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DRYING CHARACTERISTICS OF OLIVE POMACE USING ACCELERATED DRYING TECHNIQUE

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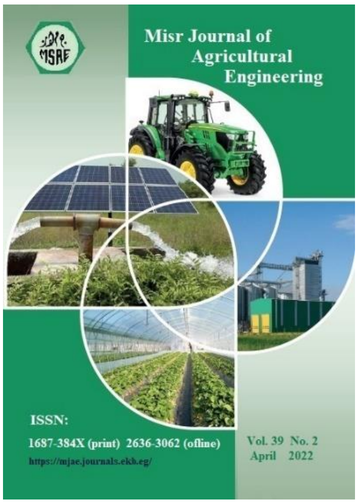

Keywords:
Olive pomace; Drying behavior; Accelerated drying.

ABSTRACT

Olive pomace is a sub-product of the mechanical olive oil extraction industry. The study was carried out to test and evaluate the effect of high temperature short time conduction heating technique using a laboratory scale rotary dryer on drying of wet olive pomace. The drying experiments were performed at a wide range of drying temperatures (80, 95, 110, 125 and 140°C) and three levels of olive pomace mass (1, 1.5 and 2 kg/patch). Five thin layer drying models were evaluated and fitting to the experimental moisture data. The fit quality of the models was evaluated using the determination coefficient, chi-square, and root mean square error. In addition, the effects of studied parameters on the drying characteristics, the final quality of the dried pomace was also determined. The obtained results showed rapid moisture removal from the wet olive pomace was obvious particularly at higher levels of heating surface temperature. A constant rate period was not observed in the drying of olive pomace; all the drying process occurred in falling rate period. Among the selected models, Page model was found to be the best model for describing the drying behavior of olive pomace.

1. INTRODUCTION

Olive oil extraction represents an industrial activity of high economic and healthy relevance in the Mediterranean countries. The annual average production of olive oil was around 3.1 million tons in the 2020/2021crop year. Meanwhile the annual average production in Egypt was around 40.000 tons **(International olive oil council (IOC), 2020).** The extraction of olive oil generates significant amounts of residues, both liquids and solids. Olive pomace is a biomass by-product of olive oil production and is a very abundant agricultural waste in the Mediterranean area. It still contains significant oil content and an important moisture content, depending on the olive oil extraction process **(Maragkaki et al., 2016)**. In Egypt, most of the produced fresh olive pomace is piled near olive mills. It stays as such until the winter season is over. This practice adds more moisture because the pomace was not protected from rain and snow. Also, fermentation and some other physicochemical processes are very likely to take place during this temporary storage period. At the end of April of each year, the pomace is spread for sun drying. The sundried pomace is either use as a fuel for the mill or sold in its loose form. The disposal of this waste without any treatment causes serious environmental problems that may have a great impact on land and water environments. Therefore, it is necessary to dry this agricultural waste quickly before spoilage begins to occur. In addition, a greater yield and a higher grade of olive pomace oil could be obtained from pomace dried immediately after the extraction process of olive oil **(Meziane, 2011).**

Drying is one of the oldest and most widely used methods of agricultural products preservation. It is based on removal of moisture contained in the product by means a complicated process involving simultaneous heat and mass transfer **(Krokida et al., 2003; Yilbas et al., 2003)**. Several authors in the scientific literature have focused their efforts on the modeling of the convective drying kinetics for wet olive pomace. For instance, **Gómez-de la Cruz et al. (2014)** showed the characterization of the thin-layer dying kinetics of wet pomace, in the range of drying temperatures (between 100 ºC to 425 ºC), drying air velocity (between 1 m/s and 7 m/s), and sample size (between 10 mm and 50 mm). **Sadi and Meziane (2015)** studied the effects of microwave drying power on drying kinetics of olive pomace at three different microwave power levels of 170, 360 and 510 W. **Koukouch et al. (2017)** performed studies on olive pomace drying processes at different drying temperatures (40, 60 and 80 °C) and for two drying air flow rates (0.042 and 0.083 m^3/s) using a partially indirect solar convective dryer operating in forced convection. **Baysan et al. (2020)** studied in laboratory tray dryer the drying process of olive pomace and the drying rate was determined with respect to operating conditions (temperature, thickness and air velocity). Consequently, knowledge of moisture content in the olive pomace is important for drying process design and conditions. Moreover, mathematical models would also be desirable for describing the drying mechanism.

The present study aims to test and evaluate the use of high temperature short time conduction heating technique for drying high moisture olive pomace and modeling of pomace over a wide temperature range by using mathematical models. In addition, the effect of heating treatment on the olive pomace quality was also investigated immediately after the drying process.

2. MATERIALS AND METHODS

Olive pomace sample

The samples of fresh olive pomace were obtained from a local oil mill located in North Sinai governorate, Egypt. It had an average initial moisture content of 49.36 ± 0.3% (w.b.), which was the arithmetic average of the initial moisture contents of the samples of all drying experiments. The initial and final moisture content was determined by drying in an oven at 105 °C for 4 h until reaching a constant weight as mentioned by **(Doymaz et al., 2004).**

Experimental set-up

In this study, the drying process of olive pomace was conducted in accelerated drying unit. **Figure (1)** shows a schematic drawing for accelerated drying rotary unit. The dryer consists of a rotary cylinder (0.6 m in diameter and a 0.2 m long) enclosed by a fixed insulated cylinder (0.8 m in diameter and 0.3 m long). One side of the rotary cylinder connected to a driving mechanism consists of a 0.15 m diameter steel flange fixed to the side cover of the rotary cylinder and welded to a steel bar riding into a heavy-duty ball bearing. A 0.5 kW/h low speed motor with different sizes of pulleys used for power supply and speed control of the rotary cylinder. The other side of the rotary cylinder serves as an inlet for olive pomace samples through a 0.1 m diameter center hole. The heat-treated olive pomace discharged through a perforated removable sector of the cylinder bottom. For heating and temperature control of the rotary cylinder surface, two kW electric resistance heater were placed at the inner surface of the fixed insulated cylinder (between the rotary cylinder and the insulated exterior cylinder) to heat the surface of the rotary cylinder.

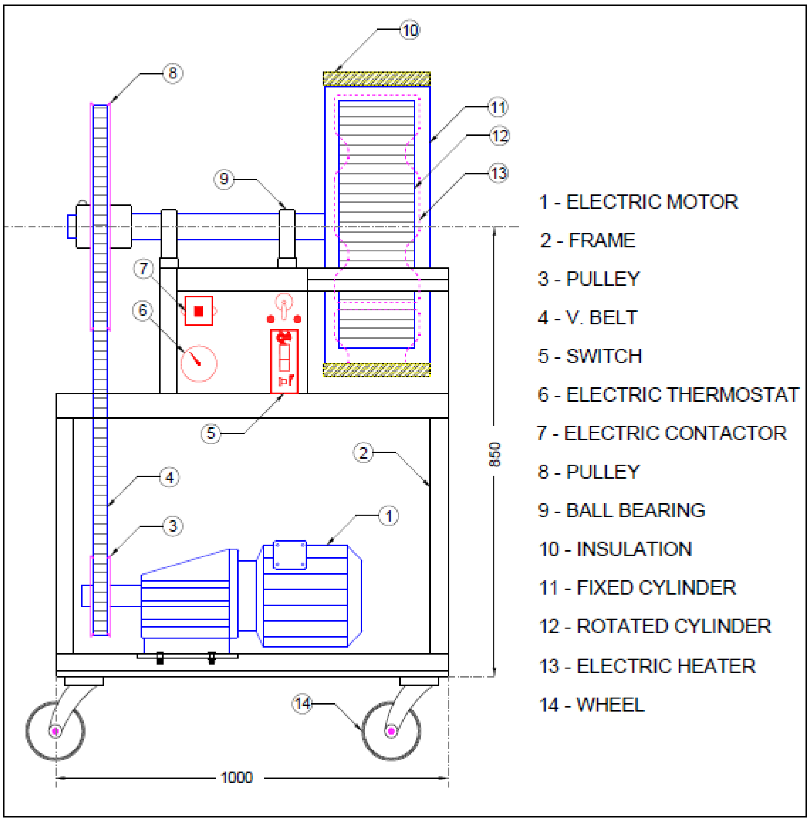

Figure (1): Schematic diagram of the accelerated drying unit

Experimental Procedure

Drying experiments were performed at different cylinder surface temperature (80, 95, 110, 125 and 140 ˚C) and three levels of pomace mass (1, 1.5 and 2 kg/patch). Moisture loss was recorded at 5 min intervals during the drying process in order to determine the changes of moisture content. The dried samples were cooled at the laboratory conditions after each drying experiment and kept to use in further experiments.

Quality Evaluation of the Dried Olive Pomace

Determination of oil peroxide value

Peroxide value was measured according to the method 965.33 described by **A.O.A.C. (2000)** in order to determine the oxidation level of oils and fats.

Determination of the extracted oil acid value

The acid value was determined according to the method 696.17 described by **A.O.A.C (2000).**

Determination of crude protein

The crude protein was determined by Kjeldahl method which performed according to method 981.10 of the AOAC International as described by **Horwitz (2010).**

Determination of the free fatty acids (FFA%) of olive pomace oil

The FFA % of oil samples were calculated as oleic acid to determine the level of oil and fat degradation using the corresponding acid value of each sample according to the **A.O.A.C. (1991)** as follows:

$$FFA\% = \frac{A.\mathrm{V}}{1.99} \quad \text{.. (1)}$$

Where:

A.V: Acid value

Mathematical modeling of drying curves

The moisture content values obtained for the range of the different levels of drying temperatures and pomace mass were converted into the moisture ratio. The dimensionless moisture ratio can be calculated using the following equation:

$$MR = \frac{M - M_e}{M_o - M_e} \quad \text{.. (2)}$$

where :

MR : Moisture ratio, dimensionless

M : The moisture content at time t, % (w.b.)

M_o : The initial moisture content, % (w.b.).

M_e : The equilibrium moisture content, % (w.b.).

Since the values of the dynamic equilibrium moisture content Me are relatively small compared to M or Mo, respectively. Thus, the dimensionless moisture ratio MR can be simplified to MR= M / M_o **(Thakor et al., 1999)**. Experimental results of moisture ratio with drying time were fitted to five thin layer semi-theoretical models, widely used in the scientific literature to describe the kinetics of the drying process. The selected mathematical models are identified in **Table 1**.

Table (1): Mathematical models applied to drying curves.

NO.	Model name	Model
1	Lewis	MR = exp(-kt)
2	Page	MR = exp(-kt^n)
3	Henderson and Pabis	MR = aexp(-kt)
4	Wang and Singh	MR = 1+at+br^2
5	Logarithmic	MR = aexp(-kt) +c

The non-linear regression analysis was performed using Statistical Software (Costat, Version 6.311, USA) to obtain different constants of each studied model. The coefficient of determination (R^2), reduced chi-square (χ^2) and root mean square error (RMSE) were calculated to evaluate the fitting of each model to the experimental data. The highest value of the coefficient of determination (R^2) and the lowest value of the reduced chi-square (χ^2) and RMSE were chosen for goodness of fit. These parameters can be calculated as below **(Rossello et al., 1992)**

$$X^2 = \frac{\sum_{i=1}^{N}(MR_{ei}-MR_{pi})^2}{N-z} \quad \text{.......} (3)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(MR_{ei}-MR_{pi})^2}{N}} \quad \text{.......} (4)$$

where :

MR_{ei} : The experimental moisture ratio.

MR_{pi} : The predicted moisture ratio.

N : The number of observations.

z : The number of constants in a model.

3. RESULTS AND DISCUSSION

Change in pomace moisture content

Figure (2) illustrates the change in pomace moisture content as related to drying time at different levels of cylinder surface temperature. The results presented in **Figure (2)** show that, there was no constant drying rate period in the drying of olive pomace. All the drying process occurred at the falling rate period. Rapid moisture removal from olive pomace was obvious in all experiments particularly at higher heating surface temperature and longer heating duration which indicates that the removed moisture increased with the increase of heating time and cylinder surface temperatures. Also, the reduction rate of pomace moisture content was highest for the pomace mass of 1 Kg /patch in comparison with the pomace mass of 1.5 and 2 Kg /patch at all levels of cylinder surface temperature. This is due to the exposure of more surface area of pomace to the cylinder surface which increased the pomace bulk temperature and the corresponding moisture reduction rate.

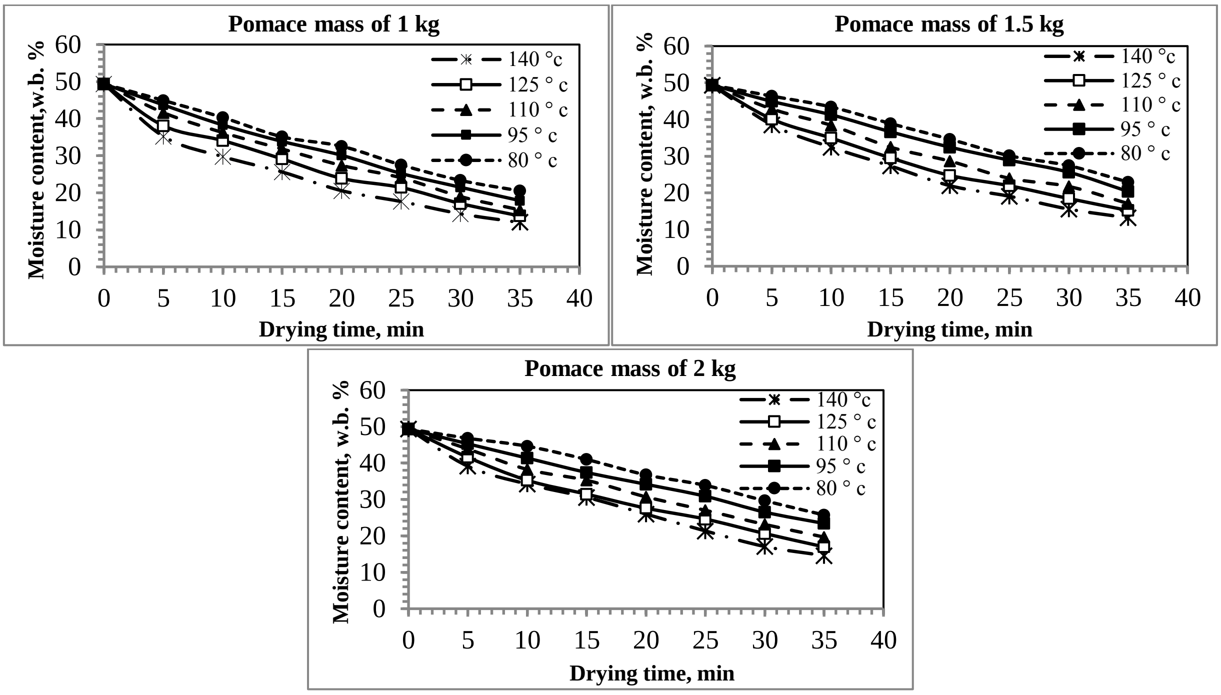

Figure (2): Change in olive pomace moisture content as related to drying time, for different cylinder surface temperature and pomace mass.

Change in pomace bulk temperature

Changes in bulk temperature with drying time at different levels of heating surface temperature during accelerated drying of olive pomace are shown in **Figure (3) through**

Figure (5). The temperature of heat-treated pomace samples was ranged from 24.7 to 119.8 ˚C under the tested conditions. It was consistently observed that the pomace bulk temperature increased with the increase of heating surface temperature and heating time and it was decreased slightly with the increase of pomace mass.

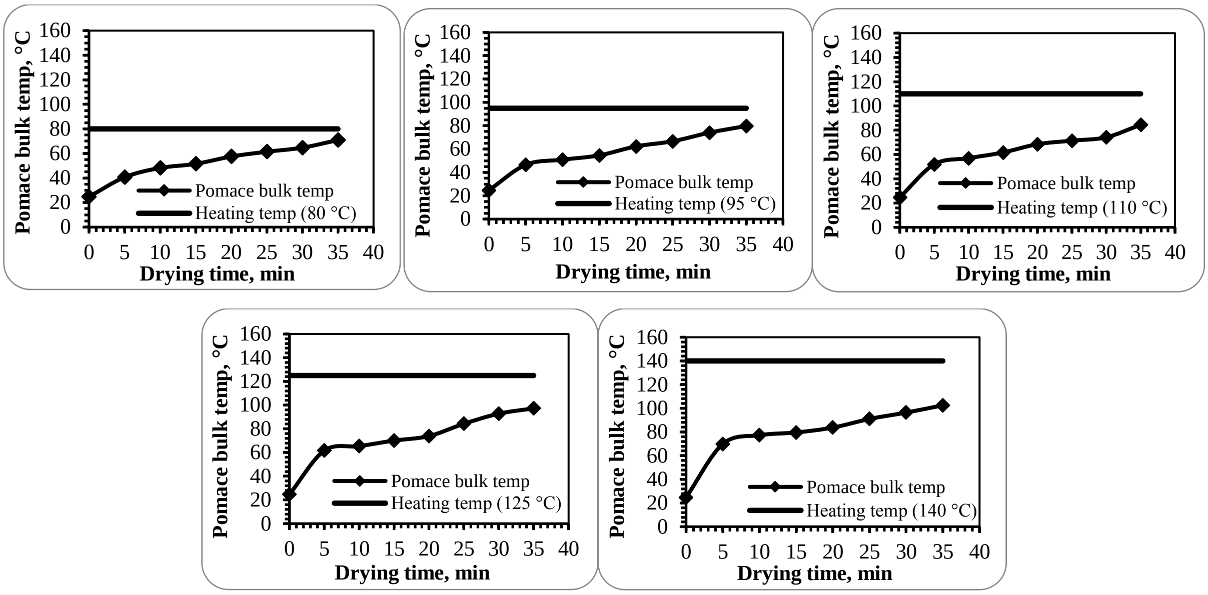

Figure (3): Changes in pomace olive bulk temperature as related to drying time at different cylinder surface temperature for pomace mass of 1 kg/patch.

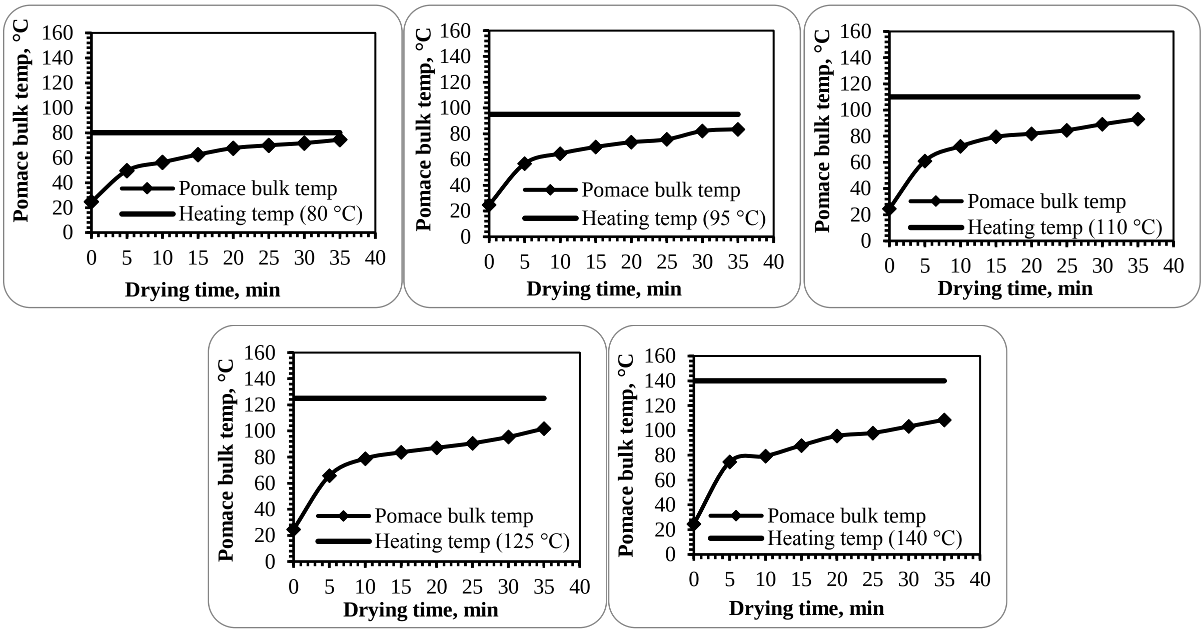

Figure (4): Changes in pomace olive bulk temperature as related to drying time at different cylinder surface temperature for pomace mass of 1.5 kg/patch.

Modelling of drying curves

The values of drying constants for the studied drying models and the values of the determination coefficient (R^2), the reduced chi-square (X^2) and the root mean square error (RMSE) determined by non-linear regression analysis in the temperature range of 80–140 °C of olive pomace and three pomace mass of olive are listed in **Table (2) through Table (4).**

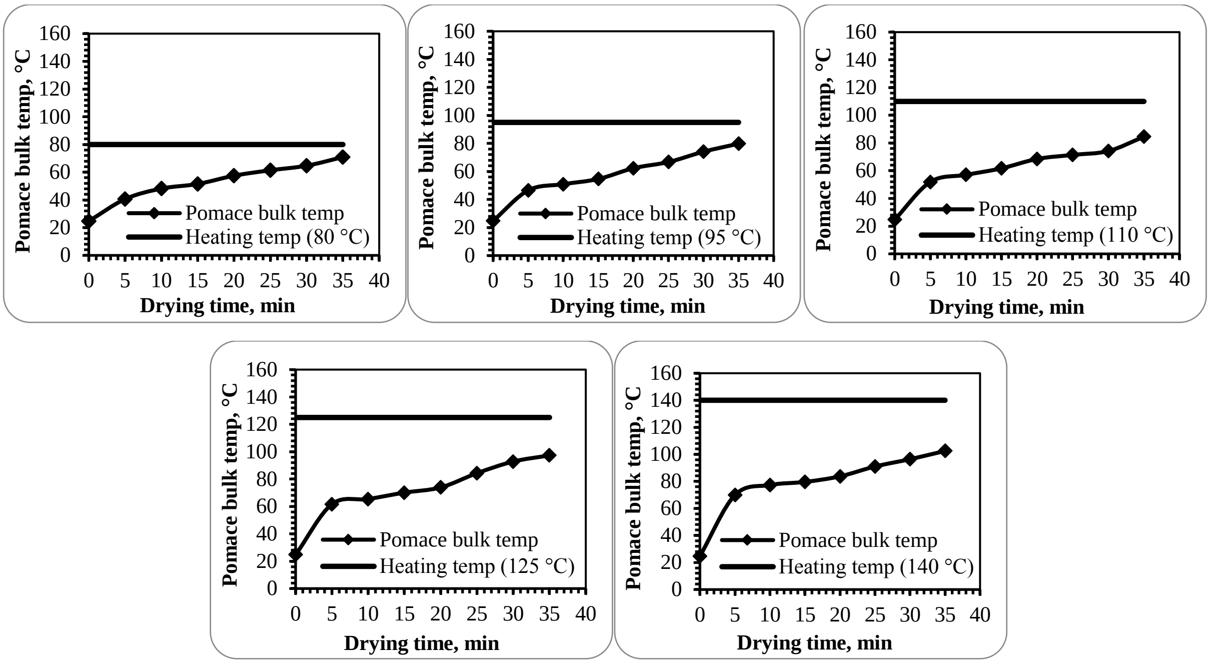

Figure (5): Changes in pomace olive bulk temperature as related to drying time at different cylinder surface temperature for pomace mass of 2 kg / patch.

As shown in the **Tables**, the values of the drying constant (k) varied with the drying temperatures in which it was increased with the increase of drying temperature, while it was decreased with the increase of pomace mass.

Table (2): Values of drying constants and statistical results for the studied drying models in the temperature range of 80–140 °C and pomace mass of 1 kg.

Model No.	Temp. ˚C	Model constants	R^2	X^2	RMSE
1	80	k_L = 0.037612	0.997	0.000173	1.113×10^{-2}
	95	k_L = 0.042705	0.996	0.000111	9.144×10^{-3}
	110	k_L = 0.048923	0.994	0.000801	2.450×10^{-2}
	125	k_L = 0.057697	0.978	0.003154	4.863×10^{-2}
	140	k_L = 0.071688	0.964	0.005525	6.437×10^{-2}
2	80	k_P = 0.034786, u = 1.0255305	0.998	0.000153	1.073×10^{-2}
	95	k_P = 0.047978, u = 0.9615194	0.999	0.000075	7.516×10^{-2}
	110	k_P = 0.073380, u = 0.8635704	0.997	0.000211	1.256×10^{-2}
	125	k_P = 0.128268, u = 0.7246364	0.994	0.000449	1.836×10^{-2}
	140	k_P = 0.200920, u = 0.6300252	0.998	0.000189	1.192×10^{-2}
3	80	k_H = 0.037853, a = 1.0045284	0.998	0.000162	1.102×10^{-2}
	95	k_H = 0.042232, a = 0.9916059	0.996	0.000085	8.007×10^{-3}
	110	k_H = 0.047069, a = 0.9696002	0.996	0.000411	1.755×10^{-2}
	125	k_H = 0.053397, a = 0.9377266	0.987	0.001644	3.511×10^{-2}
	140	k_H = 0.065147, a = 0.9216118	0.978	0.003198	4.897×10^{-2}
4	80	a= -0.033932, b = 0.0003714	0.997	0.000195	1.209×10^{-2}
	95	a= -0.038726, b = 0.0004843	0.996	0.000342	1.601×10^{-2}
	110	a= -0.044306, b = 0.0006253	0.987	0.001399	3.239×10^{-2}
	125	a= -0.052033, b = 0.0008404	0.965	0.004061	5.519×10^{-2}
	140	a= -0.061023, b = 0.0010895	0.943	0.007110	7.302×10^{-2}
5	80	k_g= 0.0351, a= 1.0446, c= -0.0439	0.998	0.000156	1.081×10^{-2}
	95	k_g= 0.0437, a= 0.9755, c= 0.0181	0.999	0.000084	7.968×10^{-3}
	110	k_g= 0.0569, a= 0.9044, c= 0.0774	0.995	0.000389	1.709×10^{-2}
	125	k_g= 0.0791, a= 0.8308, c= 0.1403	0.992	0.000675	2.251×10^{-2}
	140	k_g= 0.1128, a= 0.8187, c= 0.1575	0.985	0.001421	3.265×10^{-2}

Table (3): Values of drying constants and statistical results for the studied drying models in the temperature range of 80–140 °C and pomace mass of 1.5 kg.

Model No.	Temp. ˚C	Model constants	R^2	X^2	RMSE
1	80	k_L = 0.030832	0.991	0.000979	2.709×10^{-2}
	95	k_L = 0.035369	0.997	0.000206	1.242×10^{-2}
	110	k_L = 0.046075	0.989	0.001007	2.749×10^{-2}
	125	k_L = 0.054131	0.989	0.001703	3.573×10^{-2}
	140	k_L = 0.062964	0.985	0.002343	4.192×10^{-2}
2	80	k_P = 0.015723, u = 1.2160413	0.998	0.000109	9.055×10^{-2}
	95	k_P = 0.039830, u = 1.0552910	0.998	0.000102	8.767×10^{-2}
	110	k_P = 0.061938, u = 0.9008905	0.991	0.000695	2.283×10^{-2}
	125	k_P = 0.101782, u = 0.7839469	0.999	0.000074	7.474×10^{-2}
	140	k_P = 0.128457, u = 0.7497553	0.999	0.000052	6.294×10^{-2}
3	80	k_H = 0.032413, a = 1.0323092	0.990	0.000691	2.276×10^{-2}
	95	k_H = 0.035726, a = 1.0068791	0.997	0.000182	1.169×10^{-2}
	110	k_H = 0.045039, a = 0.9824913	0.990	0.000868	2.552×10^{-2}
	125	k_H = 0.051127, a = 0.9543643	0.994	0.000855	2.533×10^{-2}
	140	k_H = 0.059189, a = 0.9483564	0.991	0.001297	3.118×10^{-2}
4	80	a= -0.025280, b = 0.0001507	0.997	0.000234	1.327×10^{-2}
	95	a= -0.031160, b = 0.0002999	0.998	0.000117	9.380×10^{-3}
	110	a= -0.043120, b = 0.0006122	0.988	0.000968	2.695×10^{-2}
	125	a= -0.049977, b = 0.0007924	0.983	0.001921	3.796×10^{-2}
	140	a= -0.055750, b = 0.0009386	0.976	0.002964	4.714×10^{-2}
5	80	k_g= 0.0166, a= 1.6127, c= -0.6019	0.997	0.000202	1.232×10^{-2}
	95	k_g= 0.0382, a= 1.1514, c= -0.1549	0.998	0.000104	8.838×10^{-3}
	110	k_g= 0.0568, a= 0.9138, c= 0.1049	0.991	0.000702	2.294×10^{-2}
	125	k_g= 0.0736, a= 0.8457, c= 0.1383	0.996	0.000361	1.645×10^{-2}
	140	k_g= 0.0874, a= 0.8502, c= 0.1334	0.995	0.000455	1.848×10^{-2}

Table (4): Values of drying constants and statistical results for the studied drying models in the temperature range of 80–140 °C and pomace mass of 2 kg.

Model No.	Temp. ˚C	Model constants	R^2	X^2	RMSE
1	80	k_L = 0.026087	0.987	0.001280	3.098×10^{-2}
	95	k_L = 0.032370	0.999	0.000069	7.219×10^{-3}
	110	k_L = 0.039916	0.996	0.000318	1.545×10^{-2}
	125	k_L = 0.048076	0.988	0.001602	3.466×10^{-2}
	140	k_L = 0.054764	0.982	0.002455	4.290×10^{-2}
2	80	k_P = 0.010798, u = 1.2795232	0.998	0.000114	9.260×10^{-3}
	95	k_P = 0.031221, u = 1.0116610	0.999	0.000047	5.989×10^{-3}
	110	k_P = 0.050618, u = 0.9218688	0.998	0.000145	1.043×10^{-2}
	125	k_P = 0.089814, u = 0.7896975	0.998	0.000141	1.030×10^{-2}
	140	k_P = 0.110474, u = 0.7602331	0.994	0.000475	1.887×10^{-2}
3	80	k_H = 0.027717, a = 1.0347693	0.991	0.000715	2.316×10^{-2}
	95	k_H = 0.032396, a = 1.0005245	0.999	0.000067	7.106×10^{-3}
	110	k_H = 0.039038, a = 0.9841125	0.997	0.000209	1.252×10^{-2}
	125	k_H = 0.045387, a = 0.9564095	0.993	0.000835	2.503×10^{-2}
	140	k_H = 0.051130, a = 0.9451007	0.989	0.001269	3.085×10^{-2}
4	80	a = -0.020003, b = 0.0000400	0.997	0.000159	1.094×10^{-2}
	95	a = -0.029654, b = 0.0002919	0.998	0.000112	9.185×10^{-3}
	110	a = -0.037276, b = 0.0004678	0.994	0.000159	1.094×10^{-2}
	125	a = -0.045677, b = 0.0006911	0.982	0.001794	3.668×10^{-2}
	140	a = -0.049521, b = 0.0007687	0.971	0.003318	4.989×10^{-2}
5	80	k_g= 0.0056, a= 3.6318, c= -2.6255	0.997	0.000146	1.049×10^{-2}
	95	k_g= 0.0292, a= 1.1617, c= -0.0655	0.999	0.000051	6.234×10^{-3}
	110	k_g= 0.0441, a= 0.9284, c= 0.0627	0.997	0.000193	1.205×10^{-2}
	125	k_g= 0.0671, a= 0.8290, c= 0.1568	0.995	0.000420	1.775×10^{-2}
	140	k_g= 0.0703, a= 0.8483, c= 0.1223	0.988	0.001072	2.835×10^{-2}

For all studied models, the statistical parameter estimations showed that R^2, X^2 and RMSE values ranged from 0.943 to 0.999, 0.000047 to 0.007110, and 0.005989 to 0.07516, respectively within the experimental range of study. Among the models considered, Page, Henderson and Pabis and Logarithmic models gave a good fitness for the experimental data with R^2 values greater than 0.978 in all cases. These models appear to be the most adequate for describing the drying processes of olive pomace under the studied experimental conditions. However, page model gave comparatively higher R^2 values in all cases.

In this sense, the highest value of R^2 (0.999) and the lowest values of x^2 (0.000047) and RMSE (0.0059895) were observed for this model. Thus, page model may be assumed to represent the drying behavior of olive pomace using the accelerated rotary dryer in comparison with other studied model within the experimental study range. While, the Lewis model and Wang and Singh model appear to be the least suitable models for describing the drying behavior of olive pomace.

Figure (6) shows a comparison between the observed and predicted moisture ratio using page model at the three studied pomace mass and different level of drying temperature. The data was generally banded around a straight line of 45˚. Consequently, it can be said that, the page model could adequately describe the drying of olive pomace at all studied levels of temperature.

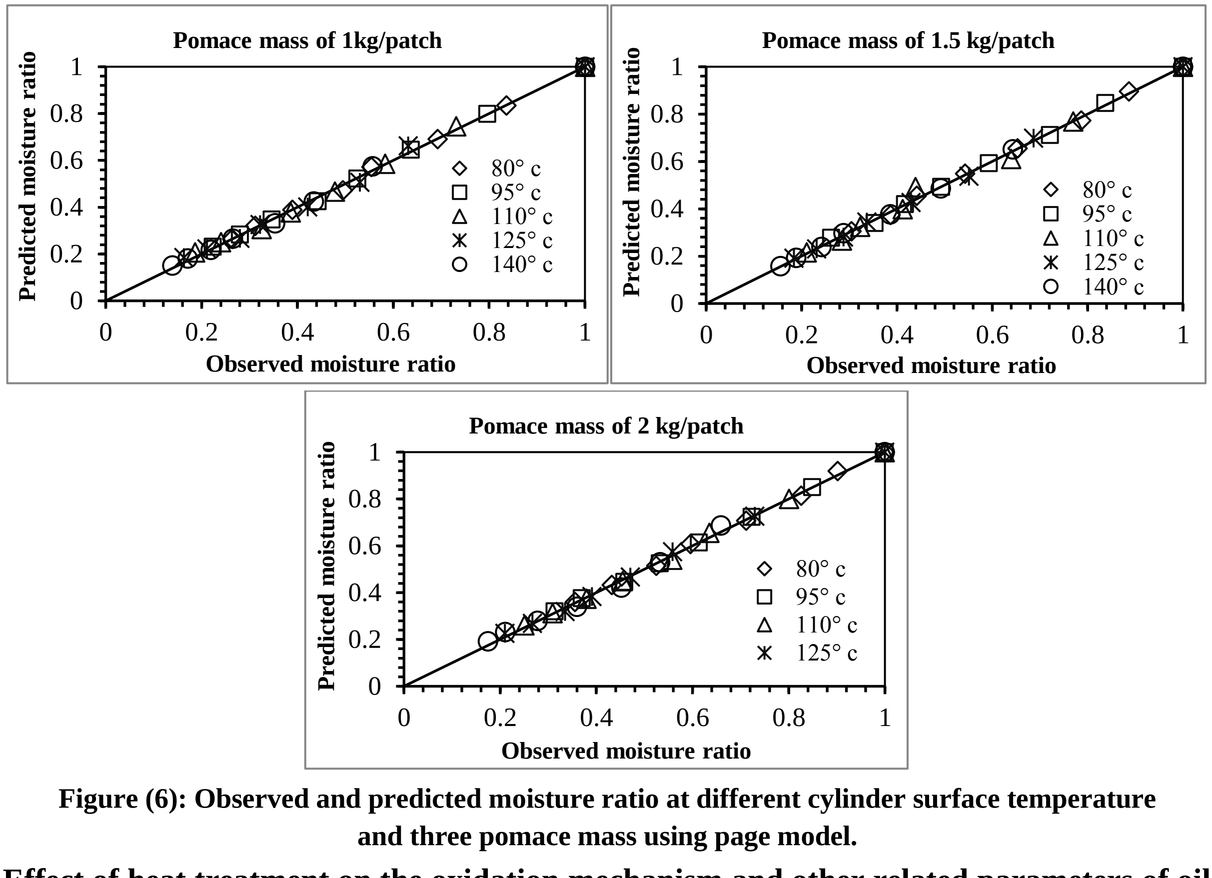

Figure (6): Observed and predicted moisture ratio at different cylinder surface temperature and three pomace mass using page model.

Effect of heat treatment on the oxidation mechanism and other related parameters of oil obtained from dried olive pomace

It is important to investigate the chemical properties of the dried olive pomace in order to obtain the knowledge of olive pomace quality. The peroxide values, acid value, free fatty acid and crude protein content of dried olive pomace as functions of drying temperature using the rotary dryer are given in **Table (10).** As shown in the Table, the peroxide value of the oil obtained from dried olive pomace increased with increasing drying temperature and decreased with the increasing of the pomace mass. The maximum peroxide value (20.6 meq /kg oil) was obtained from the product dried at high temperature of 140 °C and low pomace mass of 1 kg/patch. On the other side, the acid value and free fatty acid of olive pomace oil were increasing with the increasing of drying temperature till 110 ˚C then start to decrease till the temperature of 140 ˚C. Meanwhile, those values were decreasing with the increasing of pomace mass during the experimental tests. In general, the free fatty acids and acid values not exceeded 5% for all studied experimental treatments which means elimination of rancidity of the extracted oil. However, the olive pomace dried at cylinder surface temperature of 80 ˚C and pomace mass of 2 kg/ patch or dried at 140 ˚C with pomace mass of 1 kg/patch showed nearly similar values of acid value and free fatty acid (FFA). In general, pomace drying at heating surface temperature of 80 ˚C and pomace mass of 2 kg/patch could be consider more economic and productive in terms of energy saving and higher productivity.

Table (5): Peroxide value, acid value, free fatty acids and crude protein, as related to heating surface temperature and pomace mass.

Cylinder surface temperature (C°)	Pomace mass (kg)	Acid value (mg KOH/g)	Peroxide value (meq/kg)	F.F.A., %	Crude protein, %
Pre-dried pomace	**-**	**1.59**	**10.92**	**0.804**	**8.58**
80	**1**	2.26	15.30	1.135	8.56
	1.5	2.08	15.11	1.044	8.56
	2	1.91	13.98	0.958	8.57
95	**1**	3.47	15.87	1.743	8.57
	1.5	2.99	15.43	1.502	8.53
	2	2.71	14.67	1.361	8.55
110	**1**	4.55	16.54	2.285	8.51
	1.5	4.08	15.71	2.049	8.49
	2	3.76	15.32	1.888	8.53
125	**1**	2.59	18.73	1.301	8.52
	1.5	3.23	16.61	1.622	8.48
	2	3.56	16.21	1.788	8.50
140	**1**	1.83	20.60	0.919	8.40
	1.5	2.81	17.55	1.411	8.51
	2	3.22	16.73	1.617	8.47

Percentage of crude protein (CP), is the most costly dietary ingredients and one of the criteria in defining high quality dried pomace. The results show that, the crude protein of dried olive pomace was ranged from 8.4 to 8.57% for the heat-treated samples. Furthermore, the results indicated that, an increase or a decrease in drying temperature and pomace mass did not indicate a trend on the crude protein of the product.

4. CONCLUSION

Under the test conditions of this investigation, the accelerated drying process occurred in the falling drying rate period. Moreover, it was observed that, rapid moisture removal from wet pomace was obvious particularly at higher heating surface temperature and lower pomace mass. The temperature of heat-treated pomace samples ranged from 24.7 to 119.8 ºC depending upon the heating temperature, the exposure time and the pomace mass. Five mathematical models of thin layer accelerated drying for wet olive pomace were studied in this work using a nonlinear regression analysis. The Page drying model was considered to be the best model for describing the drying behavior of olive pomace for the studied heating temperature and pomace mass. The peroxide value of dried olive pomace increased with increasing drying temperature. Meanwhile, the acid and free fatty acid values of olive pomace oil were increasing with increasing drying temperature till 110 °C then decreasing till the temperature of 140 °C. While, an increase or a decrease in drying temperature and pomace mass did not indicate a trend on the crude protein of the product during the experimental test.

5. REFERENCES

A.O.A.C (1991). Official Methods of Analysis of the association of official analytical chemists, 15th Edition, D.C. USA.

A.O.A.C (2000). Official Methods of Analysis of the association of official analytical chemists, 17th Edition, Washington D.C.

Baysan, U., Koç, M., Güngör, A. and Ertekin, F. K. (2020). Investigation of drying conditions to valorize 2-phase olive pomace in further processing. Drying Technology, 1-12.

Doymaz, I., Gorel, O. and Akgun, N. A. (2004). Drying characteristics of the solid by-product of olive oil extraction. Biosystems Engineering, 88(2), 213-219.

Gómez-de la Cruz, F. J., Casanova-Peláez, P. J., Palomar-Carnicero, J. M., Sánchez, S., Pacheco, R. and Cruz-Peragón, F. (2014). Obtaining of the drying rate of alpeorujo for applications on rotary dryers. International Scientific Journal-Journal of Environmental Science, 3, 191-197.

Horwitz, W. (2010). Official methods of analysis of AOAC International. Volume I, agricultural chemicals, contaminants, drugs/edited by William Horwitz. Gaithersburg (Maryland): AOAC International, 1997.

International olive oil council (IOC). 2020. " World olive oil figures: annual Production".

Koukouch, A., Idlimam, A., Asbik, M., Sarh, B., Izrar, B., Bostyn, S. and Amine, A. (2017). Experimental determination of the effective moisture diffusivity and activation energy during convective solar drying of olive pomace waste. Renewable Energy, 101, 565-574.

Krokida, M. K., Karathanos, V. T., Maroulis, Z. B. and Marinos-Kouris, D. (2003). Drying kinetics of some vegetables. Journal of Food Engineering, 59(4), 391-403.

Maragkaki, A., Galliou, F., Markakis, N., Sabathianakis, G., Tsompanidis, C., Lolos, G. and Manios, T. (2016). Initial investigation of the solar drying method for the drying of olive oil by-products. Waste and biomass valorization, 7(4), 819-830.

Meziane, S. (2011). Drying kinetics of olive pomace in a fluidized bed dryer. Energy Conversion and Management, 52(3), 1644-1649.

Rossello, C., Canellas, J., Simal, S. and Berna, A. (1992). Simple mathematical model to predict the drying rates of potatoes. Journal of Agricultural and Food Chemistry, 40(12), 2374-2378.

Sadi, T. and Meziane, S. (2015). Mathematical modelling, moisture diffusion and specific energy consumption of thin layer microwave drying of olive pomace. International Food Research Journal, 22(2), 494-501.

Thakor, N. J., Sokhansanj, S., Sosulski, F. W. and Yannacopoulos, S. (1999). Mass and dimensional changes of single canola kernels during drying. Journal of Food Engineering, 40(3), 153-160.

Yilbas, B., Hussain, M. and Dincer, I. (2003). Heat and moisture diffusion in slab products due to convective boundary condition. Heat and Mass Transfer, 39(5), 471-476.

خصائص تجفيف تفل الزيتون باستخدام تقنية التجفيف السريع

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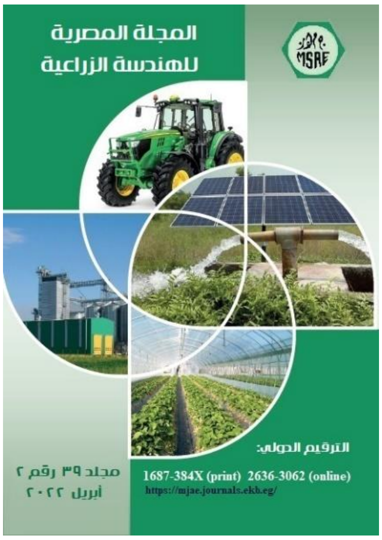

الكلمات المفتاحية:
تفل الزيتون؛ سلوك التجفيف؛ التجفيف السريع.

الملخص العربي

تفل الزيتون هو المنتج الثانوي الذي ينتج من عملية استخلاص زيت الزيتون. وقد اجريت هذه الدراسة بهدف اختبار وتقييم تأثير تقنية التجفيف السريع باستخدام درجات حرارة عالية لوقت قصير باستخدام مجفف دوارني. أجريت تجارب التجفيف على مدى واسع من درجات حرارة التجفيف (٨٠ ، ٩٥ ، ١١٠ ، ١٢٥ و١٤٠ درجة مئوية) وثلاث كميات مختلفة من تفل الزيتون (١ ، ١,٥ و٢ كجم/دفعة). تم تقييم خمسة نماذج رياضية لمحاكاة عملية التجفيف حيث تم تقييم مدى ملائمة النماذج من خلال معامل الارتباط R^2 ومربع كاى X^2 ومجموع مربعات الخطأ RMSE. أظهرت النتائج المتحصل عليها انخفاض المحتوى الرطوبي لتفل الزيتون بطريقة سريعة عند المستويات المرتفعة من درجة حرارة سطح التسخين والمنخفضة من كمية التفل . لم يتم ملاحظة فترة معدل التجفيف الثابت لتفل الزيتون حيث حدثت كل عملية التجفيف في فترة معدل التجفيف المنخفض. وجد أن نموذج page هو أفضل نموذج من بين النماذج المدروسة لوصف سلوك تجفيف ثفل الزيتون.