_{\exp,i})^2 \right]^{\frac{1}{2}}$$

Where: $MR_{exp,i}$: The stands for the experimental moisture ratio found in any measurement; $MR_{pre,i}$: Predicted moisture ratio for this measurement; N: Number of observations; n: Number constants.

Table (1): Mathematical models given by various authors for the drying curves

Model No	Model Name	Model	References
1	Newton	MR = exp(-kt)	**(O'Callaghan *et al.*, 1971) and (Liu and Bakker-Arkema, 1997).**
2	Page	MR = exp(-kt^n)	**(Agrawal and Singh, 1977) and (Zhang and Litchfield, 1991).**
3	Modified Page (I)	MR = exp[-(kt)^n]	**(Agrawal and Singh, 1977) and (Zhang and Litchfield, 1991).**
4	Henderson and Pabis	MR = a exp(-kt)	**(Westerman *et al.*, 1973) and (Chhninman, 1984).**
5	Wang and Singh	MR = 1 + at + bt^2	**(Wang and Singh, 1978).**

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following heads:

1. Effect of some different parameters on the behavior of drying rate

Fig.1 showed the relation between drying rate and drying time under two drying methods of fruits peels. It was cleared that the drying rate decreased continuously with drying time. There was not any constant-rate drying period and all the drying operations are seen to occur in the falling rate period. The drying rates were higher at the beginning of the drying operation, when the product moisture content was higher. The moisture content of the material was very high during the initial phase of the drying. Concerning the effect of drying methods on drying rate,

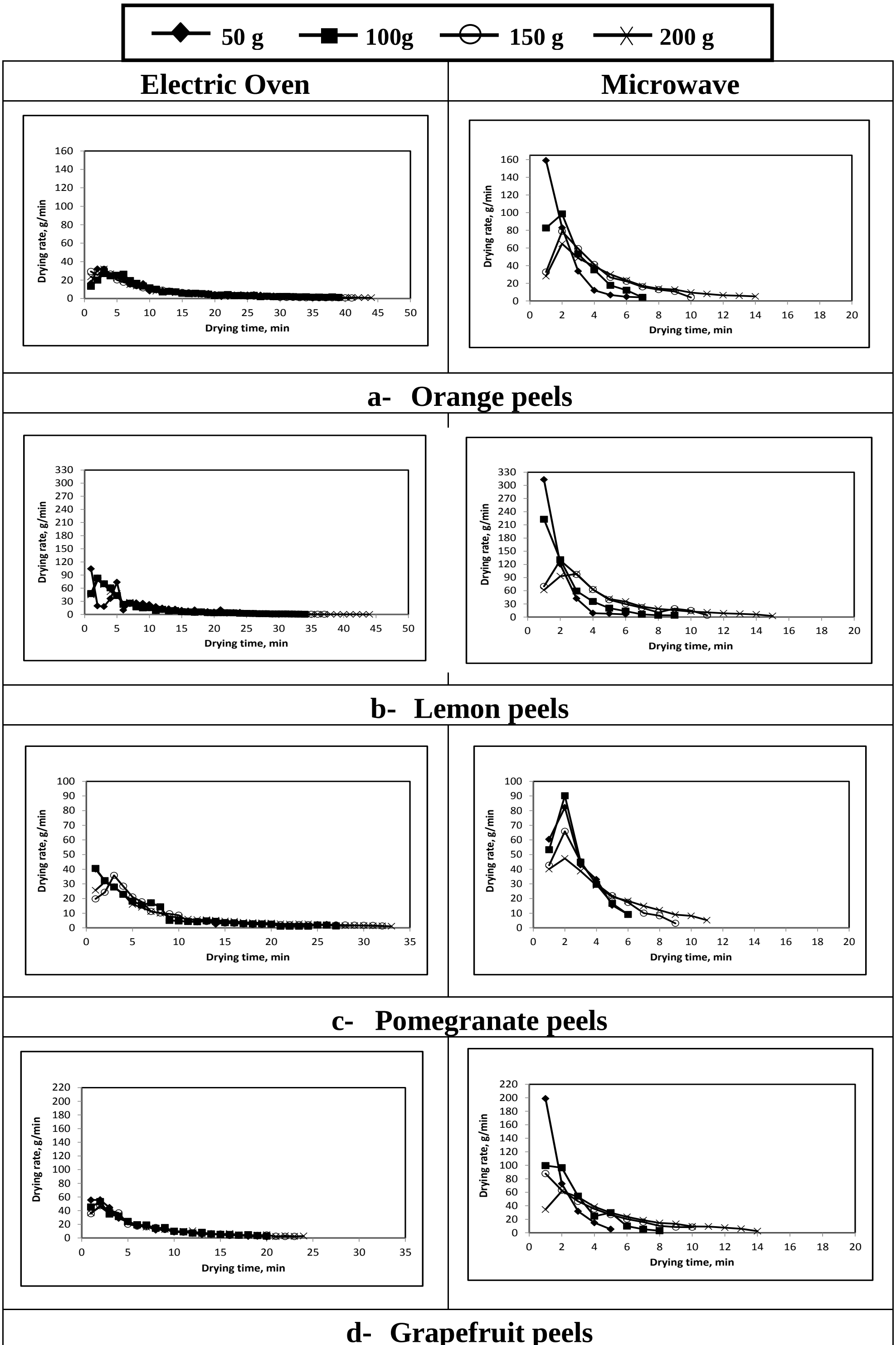

Fig. (1): Variation of drying rate versus drying time for the two used drying methods of some fruit peels masses

the results showed that drying rate of fruit peels using a microwave was faster and took less time than an electric oven. In microwave drying, the quick absorption of energy by water molecules causes rapid evaporation of water, resulting in high drying rates of the food **(Tippayawong *et al.*, 2008)**. The average values of drying rate in electric oven and microwave were (7.76 and 43.29g/min), (14.59 and 55.16g/min), (9.00 and 22.17g/min) and (16.07 and 40.32g/min) for 100g fruit peels of orange, lemon, pomegranate and grapefruit, respectively.

Regard to the effect of peels masses on drying rate, from obtained data, it was noticed that the increase of peels masses was accompanied with more time in drying. In oven, the consumed time for drying 50, 100, 150 and 200g peels masses were (32, 39, 41 and 44min) for orange peels, (30, 34, 37 and 44min) for lemon peels, (27, 27, 32 and 33min) for pomegranate and (20, 20, 23 and 24min) for grapefruit, in that order. While, drying peels by microwave, the drying time was (7, 7, 10 and 14min), (6, 9, 11 and 15min), (6, 6, 9, 11min) and (5, 8, 10 and 14min) for orange, lemon, pomegranate and grapefruit peels, respectively at the same previous conditions. Increasing peels masses, the overall amount of moisture content was increased and thus, the drying rates were decreased at highly masses.

2- Effect of different parameters on specific energy and drying efficiency

Specific energy and drying efficiency of fruit peels under different drying methods were shown in Fig. 2.

Data clarified that using microwave in drying; the water loss was increased than oven. This effect is explained in the driving forces of this drying stage, in fall rate stage the driving forces are the internal transport of water; the microwave energy has high penetration increasing the mobility of the water dropped in the tissue **(Talens *et al.*, 2013)**. So, microwave gave the lowest specific energy consumed for drying peels and thus, the drying efficiency was increased. For 150g mass of peels, the specific energy for drying peels in oven and microwave dryers were (39.96 and 6.03MJ/kg) of orange peels, (32.23 and 5.92MJ/kg) of lemon peels, (33.39 and 5.76MJ/kg) of pomegranate peels and (25.23 and 5.93MJ/kg) of grapefruit peels, respectively.

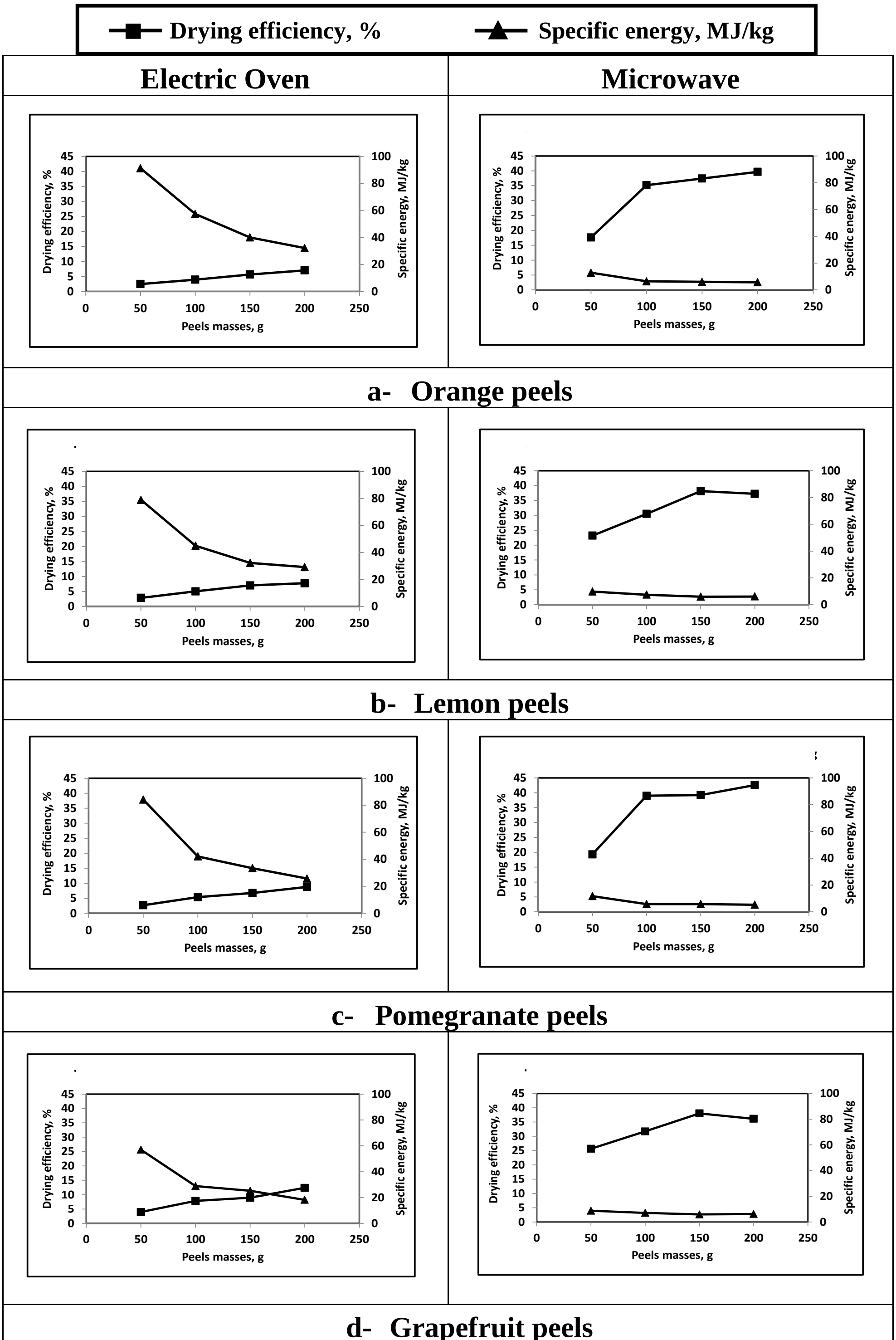

Fig. (2): Effect of fruit peels masses on drying efficiency and specific energy under the two drying methods

While, drying efficiencies in oven and microwave were (5.65 and 37.43%) of orange peels, (7.00 and 38.13%) of lemon peels, (6.76 and 39.20%) of pomegranate peels and (8.94 and 38.03%) of grapefruit peels, under the same previous conditions. This is in agreement with **(Diaz *et al*., 2003)**.

Concerning the effect of fruit peels masses; results explained that increasing the peels masses; the specific energy decreased vice versa, drying efficiency was increased. Overall mass of evaporated water was increased by increasing peels masses and thereby the specific energy was decreased. The drying efficiency for fruit peels in a microwave were 17.63, 35.20, 37.43 and 39.66% for orange, 23.20, 30.51, 38.13 and 37.24% for lemon, 19.31, 39.00, 39.20 and 42.58% for pomegranate, while 25.65, 31.74, 38.03 and 36.14% for grapefruit under 50, 100, 150 and 200g, respectively.

3- Effect of different drying methods on product quality of fruit peels

Vitamin C, fiber content, essential oil and phenolic content in orange, lemon, pomegranate and grapefruit peels as shown in Table 2 were determined as an indicator for the quality of the dried product.

From quality analysis of the used fruit peels, it was observed that the largest amount of vitamin C was in orange peels, highest percentage of fiber content was in grapefruit peels, while lemon peels contained the highest percentage of essential oil, but the phenolic content was at highest value in pomegranate peels.

Drying peels by oven were taken the longest drying period, lowest drying rates in the falling rate period, worsening of the nutritional content of the product, comparing with drying by microwave that reduced the decline in quality and provided rapid and effective heat distribution in the material as well; this is agreement with **(Rayaguru and Routray; 2011 and Diaz *et al*., 2003)**.

The product quality indicators of dried fruit peels in microwave and oven were as follows: at 50g of orange peels, 47.60 and 36.07 mg/100g vitamin C, 3.29 and 2.09% fiber content, 0.20 and 0.20% essential oil and 275.89 and 305.43mg/g phenolic content, respectively. The same trend was observed at the other fruit peels under the same previous conditions.

Table (2): Fruit peels quality under different drying methods and masses

Parameters		Vitamin C, mg/100g		Fiber content, %		Essential oil, %		Phenolic content, mg/g	
		T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
Fresh peels		53.11		4.44		0.21		332.84	
Orange peels	50	47.60	36.07	3.29	2.09	0.20	0.20	275.89	305.43
	100	42.82	37.46	2.82	3.07	016	0.17	255.39	283.18
	150	39.49	44.14	2.09	3.16	0.15	0.16	260.81	275.59
	200	33.15	48.99	2.14	4.06	0.20	0.19	311.67	321.74
Fresh peels		47.10		2.80		0.30		208.40	
Lemon peels	50	41.33	25.27	2.16	2.13	0.26	0.18	197.51	200.89
	100	37.27	30.72	2.24	1.90	0.16	0.21	201.23	185.19
	150	31.56	33.23	1.98	2.03	0.19	0.19	183.72	167.91
	200	27.20	39.00	2.05	2.13	0.23	0.29	195.19	206.17
Fresh peels		15.82		1.66		0.10		456.97	
Pomegranate peels	50	11.23	13.16	1.36	1.43	0.06	0.07	385.58	310.62
	100	10.59	12.08	1.26	1.19	0.06	0.05	346.51	218.52
	150	9.91	13.62	1.56	1.26	0.09	0.04	239.74	324.52
	200	8.56	14.17	1.60	1.37	0.08	0.09	210.30	377.21
Fresh peels		38.17		4.96		0.18		305.70	
Grapefruit peels	50	30.44	30.94	3.77	4.07	0.15	0.07	278.39	227.89
	100	31.55	27.86	3.53	3.82	0.12	0.10	250.20	260.71
	150	28.76	33.51	2.85	2.16	0.09	0.12	236.90	269.59
	200	25.08	34.43	4.10	3.09	0.12	0.15	241.20	301.51

Where:

T_1: Microwave drying method. T_2: Electric oven drying method.

Table (3): Modeling of moisture ratio of different fruits peels at 50 g in oven

Model	Fruit peels	Constants				R^2	MBE	X^2	RMSE
		k	n	a	b				
Newton	A	0.102				0.991	-0.017	0	0.009
	B	0.129				0.997	-0.007	0.001	0.04
	C	0.105				0.979	0.076	-0.157	0.393
	D	0.161				0.997	0.001	0	0.001
Page	A	0.082	1.073			0.986	0.005	0.001	0.03
	B	0.146	0.945			0.980	-0.006	0.001	0.031
	C	0.202	0.834			0.990	0.004	0	0.022
	D	0.163	0.996			0.997	0.001	0	0.004
Modified Page (I)	A	0.097	1.073			0.986	0.005	0.001	0.031
	B	0.135	0.945			0.980	-0.014	0.001	0.075
	C	0.148	0.834			0.99	0.004	0	0.019
	D	0.162	0.996			0.997	0.001	0	0.003
Henderson and Pabis	A	0.01		1.012		0.991	0.002	0	0.012
	B	0.129		1.039		0.997	-0.014	0.001	0.078
	C	0.105		0.751		0.979	-0.011	0.005	0.06
	D	0.162		0.999		0.997	0.002	0	0.007
Wang and Singh	A			-0.065	0.001	0.977	0.059	0.006	0.335
	B			-0.071	0.001	0.984	-0.304	0.259	1.666
	C			-0.078	0.002	0.951	0.148	0.026	0.767
	D			-0.104	0.003	0.983	-0.302	0.246	1.35

Where: A: Orange peels. B: Lemon peels. C: Pomegranate peels. D: Grapefruit peels.

Table (4): Modeling of moisture ratio of different fruits peels at 50 g in microwave

Model	Fruit peels	Constants				R^2	MBE	X^2	RMSE
		k	n	a	b				
Newton	A	0.462				0.952	0.078	0.011	0.206
	B	0.652				0.963	-0.175	0.052	0.679
	C	1.096				0.986	-0.206	0.074	0.505
	D	0.717				0.990	0	0	0
Page	A	0.788	0.777			0.973	0.002	0.001	0.005
	B	1.033	0.782			0.979	-0.200	0.079	0.774
	C	0.821	1.249			0.998	-0.184	0.005	0.452
	D	0.921	0.861			0.998	0	0	0
Modified Page (I)	A	0.737	0.777			0.973	0.001	0	0.003
	B	1.041	0.782			0.979	-0.200	0.079	0.774
	C	0.157	1.249			0.998	0.346	0.193	0.848
	D	0.952	0.861			0.998	0.001	0	0.003
Henderson and Pabis	A	0.462		0.704		0.952	0.033	0.019	0.088
	B	0.630		0.683		0.953	-0.217	0.501	0.774
	C	0.534		1.193		0.991	0.012	0.11	0.030
	D	0.717		0.858		0.990	-0.019	0.01	0.043
Wang and Singh	A			-0.357	0.034	0.946	0.113	0.024	0.299
	B			-0.4374	0.0506	0.934	1.436	6.890	5.561
	C			-0.3331	0.0286	0.995	-0.022	0.002	0.053
	D			-0.4936	0.0643	0.966	-0.245	0.36	0.150

Where: A: Orange peels. B: Lemon peels. C: Pomegranate peels. D: Grapefruit peels.

Regarding to the effect of peels masses, results clarified that the optimum masses of drying peels were 50g in a microwave and 200g of peels in oven for different fruit peels.

It is observed that the use of higher peels masses in microwave, accelerate the evaporation of water with higher drying rates, that tends to lose some properties of the dried material which is reflected on the product quality.

While, drying the highest masses in oven took the required time of drying rate and thereby, the quality was improved.

4- Mathematical models

Non-linear regression was used to obtain each parameter value of every model. The results of statistical analyses undertaken on these models are given in Tables 3 and 4 at 50g for different fruit peels in oven and microwave, respectively.

It was noticed in the case of oven drying that Newton and Henderson and Pabis models showed good agreement with orange and lemon peels, while Page and Modified Page (I) gave the best descriptive models for pomegranate.

On the other hand drying in microwave; Newton, Modified Page (I) and Henderson and Pabis models showed good agreement with grapefruit. While, Page and Modified Page (I) models showed good agreement with all fruit peels (orange, lemon, pomegranate and grapefruit).

CONCLUSIONS

From the obtained results, it can be concluded that:

- For drying fruit peels, it is prefer to use the microwave whereas, it has faster drying rate, lower specific energy and higher drying efficiency compared to the electrical oven.
- To obtain good product quality, it is advised to use fruit peels mass of 50g in a microwave and 200g in an oven.
- For predicting the change in the moisture content as the best descriptive, it is used Newton and Henderson and Pabis models for good agreement with orange and lemon; Page and Modified Page (I) models for pomegranate peels in the case of using oven.

  In microwave, Page and Modified Page (I) models showed good agreement with all the used fruit peels (orange, lemon, pomegranate and grapefruit).

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الملخص العربي

تأثير طرق التجفيف المختلفة على الخواص الفيزيائية والجودة لبعض قشور الثمار

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يهدف البحث الى تجفيف قشور بعض الثمار (الرمان، الليمون، الجريب فروت والبرتقال) باستخدام الميكروويف و فرن التجفيف الصناعى ودراسة تأثيرهما على خواص وجودة المنتج المجفف.

تم اختيار مجموعة من قشور الثمار تحت الدراسة وذلك لفوائدها المتعددة ومنها:

- **قشور البرتقال** وهو إحدى أكثر القشور فائدة لجسم الإنسان حيث تحتوي على فيتامين سى ، وماء وألياف وحديد وكالسيوم ومواد كربوهيدراتيه وكذلك مركب البكتين غير القابل للهضم والذي يشجع على نمو البكتيريا المفيدة في الأمعاء الغليظة التي تمنع الإصابات المعوية، كما إنها تساعد في الوقاية من الجراثيم المسببة للتسمم الغذائي.
- **قشور الليمون** بها مثل ما هو موجود بقشر البرتقال، وتحتوي قشرة الليمون أيضا على كربوهيدرات حيوية.
- **قشر الرمان** يساعد فى محاربة السمنة و الالتهابات و بعض انواع السرطانات.
- **قشر الجريب فروت** يستخرج منه الزيوت الطياره و مادة البكتين التى تستخدم فى عمل المربى و الحلويات.

تقوم بعض شركات التجميل بتجفيف هذه القشور وطحنها وإدخالها في الصناعات التجميلية كالصابون والشامبو والبلسم والمراهم.

تم استخدام أربعة اوزان مختلفة لكل نوع من أنواع القشور (٥٠ ، ١٠٠ ، ١٥٠و ٢٠٠جم) مع نوعين مختلفتين للمجففات.

تم تطبيق بعض المعادلات الرياضية للتنبؤ بالتغير فى المحتوى الرطوبى لقشور الثمار المختلفة.

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أهم النتائج التى تم التوصل اليها:

١- معدل التجفيف للميكروويف كان أسرع من التجفيف فى الفرن الصناعى فكان متوسط معدل التجفيف لوزن ١٠٠جم من القشور (٧,٧٦ و ٤٣,٢٩)جم/دقيقة ، (١٤,٥٩ و ٥٥,١٦)جم/دقيقة ، (٩,٠٠ و ٢٢,١٧)جم/دقيقة و (١٦,٠٧ و ٤٠,٣٢)جم/دقيقة لقشور البرتقال ، الليمون ، الرمان والجريب فروت فى الفرن والميكروييف على التوالى.

٢- استخدام الميكروويف قلل من الطاقة المستهلكه فى التجفيف وأعطى زياده فى كفاءة عملية التجفيف.

٣- استخدام ٥٠جم من القشور فى الميكروويف و٢٠٠جم فى الفرن أعطى مواصفات جوده عاليه للمنتج.

٤- بعض المعادلات أمكنها وصف سلوك عملية التجفيف بشكل مرضي تحت ظروف التجفيف بالطريقتين وكان ذلك مصحوبا بقيم عاليه لمعامل الارتباط (R^2) كالآتى:

بالنسبة للفرن:

تنبأت معادلتى نيوتن و هندرسون وبابس بالتغير في المحتوي الرطوبي بشكل أكثر ملائمة بالمقارنة بالمعادلات الأخرى بالنسبة للبرتقال والليمون اما بالنسبة للرمان كانت معادلتى بيج وبيج المعدلة هما الاكثر ملائمة أما المعادلات نيوتن ، بيج المعدلة و هندرسون و بابس متوافقين مع قشور الجريب فروت.

بالنسبة للميكرييف:

كانت معادلتى بيج و بيج المعدلة هما الاكثر ملائمة بالنسبة لكل أنواع القشور المستخدمة فى الدراسة.