21st International Drying Symposium
IDS'2018

IDS'2018 – 21st International Drying Symposium
València, Spain, 11-14 September 2018
DOI: http://dx.doi.org/10.4995/ids2018.2018.7719

Effect of tray dryer's independent variables (drying temperature and air velocity) on the quality of olive pomace and system's energy efficiency

Baysan, U.[a,b]; Koç, M.[b]; Güngör, A.[c]; Kaymak-Ertekin, F.[a]

[a] Ege University, Faculty of Engineering, Food Engineering Department, 35100, Bornova Izmir, Turkey

[b] Adnan Menderes University, Faculty of Engineering, Food Engineering Department, 09010, Aydın, Turkey

[c] Ege University, Faculty of Engineering, Mechanical Engineering Department, 35100, Bornova Izmir, Turkey

*E-mail of the corresponding author: mehmetkoc@adu.edu.tr

Abstract

In this study, the effects of drying temperature (70, 80, 90°C) and air velocity (0.5, 1.8 m/s) of hot air drying (tray drying) on quality of dried 2-phase olive pomace and system's energy efficiency were investigated. The drying experiments were carried out in a tray dryer. The effects of drying conditions were evaluated with analyzing drying time, the primary and secondary oxidation and calculating specific moisture extraction rate (SMER), moisture extraction rate (MER) and specific energy consumption (SEC). The results showed that increase in drying temperature and decrease in air velocity led to decrease in quality of dried olive pomace.

Keywords: *Waste valorization, 2-phase olive pomace, Tray dryer, Energy efficiency, oxidation stability*

1. Introduction

The differences in olive oil production methods in terms of 2-phase and 3-phase extraction result in varies wastes in terms of property and quantity [1]. The olive mill waste water and olive pomace (35-40 % moisture) are obtained as wastes in 3-phase extraction, while 2-phase extraction only consists of olive pomace with higher moisture content (60-70 %) as waste. The pollution degree with respect to COD (chemical oxygen demand) and BOD (biological oxygen demand) of olive pomace in 3-phase system are considerably high compared to 2-phase system [2]. Although olive pomace is presented as a waste, it can be used as an ingredient in animal feed additives, fertilizer and source of alternative fuel [3].Moreover, lipase enzyme by fermentation, activated carbon by hydrolysis and biodiesel are also obtained from olive pomace [3]. It is necessary to dry the olive pomace in order to be evaluated as a high-value-added by-product. The drying process improves the processability and durability of the olive pomace. Drying of olive pomace is generally carried out in rotary dryer at a range of 400 to 800°C in the industry [4]. Unfortunately, 2-phase olive pomace (2-POP) cannot be easily dried in rotary dryer at this temperature range due to high moisture content and low thermal stability [5]. For these reasons, 2-POP is mixed with different amounts of 3-phase olive pomace to regulate the moisture content and to avoid the adhesion on dryer wall [4]. However, the quality of 2-POP decreases due to high drying temperature and long drying time. New drying methods should be taken into consideration to overcome this issue.

The aim of this study was to determine the effects of drying temperature and air velocity of tray drying as an alternative drying method on the quality of dried 2-POP and the system's energy efficiency.

2. Materials and Methods

2.1. Materials

2-phase olive pomace (2-POP) was purchased from a factory where 2-phase olive oil is produced by 2-phase extraction system in Aydın, Turkey. Then, it was stored at -25°C until drying experiments. Prior to drying, the samples were thawed at 4°C in a refrigerator. The moisture content of 2-POP was determined as 66.4 % (wb.).

2.2. Drying Procedure

Due to high moisture content, 2-POP was pre-dried in a drum dryer whose conditions were selected as vapor pressure~3 bar (133.52°C), drum rotational speed:~6 rpm, drums gap:~3 mm in order to decrease the moisture content from 66.4% to 50% (wb.). After pre-drying, 1 kg of pre-dried 2-POP having 50% moisture content was dried in a tray dryer (Eksis makine, Isparta, Turkey) until 8% moisture content at different conditions. Drying temperature (70, 80, 90°C) and air velocity (0.5, 1.8 m/s) were selected as independent variables of tray dryer. Drying experiments of 2-POP were performed at each drying temperature and air velocity, while the sample thickness (0.5 cm) and drying area (25x25 cm) were kept constant for all experiments. All drying experiments were done in duplicate for each drying condition and all analysis was applied triplicate.

2.3. Analysis

2.3.1. Moisture Content

Moisture content of raw, pre-dried and dried olive pomace was determined by vacuum oven at 65°C and 0.25 bar [6]. Moisture content of samples was identified as wet basis.

2.3.2. Oxidation Level

For determination of oxidation level of dried samples, the oil was extracted from 2-POP by cold extraction with chloroform/methanol as solvent. After that, this mixture was evaporated at 50°C by a rotary evaporator (Heidolph, Germany). Peroxide value, free fatty acid and ultraviolet (UV) absorbance (K_{232} and K_{270}) were analyzed to determine oxidation level. *Peroxide value* of samples was analyzed by titration method given in AOAC (1990) [7]. *Free Fatty Acid* analysis was performed by titration used KOH according to Sun-Waterhouse et al. (2011) [8]. *Ultraviolet (UV) Absorbance (K_{232}, K_{270}) value of* oil obtained from samples was measured by spectrophotometer after that oil was diluted in iso-octane (2,2,4-trimethylpentane).

2.3.3. Drying system efficiency

Criteria of Specific Moisture Extraction Rate (SMER), Moisture Extraction Rate (MER) and Specific Energy Consumption (SEC) were calculated to determine drying efficiency of system. *Specific moisture extraction rate (SMER)* (kg water/kWh) shows that the mass of water removed from the product to be dried for consuming per unit the energy kWh. According to Hawlader ve Jahangeer (2006), SMER values were calculated [10]. *Moisture Extraction Rate (MER)* (kg water/h) is defined as the mass of moisture removed from the dryer at the unit time. This proportion is calculated according to Gürlek et al. (2015)[9]. *Specific Energy Consumption (SEC)* (kJ/kg water) is described as the amount of energy required to remove per unit moisture (kg) from the samples during drying. According to Sadi et al. (2015), these values were calculated [10].

2.3.4. Statistical analysis

ANOVA test was conducted to determine the effect of drying temperature and air velocity on dried 2-POP. The statistical analyses were performed using SPSS (Statistical Package for the Social Sciences, SPSS Chicago, Illinois, USA) software version 15.0.

3. Results and Discussion

As a result of drying experiments at different temperatures and air velocities, drying time changed between 74 and 170 min. Drying at high temperature and air velocity (90°C and 1.8 m/s) had a short drying time (74±1.4 min), while drying time (170.0±2.1 min) at low temperature and air velocity (70°C, 0.5 m/s) was longer than other experiments (Table 1). Increase in drying temperature and air velocity caused a decrease in drying time due to the increase heat transfer rate. Increase in air velocity gave rise to accelerate the mass transfer from the surface of samples. Thus, drying time also decreased at high air velocity. Moreover, the process conditions of tray dryer in terms of temperature and air velocity had significant effect on the drying time as given in Table 2 (p<0.05).

Olive pomace, which is rich in poly unsaturated fatty acids, is easily exposed to oxidative degradation. Oxidative degradation is one of the important factors for limiting the shelf life of products and causing quality losses [11]. Hence, it is necessary to examine oxidation mechanism during drying of 2-POP.

The drying temperature and air velocity were considerably effective variables on dried olive pomace's peroxide value, free fatty acid, K_{232} and K_{270} values (Table 1). Increase in drying temperature and decrease in air velocity caused an increase in peroxide value, free fatty acid, K_{232} and K_{270} values showing the quality loss of product. Long drying time caused an increase in oxidation level of samples [12]. Although drying at high temperature resulted in a decrease in drying time, the oxidation level of samples dried at high temperature were higher compared to those dried at low temperature (Table 1). According to the literature, oxidation mechanism accelerates with heat treatment. Application of heat treatments at high process time and temperature causes an increase in quality loss of samples [13]. The peroxide, K_{232} and K_{270} values of samples were significantly affected by temperature and air velocity. Although free fatty acid values of samples were affected by drying temperature and velocity, free fatty acid values only changed with drying temperature at significant level (Table 2; p <0.05).

Energy consumption of drying process constitutes 10-25 % percentage of industrial energy consumption [14]. Thus, drying processes and systems which are provided to use efficient energy are necessary to develop [4]. SMER, MER and SEC values were calculated and compared to determine tray dryer's system efficiency at different conditions in this study.

Table 1. Results of dried 2-POP's drying time (min), peroxide value (meq O_2 /kg oil), free fatty acid (% Oleic Acid) and specific absorption value at UV light (K_{232}, K_{270}) and results of drying system efficiency definitions at different process conditions

T (°C)	V (m/s)	Drying time (min)	PV	FFA	K_{232}	K_{270}	SMER	MER	SEC
90	**1.8**	74.0 ±1.4	10.55 ±0.38	0.481 ±0.010	0.680 ±0.002	0.328 ± 0.001	0.2820 ± 0.0245	0.314 ± 0.009	3.56 ±0.31
80	**1.8**	82.5 ±3.5	9.57 ±0.02	0.472 ±0.021	0.545 ±0.004	0.301 ± 0.002	0.2746 ± 0.1017	0.247 ± 0.049	3.91 ±0.45
70	**1.8**	102.5 ±3.5	8.64 ±0.64	0.458 ±0.004	0.511 ±0.002	0.284 ± 0.001	0.2493 ± 0.0347	0.170 ± 0.010	4.05 ±0.26
90	**0.5**	117.0 ±4.9	14.38 ±0.01	0.573 ±0.012	0.869 ±0.004	0.373 ± 0.002	0.2072 ± 0.0133	0.126 ± 0.027	4.84 ±0.31
80	**0.5**	132.5 ±3.5	13.35 ±0.74	0.570 ±0.019	0.851 ±0.002	0.367 ± 0.001	0.1833 ± 0.0013	0.096 ± 0.002	5.46 ±0.04
70	**0.5**	170.0 ±2.1	12.91 ±0.33	0.555 ±0.015	0.806 ±0.001	0.359 ± 0.003	0.1820 ± 0.0085	0.063 ± 0.013	5.50 ±0.26

T:Drying Temperature; V: Air Velocity; PV: Peroxide value; FFA: Free fatty acid

Table 2. ANOVA evaluation for each response variable for 2-POP (β_1 : Temperature; β_2 :Air Velocity).

Variation Source	df	*p*-value							
		Drying time (min)	**PV**	**FFA**	K_{232}	K_{270}	**SMER**	**MER**	**SEC**
Corrected Model	5	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Intercept	1	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
β_1	2	<0.0001	<0.0001	0.082	<0.0001	<0.0001	0.063	<0.0001	0.12
β_2	1	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
$\beta_1 \beta_2$	2	<0.0001	0.596	0.931	<0.0001	<0.0001	0.550	0.040*	0.735
R^2		0.993	0.970	0.943	1.000	0.998	0.875	0.951	0.907
Adj-R^2		0.990	0.958	0.919	1.000	0.997	0.823	0.931	0.868

PV: Peroxide value; FFA: Free fatty acid

Results of SMER (kg water/kWh), MER (kg water/h) and SEC (kJ/kg water) values are given Table 1 while their ANOVA results are shown in Table 2. It is necessary to reach maximum SMER and MER value and minimum SEC value in order to operate the dryer with high drying performance and energy efficiency. Motevali et al. (2011) investigated the effect of drying temperature on drying system efficiency. They found that drying system efficiency in tray dryer decreased with increasing temperature at constant air velocity [16]. Increasing drying temperature resulted in increase in SMER and MER values; a decrease in SEC values (Table 1). Although high-energy consumption needed to reach high temperature in tray dryer, energy efficiency of dryer system was increased at high temperature due to shorter drying time. With increasing air velocity, SMER and MER values had an upward tendency whereas SEC values had a downward tendency. An increase in air velocity caused a decrease in drying time so dryer system's performance was increased. It was determined that SMER and SEC values were significantly affected by temperature (Table 2; $p<0.05$) in contrast to air velocity (Table 2; $p>0.05$). Moreover, temperature and air velocity were effective variables on MER values (Table 2; $p<0.05$).

4. Conclusion

In this study, the effects of temperature and air velocity on quality of dried 2-POP and the system's energy efficiency were determined. Increase in temperature and decrease in air velocity caused an increase in the peroxide value, free fatty acid and specific absorption value at UV light (K_{232}, K_{270}) of 2-POP whereas decrease in the drying time. It was determined that drying at low temperature and high air velocity led to increase in oxidation stability of olive pomace dried in a tray dryer. Maximum SMER, MER and minimum SEC values were expected to determine for high performance and energy efficient dryer system. The effective conditions of tray dryer were specified at high drying temperature and air velocity (90°C and 1.8 m/s). As a conclusion, this study showed that it was necessary to examine the quality of product and energy efficiency of dryer systems together in drying applications.

5. Nomenclature

2-POP	2 phase olive pomace	
FFA	free fatty acid	% Oleic Acid
MER	moisture extraction rate	(kg water/h)
PV	peroxide value	meq O^2/kg oil)
SEC	specific energy consumption	(kJ/kg water)
SMER	specific moisture extraction rate	(kg water/kWh)
T	drying temperature	°C
V	Air velocity	m/s
w.b	wet basis	

6. References

[1] A. Ranalli and N. Martinelli, "Integral centrifuges for olive oil extraction, at the third millenium threshold. Transformation yields," *Grasas Aceites*, vol. 46, no. 4–5, pp. 255–263, 1995.

[2] M. D. Liebanes, J. M. Aragon, M. C. Palancar, G. Arevalo, and D. Jimenez, "Fluidized bed drying of 2-phase olive oil mill by-products," *Dry. Technol.*, vol. 24, no. 12, pp. 1609–1618, 2006.

[3] V. Hernández, J. M. Romero-García, J. A. Dávila, E. Castro, and C. A. Cardona, "Techno-economic and environmental assessment of an olive stone based biorefinery," *Resour. Conserv. Recycl.*, vol. 92, pp. 145–150, 2014.

[4] R. Arjona, P. Ollero, and others, "Automation of an olive waste industrial rotary dryer," *J. Food Eng.*, vol. 68, no. 2, pp. 239–247, 2005.

[5] J. S. Torrecilla, J. M. Aragón, and M. C. Palancar, "Modeling the drying of a high-moisture solid with an artificial neural network," *Ind. Eng. Chem. Res.*, vol. 44, no. 21, pp. 8057–8066, 2005.

[6] Association of Official Analytical Chemists (AOAC), *Official Methods of Analysis*, 13th ed. Arlington, VA: Official Method, 1980.

[7] Association of Official Analytical Chemists (AOAC), *Official Methods for Analysis*, 15th ed., 2 vols. Arlington, VA: Official Method, 1990.

[8] D. Sun-Waterhouse, J. Zhou, G. M. Miskelly, R. Wibisono, and S. S. Wadhwa, "Stability of encapsulated olive oil in the presence of caffeic acid," *Food Chem.*, vol. 126, no. 3, pp. 1049–1056, 2011.

[9] G. Gürlek, Ö. Akdemir, and A. Güngör, "Gıda Kurutulmasında Isı Pompalı Kurutucuların Kullanımı ve Elma Kurutmada Uygulanması," *Pamukkale Üniversitesi Mühendis. Bilim. Derg.*, vol. 21, no. 9, pp. 398–403, 2015.

[10] T. Sadi, S. Meziane, and others, "Mathematical modelling, moisture diffusion and specific energy consumption of thin layer microwave drying of olive pomace," *Int Food Res J*, vol. 22, no. 2, pp. 494–501, 2015.

[11] Ö. E. Çoban and B. Patır, "Antioksidan etkili bazı bitki ve baharatların gıdalarda kullanımı," *Gıda Teknol. Elektron. Derg.*, vol. 5, no. 2, pp. 7–19, 2010.

[12] N. K. Andrikopoulos, N. Kalogeropoulos, A. Falirea, and M. N. Barbagianni, "Performance of virgin olive oil and vegetable shortening during domestic deep-frying and pan-frying of potatoes," *Int. J. Food Sci. Technol.*, vol. 37, no. 2, pp. 177–190, 2002.

[13] A. Zungur, M. Koç, B. Yalçın, F. Kaymak-Ertekin, and S. Ötleş, "Storage stability of microencapsulated extra virgin olive oil powder," in *9th Baltic Conference on Food Science and Technology "Food for Consumer Well-Being,"* 2014, p. 257.

[14] E. Eroğlu and H. Yıldız, "Gıdaların ozmotik kurutulmasında uygulanan yeni tekniklerin enerji verimliliği bakımından değerlendirilmesi," *Gıda Teknol. Elektron. Derg.*, vol. 6, no. 2, pp. 41–48, 2011.

[15] K. J. Chua, S. K. Chou, J. C. Ho, and M. N. A. Hawlader, "Heat pump drying: recent developments and future trends," *Dry. Technol.*, vol. 20, no. 8, pp. 1579–1610, 2002.

[16] A. Motevali, S. Minaei, M. H. Khoshtaghaza, and H. Amirnejat, "Comparison of energy consumption and specific energy requirements of different methods for drying mushroom slices," *Energy*, vol. 36, no. 11, pp. 6433–6441, 2011.