DRYING CHARACTERISTICS, MINERAL CONTENT, TEXTURE AND SENSORIAL PROPERTIES OF PUMPKIN FRUIT LEATHER

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***Abstract*— The objective of this study was to investigate the influences of hot air (HAD: 50, 60, 70°C), vacuum (VD: 50, 60, 70°C at 300 mbar) and microwave methods (MWD: 90, 180W) on drying characteristics, effective moisture diffusivity (D_{eff}), mineral content, texture, and sensorial properties of pumpkin pestils. MWD led to the highest drying rate and the lowest drying time in all methods. Page and Modified Page were ideally fitted to experimental results among seven thin layer drying models. Mineral content (Ca, K, Na, P, Mg, Fe, Zn, Cu, Mn) of the pestils showed higher values than non-dried (paste) mixture. Significant differences were determined between textural features of the pestils ($p < 0.05$). Furthermore, products dried with HAD and VD were preferred rather than MWD in terms of sensorial properties.**

***Keywords*— Drying Characteristics, Mineral, Pumpkin Pestil, Texture**

I. INTRODUCTION

Cucurbita moschata which belongs to the Cucurbitaceae family is called as “pumpkin” (Limpaiboon *et al*., 2011). China and India lead the world production of pumpkin whereas U.S., Egypt, Mexico, Ukraine, Cuba, Italy, Iran and Turkey take the other part of the producer countries (Ferriol and Pico, 2008). According to Turkish Statistical Institute data, 87207 tons of pumpkin were harvested in Turkey in the year of 2018 (TUIK, 2019). Pumpkin is known as a health promoting fruit due to being a valuable source of β-carotene, phenolics, flavonoids, vitamins, minerals, amino acids and carbohydrates (Yadav *et al*., 2010). Pumpkin is also susceptible to microbial growth even if stored at refrigerator conditions due to its seasonal and perishable features. Therefore, it can be used in frozen or dried forms and pumpkin has been utilized in the production of jam, jelly, sweets, beverages and other products (Dutta *et al*., 2006).

There is also an alternative method in which concentrated fruit pulp or juice can be dried and named as fruit leather or pestil (Tontul and Topuz, 2017). It is generally produced by the addition of sucrose and starch in the pulp and the dehydration of the paste mixture stated on the leathery sheets (Suna and Özkan-Karabacak, 2019). Fruit pestil has a sweet taste due to the reduced water content after drying treatment and has a high nutritional value resulted from carbohydrates and minerals. Therefore pestil can be consumed as a healthy snack food which is a good source of energy (Cagindi and Otles, 2005).

Drying is a widespread process in the preservation of foods which consists of the removal of water from the product (Limpaiboon *et al*., 2011). It provides longer periods for storage and convenience for transportation (Compaoré *et al*., 2019). For understanding of the drying phenomenon of the food products, it is essential to be applied in thin layer drying models (Panchariya *et al*., 2002). These models ensure critical information about the optimization of the dryers’ performance by allowing the definition of operational conditions such as drying temperature, air velocity, absolute pressure or microwave power (Compaoré *et al*., 2019). The modelling of drying characteristics of agricultural products is based on some mathematical equations which can efficiently describe the system. Therefore, the demonstration of the drying characteristics is important in terms of simulating and optimizing the system, along with the development of food-specific drying processes on an industrial scale (Gunhan *et al*., 2005).

Different fruits have been used as a material for pestil production by many researchers (Vatthanakul *et al*., 2010, Gupta *et al*., 2016). However, the literature contain very limited studies on the production of pumpkin pestil (Concha-Meyer *et al*., 2016), and there are no available reports on obtaining pumpkin (*Cucurbita moschata*) pestil by using hot air, vacuum and microwave drying techniques as well as describing drying characteristics and quality parameters. To the extent of the knowledge, this research was the first approach to investigate the drying characteristics of pumpkin pestil via mathematical modelling and the effects of different drying methods on mineral content and degradation kinetics of colour values.

II. METHODS

A. Materials

Pumpkin (*Cucurbita moschata*) fruits were bought from a local greengrocer in Bursa, Turkey and stored under refrigerator conditions at 4±0.5°C until used. Wheat starch (Selva, Turkey) and sucrose (Torku, Turkey) were acquired from the market.

B. Preparation of pumpkin pestil

Pumpkin fruits were washed, peeled, sliced and then boiled with distilled water (fruit/water 1:2, w/w) when the soluble solid content (° Bx) reached 17° Bx. Boiled fruits were homogenized using a domestic blender (Arzum, Turkey). Freshly prepared puree, sucrose, wheat starch, citric acid and cinnamon were used for the preparation of pumpkin pestil with the mass fractions of 0.865,

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0.100, 0.028, 0.005 and 0.002, respectively. All ingredients except wheat starch and 25 % of the puree was mixed and boiled until the mixture reached to 30° Bx. In order to diffuse wheat starch in the mixture homogeneously, it was dissolved in the remaining puree (25 %) and added to the boiling paste to be cooked for 5 more minutes. Thereafter, 25±0.5 g paste mixture was spread on a square mold (with the dimensions of 8 × 8 × 0.4 cm length/width/thickness respectively) which was stated on a greaseproof paper and dried with three different methods. Dried pestils were kept at 4±0.5°C till analysed.

C. Drying process

The paste mixture (with moisture content of 3.20 g water/g dry matter (dm.)) was dehydrated until the moisture content reached to 0.12 g water/g dm. with three different drying methods (hot air, vacuum and microwave drying). Drying experiments were replicated three times for each condition and average values were used. Hot air drying (HAD) were conducted at 50, 60 and 70°C with a constant relative humidity (20%) in a convective dryer (Yucebas Machine Analytical Equipment Industry, Y35, Izmir, Turkey). The convective dryer was run as idle for an hour to obtain targeted temperature before the each drying experiment. The mass of the samples was enrolled with a digital balance (Mettler Toledo, MS3002S, Greifensee, Switzerland) with a 0.01 g accuracy firstly at 30 min and then 10 min intervals until the desired moisture was accessed. The weight of the pestils was recorded with a period of 10 seconds.

A vacuum dryer (Memmert VO400, Schwabach, Germany, 49 L volume) with the temperatures of 50, 60 and 70°C and the absolute pressure of 300 mbar was utilized for vacuum drying (VD) experiments. The weight of the pestils was measured in every 30 min for almost 2 hours and 15 min intervals during drying process. The weighing procedure was not exceeded 10 seconds.

Domestic microwave oven (Bosh, HMT72G420, Munich, Germany) with the technical features of 230V~ 50Hz and maximum output of 800 W was used for microwave drying (MWD). The size of the microwave cavity was 290 x 461 x 351 mm and it was comprised of a rotating glass plate (245 mm diameter) stated at the base of the oven. Power levels and weighing intervals were 90, 180 W and 5, 2 min, respectively. The measurement took about 10 seconds as the same with the other methods.

D. Mathematical modelling of drying kinetics

Seven drying models were applied to determine the best model for drying characteristics of pumpkin pestils. This models were given as following equations (Özkan Karabacak, 2019):

$$\text{Page: } MR = \exp(-kt^n) \tag{1}$$

$$\text{Modified Page: } MR = \exp[(-kt)^n] \tag{2}$$

$$\text{Logarithmic: } MR = a\exp(-kt) + c \tag{3}$$

$$\text{Lewis: } MR = \exp(-kt) \tag{4}$$

$$\text{Henderson and Pabis: } MR = a\exp(-kt) \tag{5}$$

$$\text{Two Term Exponential: } MR = a\exp(-kt) + (1-a)\exp(-kat) \tag{6}$$

$$\text{Wang and Singh: } MR = 1 + at + bt^2 \tag{7}$$

The moisture ratio (MR) and drying rate of the samples were estimated from the following equations:

$$MR = \frac{M - M_e}{M_i - M_e} \tag{8}$$

$$Drying\ rate = \frac{M_{t+Dt} - M_t}{Dt} \tag{9}$$

In the Eqs. (1-2); MR, M, M_i, M_e, M_t, M_{t+Dt}, are the moisture ratio, the moisture content at a specific time (g water/g dm.), initial moisture content (g water/g dm.), equilibrium moisture content (g water/g dm.), moisture content at time t and moisture content at time $t + Dt$ (g water/g dm.), respectively, and t is the drying time (min) (Tüfekçi and Özkal, 2017). Equilibrium moisture content was accepted as zero due to M_e is much lower than M and M_i values.

The greater correlation coefficient (R^2) and reduced root mean square error ($RMSE$), Chi square (χ^2) were used as the statistical parameters to identify the integrity of the fit models describing the drying kinetics of pumpkin pestils (Gamlı *et al*., 2018). Subsequent equations were used for the calculation of these values:

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2\right]^{1/2} \tag{10}$$

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2}{N-n} \tag{11}$$

Here, $MR_{exp,i}$ and $MR_{pre,i}$ are the experimental and dimensionless moisture ratios, respectively for the test i. N is the number of observations and n is the constant number for the models.

E. Effective moisture diffusivity

Fick's second diffusion law is broadly utilized for the calculation of effective moisture diffusivities of agricultural products (Süfer and Palazoğlu, 2019). The mathematical explanation of Fick's law, when uniform initial moisture diffusion, negligible shrinkage, constant diffusion coefficient throughout the process and symmetric mass transfer in an infinite slab are assumed, is given in Eq. (12).

$$MR = \frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n-1)^2}\exp\left(-\frac{(2n-1)^2\pi^2 D_{eff}t}{4L^2}\right) \tag{12}$$

In the Eq. (12); MR, D_{eff}, L and n represent dimensionless moisture ratio, effective moisture diffusivity (m^2/s), half thickness of the slab in the pumpkin pestils (m) and positive integer, respectively. For sufficiently extended drying periods, Eq. (12) can be abbreviated to the first term in the series by using a logarithmic form as follows:

$$MR = \frac{8}{\pi^2}\exp\left(-\frac{\pi^2 D_{eff}t}{4L^2}\right) \tag{13}$$

D_{eff} was computed through the slope of a straight line which was plotted $\ln MR$ versus time in drying experiments. The equation was expressed as follows:

$$D_{eff} = -\frac{slope\ 4L^2}{\pi^2} \tag{14}$$

F. Mineral Analysis

The sample digestion of 0.5-1.0 grams was carried out by microwave oven (MWS 2 DAP 60 K, Berghof, Germany) at 180°C with the addition of 3 mL nitric acid (HNO_3) and 4 mL hydrogen peroxide (H_2O_2). Calcium (Ca), potassium (K), sodium (Na), phosphate (P), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu) and manganese

(Mn) were respectively detected at the wavelengths (nm) of 317.93, 766.49, 589.59, 213.61, 285.21, 238.20, 206.20, 327.39 and 257.61 nm by using inductively coupled plasma optical emission spectroscopy (ICP-OES) (Optima 2100 DV, Perkin Elmer, Boston, MA). Analyses were conducted in triplicate and the total concentration was given as mg/kg (Kacar, 2010).

G. Texture Analysis

Textural parameters of pumpkin pestils were determined by using TA.XT 2Plus (Stable Micro Systems, Surrey, UK) according to our previous study (Suna and Özkan-Karabacak, 2019). After the pestils were cut as 4 cm diameter, four of them were stacked and then compressed two times under a cylindrical probe (P/35). According to preliminary tests, the measurement were adjucted as; pretest speed: 1 mm/s, test speed: 2 mm/s, posttest speed: 2 mm/s, distance: 4 mm, holding time: 2 s, and trigger force: 0.049 N. The hardness, adhesiveness, springiness, chewiness and gumminess of the pestils were analysed in triplicate for each trial.

H. Sensorial Analysis

Colour, appearance, taste, chewiness and overall acceptance properties of pumpkin pestils were evaluated. A nine-point hedonic scale test differing from ''like extremely (9)'' to ''dislike extremely (1)'' was utilized for these quality criterias. Seven panellists scored the pestils according to the proximity to desired orange color, typical odor and taste (related with the origin of pumpkin) without including burnt parts.

I. Statistical Analysis

JMP software package version 8.0 (SAS Institute Inc. NC, 27513) was used for for the evaluation of statistical analyses. When significant differences were found ($p < 0.05$), the least significant difference (LSD) test was utilized to observe the differences among means.

III. RESULTS

A. Drying characteristics of pumpkin pestil

The alterations in moisture content of pumpkin pestils over time were illustrated in Figure 1. Drying times were 270, 220 and 145 min for HAD at 50, 60 and 70°C; 540, 250 and 150 min for VD at 50, 60 and 70°C with 300 mbar; and 70 and 25 min for MWD at 90 and 180 W, respectively. MWD at 180 W was the most effective drying condition within the drying times. An increase in temperature for HAD and VD, and power for MWD had shortened the drying times. When compared with VD, drying time of HAD conditions showed a decrement with the ratios of 50, 12 and 3 % for 50, 60, and 70°C, respectively. Different drying times at the same temperature between VD and HAD could be explained by the changes in heat transfer mechanisms of the dryers. The vacuum dryer used in current experiments performs conductively, with contrast to the hot air dryer which has a convective hot air velocity. This might be the reason for faster drying of pestils performed by hot air drying (Gunasekaran, 1999). As a result of the preliminary experiments in which lower absolute pressures (such as 50, 100, 150, 200 and 250 mbar) were used, a reduction in drying time

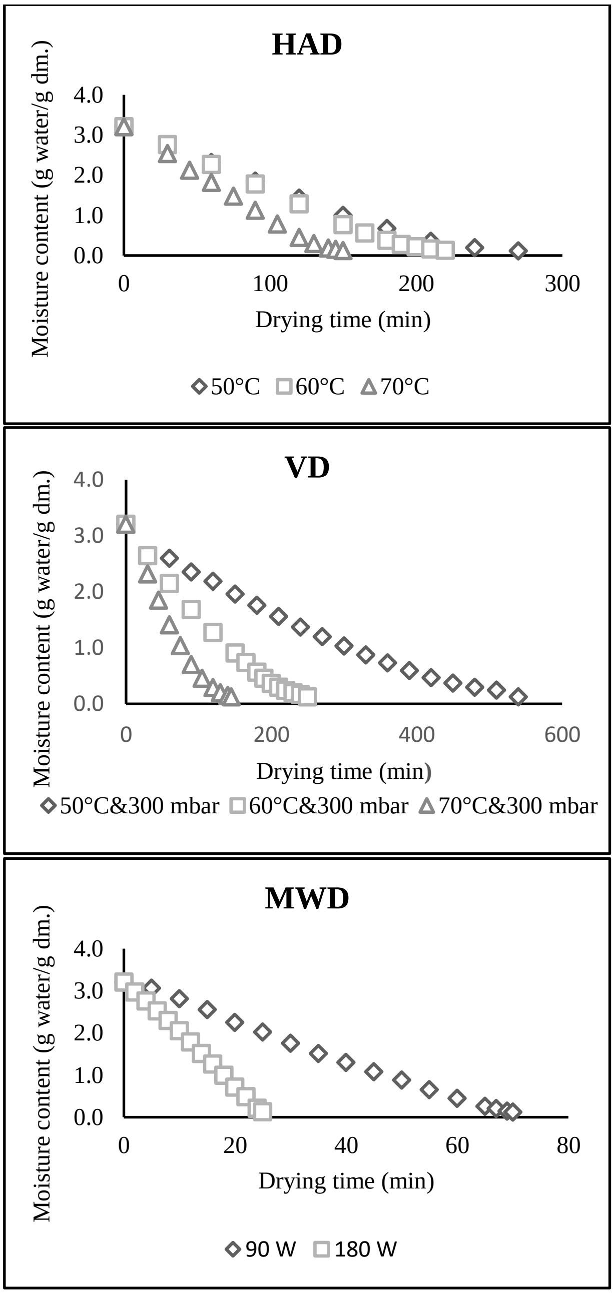

Figure 1. Drying curves of the pumpkin pestils.

together with detrimental effects on texture was observed. Thus, the most appropriate pressure was chosen as 300 mbar. The results were compatible with the former study on mulberry pestil (Suna and Özkan-Karabacak, 2019).

Drying curves (drying rate versus moisture content) of the pumpkin pestils are given in Fig. 2. As it was seen in the graphs, drying processes eventuated mainly in falling rate period, after a short rising rate period at the onset. As the temperature in HAD and VD, and power in MWD increased, drying rate enhanced in all of the methods. This result can be explained by the need for a more brief time to dry the sample to an equilibrium moisture cotent. Similar results in falling rate period were exhibited with agricultural materials (Surendhar *et al*. 2019; Tüfekçi and Özkal 2017). Furthermore, higher drying rate was ob- -

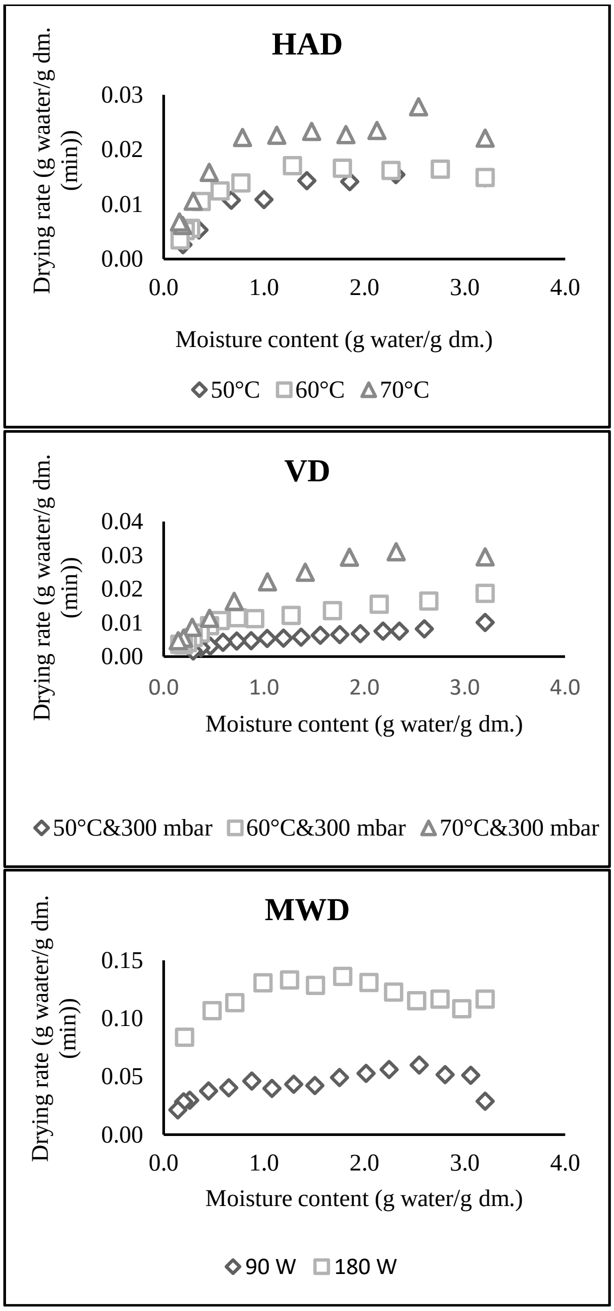

Figure 2. Drying rate versus moisture content for pumpkin pestils.

Served from microwave drying due to faster heat and mass transfer compared to the other methods. The rate of the water removal from pestils was rapidly occurred by microwave energy and as a result, drying rate increased while the drying time reduced.

χ^2 (0.000106-0.002910) values for all cases. Similar results were reported in ultrasound assisted hot air dried

B. Evaluation of the models

Drying behaviour of pumpkin pestils was evaluated with seven different thin layer drying models. Model coefficients, R^2, RMSE and χ^2 values were given in Table 1. Page and Modified Page models were chosen as the most suitable models to represent the drying characteristics of pumpkin pestils with the highest R^2 (0.9596-0.9979) and the lowest RMSE (0.002807-0.013348) and χ^2 (0.000106-0.002910) values for all cases. Similar results were reported in ultrasound assisted hot air dried okra slices (Tüfekçi and Özkal, 2017) and vacuum dried cherry pepper (Boris *et al*., 2018) for Modified Page model and in microwave dried turmeric slices (Surendhar *et al*., 2019) and microwave dried olive leaves (Gamlı *et al*., 2018) for the Page Model. Accordingly, same attributes were recorded in infrared-hot air dried onion slices for both of these models (Praveen Kumar *et al*., 2006).

C. Effective moisture diffusivity

Effective moisture diffusivity (D_{eff}) values at different drying conditions were presented in Figure 3. From this figure it can be seen that D_{eff} values of pumpkin pestils were in the range of 2.23×10^{-9}-4.56×10^{-8} m^2s^{-1}. These values were stated in the common range (10^{-11}-10^{-6} (m^2s^{-1})) determined for the dehydration of food products (Surendhar *et al*., 2019). The D_{eff} values were enhanced consistently with the raise in drying temperature (for HAD and VD) and power (for MWD). The increase in D_{eff} values might be related with the increased heating energy that activated water molecules faster with a higher temperature (Lee and Zuo, 2013). Similar results have been reported by Boris *et al*. (2018) for vacuum drying of cherry pepper (6.27×10^{-10}-1.9×10^{-9}).

D. Mineral Analysis

Element concentrations in the paste mixture and pumpkin pestils were given in Table 2. The mineral content of pumpkin pestils was statistically higher than the paste (non-dried) mixture due to the increased dry matter content of the products. Ca and K values were respectively determined as the highest in HAD at 50°C and VD at 60°C&300 mbar conditions while the samples dried with VD at 50°C&300 mbar gave the best results in Na and Fe contents (p<0.05). Besides, MWD at 90W showed the highest values in the determination of P, Mg, Zn, Cu and Mn. Moreover, element concentrations raised with drying conditions when compared to the paste mixture and significant differences were observed among all of the samples (p <0.05). Suna *et al*. (2014) also reported an increment between the fresh fruit and sun, vacuum and microwave dried apricot pestils in terms of K, Ca, Mg Zn minerals.

The Ca content of the samples varied between 227.63-871.88 mg/kg (Table 2). According to Suna *et al*. (2014) and USDA (2021a), Ca content of a fruit leather (snacks, fruit leather, pieces) and an apricot leather was reported as 1063.44 mg/kg and 180 mg/kg respectively. Current results were found in the range of the literature data. K content of the pestils was changed from 9561.23± 144.79 to 10159.64±157.09 mg/kg being as higher than a fruit leather (snacks, fruit leather, pieces) (1640 mg/kg) (USDA 2021a). Na values of the pestils were found higher than a handmade (180 mg/kg) fruit leather (including organic mango pulp, peach puree and artichoke fiber) (USDA 2021b) as well as being lower than another commercial product (1990 mg/kg) (USDA 2021a).

Table 1. Model coefficient and statistical results acquired from selected drying models for pumpkin pestils

Model No			HAD 50 °C	HAD 60 °C	HAD 70 °C	VD 50 °C & 300 mbar	VD 60 °C & 300 mbar	VD 70 °C & 300 mbar	MWD 90 W	MWD 180 W
1	Model coefficient	n	1.5786	1.5805	1.6637	1.2318	1.3570	1.4903	1.5683	1.4528
		k	0.0005	0.0006	0.0007	0.0011	0.0010	0.0019	0.0033	0.0196
	R^2		0.9924	0.9841	0.9822	0.9813	0.9854	0.9979	0.9870	0.9596
	RMSE		0.006032	0.009041	0.009042	0.006055	0.006537	0.002807	0.008238	0.013348
	X^2		0.000421	0.001177	0.001177	0.000742	0.000740	0.000106	0.001308	0.002910
2	Model coefficient	n	1.5786	1.5805	1.6637	1.2318	1.3570	1.4903	1.5683	1.4528
		k	0.0077	0.0089	0.0126	0.0040	0.0087	0.0150	0.0260	0.0669
	R^2		0.9924	0.9841	0.9822	0.9813	0.9854	0.9979	0.9870	0.9596
	RMSE		0.006032	0.009041	0.009042	0.006055	0.006537	0.002807	0.008238	0.013348
	X^2		0.000421	0.001177	0.001177	0.000742	0.000740	0.000106	0.001308	0.002910
3	Model coefficient	k	0.0145	0.0191	0.0291	0.0061	0.0167	0.0323	0.0472	0.0891
		a	1.6410	1.8857	2.1994	1.3800	1.7605	2.0045	1.5901	1.2283
		c	0.0358	0.0402	0.0391	0.0383	0.0394	0.0380	0.0382	0.0392
	R^2		0.8819	0.8522	0.8341	0.9424	0.8797	0.8835	0.8498	0.9079
	RMSE		0.078183	0.083101	0.107026	0.027696	0.058264	0.096604	0.045798	0.028478
	X^2		0.082519	0.110493	0.183272	0.016569	0.063650	0.141153	0.043298	0.014450
4	Model coefficient	k	0.0104	0.0137	0.0177	0.0051	0.0120	0.0200	0.0351	0.0770
	R^2		0.9005	0.9559	0.8649	0.9313	0.9583	0.9369	0.8438	0.8176
	RMSE		0.036729	0.041022	0.037909	0.022175	0.024788	0.027763	0.032502	0.030631
	X^2		0.013659	0.022029	0.018813	0.009372	0.009875	0.009326	0.019081	0.014146
5	Model coefficient	k	0.0127	0.0150	0.0225	0.0055	0.0130	0.0237	0.0444	0.1124
		a	1.5631	1.5817	1.7418	1.3645	1.4547	1.4999	1.6229	1.5650
	R^2		0.9415	0.9318	0.9184	0.9478	0.9514	0.9670	0.8962	0.8449
	RMSE		0.065165	0.053553	0.065371	0.024524	0.033859	0.046991	0.046443	0.052798
	X^2		0.049138	0.041298	0.061537	0.012179	0.019842	0.029688	0.041558	0.045531
6	Model coefficient	k	0.0079	0.0093	0.0138	0.0035	0.0082	0.0148	0.0274	0.0698
		a	0.6099	0.6127	0.6353	0.5771	0.5926	0.6000	0.6187	0.6101
	R^2		0.9415	0.9318	0.9184	0.9478	0.9514	0.9670	0.8962	0.8449
	RMSE		0.032224	0.031468	0.027820	0.028366	0.031016	0.032715	0.023455	0.026482
	X^2		0.012016	0.014259	0.011145	0.016294	0.016650	0.014389	0.010599	0.011455
7	Model coefficient	b	0.000006	0.000004	0.000007	0.000002	0.000008	0.00002	0.00002	0.0002
		a	-0.0048	-0.0051	-0.0074	-0.0030	-0.0058	-0.0099	-0.0152	-0.0353
	R^2		0.8613	0.8492	0.8185	0.9559	0.9847	0.9497	0.8845	0.8296
	RMSE		0.031685	0.017541	0.010961	0.010806	0.007487	0.010204	0.004120	0.029160
	X^2		0.011617	0.004431	0.001730	0.002365	0.000970	0.001400	0.000327	0.013888

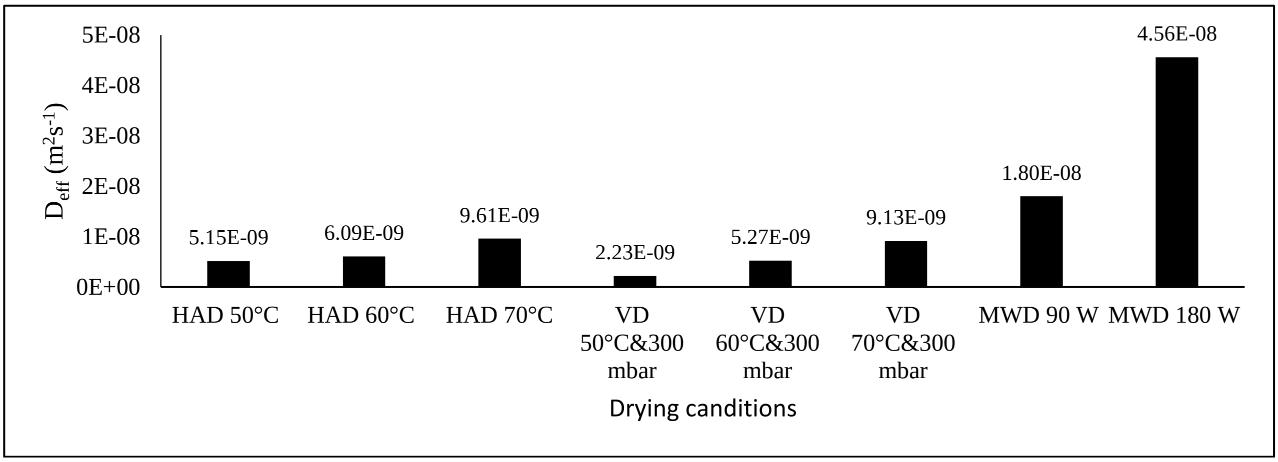

Figure 3. Effect of drying conditions on D_{eff}

Table 2. Mineral content of pumpkin pestils dried with different methods (mg/kg)

Drying conditions	Ca	K	Na	P	Mg	Fe	Zn	Cu	Mn
Paste mixture	227.63±10.88[e]	2152.31±167.60[e]	116.17±4.71[c]	150.25±15.78[d]	99.67±0.46[e]	5.40±0.28[e]	1.64±0.14[d]	0.90±0.12[c]	0.45±0.04[d]
HAD 50 °C	871.85±28.98[a]	9908.40±475.7[ab]	508.01±16.63[a]	490.09±11.41[c]	373.48±15.45[cd]	6.15±0.94[e]	4.82±0.05[bc]	2.77±0.16[b]	1.10±0.05[bc]
HAD 60 °C	829.17±16.16[bc]	10097.20±111.28[ab]	496.49±15.31[a]	553.26±14.48[b]	404.12±23.80[ab]	18.34±1.26[b]	5.01±0.11[b]	2.76±0.24[b]	1.25±0.12[bc]
HAD 70 °C	837.16±24.63[bc]	9561.23±144.79[c]	485.91±30.42[ab]	581.92±13.06[a]	396.06±11.71[bc]	18.30±3.49[b]	4.72±0.26[bc]	2.91±0.41[b]	1.19±0.18[bc]
VD 50 °C & 300 mbar	805.57±4.00[c]	9803.50±58.67[bc]	518.88±25.16[a]	542.85±2.81[b]	404.68±12.39[ab]	24.27±1.14[a]	5.15±0.59[b]	2.89±0.45[b]	1.32±0.16[b]
VD 60 °C & 300 mbar	823.06±13.68[c]	10159.64±157.09[a]	511.93±10.64[a]	532.72±6.15[b]	398.61±13.44[b]	6.53±0.52[e]	4.99±0.04[b]	2.58±0.12[b]	1.12±0.11[bc]
VD 70 °C & 300 mbar	825.87±6.24[bc]	10059.30±68.92[ab]	498.27±27.74[a]	529.91±19.88[b]	390.67±12.75[bcd]	6.32±1.00[e]	4.78±0.95[bc]	2.66±0.23[b]	1.30±0.14[b]
MWD 90 W	857.86±29.16[ab]	9856.40±86.42[abc]	516.11±14.68[a]	593.76±7.70[a]	423.41±3.1[a]	15.21±0.99[c]	6.17±0.55[a]	3.75±1.03[a]	1.87±0.19[a]
MWD 180 W	763.59±23.30[d]	9191.80±109.9[d]	461.83±12.85[b]	494.67±25.01[c]	367.61±14.12[d]	10.13±0.70[d]	4.20±0.38[c]	2.53±0.21[b]	1.04±0.05[c]

[a–e] Different letters in the same column display significant difference (p<0.05)

Table 3. Effects of drying conditions on the textural features of pumpkin pestils

Drying treatments	Hardness (g)	Adhesiveness (g.s)	Springiness (mm)	Chewiness (g mm)	Gumminess (g)
HAD 50 °C	13827.0±547.27[d]	-0.35±0.07[a]	0.65±0.03[cd]	13868.4±544.54[c]	19527.3±903.38[b]
HAD 60 °C	20762.6±488.95[b]	-1.48±0.37[ab]	0.73±0.02[bc]	15525.6±445.63[b]	21919.7±616.97[ab]
HAD 70 °C	23530.6±1104.62[a]	-3.72±1.56[b]	0.85±0.03[a]	17803.5±363.82[a]	24137.2±218.23[a]
VD 50 °C & 300 mbar	14088.3±1749.07[d]	-0.54±0.34[a]	0.57±0.02[de]	6156.2±811.23[e]	10326.5±849.59[d]
VD 60 °C & 300 mbar	18578.8±1277.76[c]	-0.61±0.07[c]	0.64±0.08[d]	10900.2±200.10[d]	16051.3±857.74[c]
VD 70 °C & 300 mbar	22889.3±1641.88[a]	-6.36±1.31[c]	0.80±0.04[ab]	14029.5±478.59[c]	21785.1±1711.37[ab]
MWD 90 W	4223.3±391.72[e]	-13.88±1.54[d]	0.51±0.06[e]	2509.0±204.57[f]	2532.9±542.78[e]
MWD 180 W	5786.1±415.93[e]	-20.85±3.28[e]	0.77±0.07[ab]	2840.0±290.14[f]	3446.2±368.64 [e]

[a–f] Different letters in the same column display significant difference (p<0.05)

P, Mg, Fe, Zn, Cu and Mn contents were compatible with the literature data (Suna *et al*., 2014; USDA, 2021a). Suna *et al*. (2014) also reported that microwave drying resulted with higher values of Mg (419.26 mg/kg) than vacuum drying (414.48 mg/kg) in accordance with this study. Although raw material/fruit type in formulation and drying parameters differ in previous studies, current results of minerals were quite consistent with literature.

Furthermore, 100 g of pumpkin pestil (average of all drying conditions for each mineral content) provides 8.26 % Ca, 20.91 % K, 3.33 % Na, 7.70 % P, 9.86 % Mg, 16.25 % Fe, 4.53% Zn, 31.67 % Cu, 5.54 % Mn of the dietary reference intakes (DRIs) given for 19-30 year males (NIH, 2021).

E. Texture Analysis

The effects of different drying treatments on the textural features of pumpkin pestil were displayed in Table 3. Significant differences were recorded in terms of hardness, adhesiveness, springiness, chewiness and gumminess (p < 0.05).The texture attributes of pestil are quite important that they influence the sensorial evaluation and the compliance to the production process. Previous literature mainly focused on the textural properties of pestils by the addition of different ingredients such as citric acid, starch, sucrose, gums, milk powder and pectin (Cagindi and Otles, 2005; Özkan Karabacak, 2019; Tontul and Topuz, 2017), while the current study was the first in revealing the textural profile of a new fruit pestil produced from pumpkin (*Cucurbita moschata*).

Levels of hardness were determined between 4223.3-23530.6 g (Table 3). The highest hardness value was obtained from HAD at 70°C whereas the lowest level was determined from MWD at 90 W. This can be attributed to the shorter drying time of microwave treatment which was resulted with a softer structure. Additionally, higher temperatures both in HAD and VD and higher level of power in MWD resulted with an increment in the hardness of the pestils. Current result was in good agreement with the previous study in which hardness value was raised with higher temperature (convective) and power level (microwave) (Süfer *et al*., 2018).

Adhesiveness demonstrates the force important to expel the material that holds fast to teeth during eating and it is a negative force. It is a significant criteria which governs the stability of the product. Cohesive and adhesive forces, viscosity and viscoelasticity characteristics affected the adhesiveness of the pestil samples (Goksel *et al*., 2013). Adhesiveness was ranged from 0.35 to 20.85 g for pumpkin pestils and raised with increasing temperature for HAD and VD and power for MWD.

Springiness value of the pestils indicates the rate and degree to which an example comes back to its unique condition after it has been distorted in the midst of first compression (Suna and Özkan-Karabacak, 2019; Szczesniak, 2002). Increased temperatures in hot air treated samples and power level in microwave drying raised the springiness of the pestils whereas the same situation was not observed from vacuum drying. The springiness of pumpkin pestils was ranged from 0.51 to 0.85 mm which was compatible with the studies conducted by Boz (2012) and Tontul and Topuz (2017) for mulberry and pomegranate pestils respectively.

As the power level for microwave, and the temperature for HAD and VD conditions raised, significant effects on textural properties in terms of chewiness and gumminess were recorded ($p<0.05$). Chewiness is characterized as the sum to assume the energy required for biting a semisolid sample to a steady status of swallowing. Besides, chewiness is defined as the multiplication of gumminess and cohesiveness (Al-Hinai *et al*., 2013) thus the parameters that affect the gumminess and correspondingly hardness are important in determining this feature. Supporting this situation, chewiness and gumminess showed resemblance to hardness in the aspects of the method and conditions (Table 3). In a different research, an increment in chewiness and gumminess were also reported for increased temperatures (Goksel *et al*., 2013). Additionally, enhanced hardness, chewiness and gumminess values for mulberry pestils were previously recorded as a result of increased temperatures in hot air and vacuum; and power for microwave drying treatments by Suna and Özkan-Karabacak (2019).

F. Sensorial evaluation

The results of the sensorial analyses were indicated in Figure 4. Significant differences in colour, appearance and overall acceptance was observed ($p<0.05$) while there was not any significant difference in taste and chewiness ($p>0.05$) attributes of pumpkin pestils. Samples dried by microwave got the lowest scores from all of the sensorial criterias. This might be attributed to the undesirable taste resulted from the partial burning during microwave drying process. Except from these samples, all the other pestils were pleasantly preferred by the panellists in terms of sensorial properties.

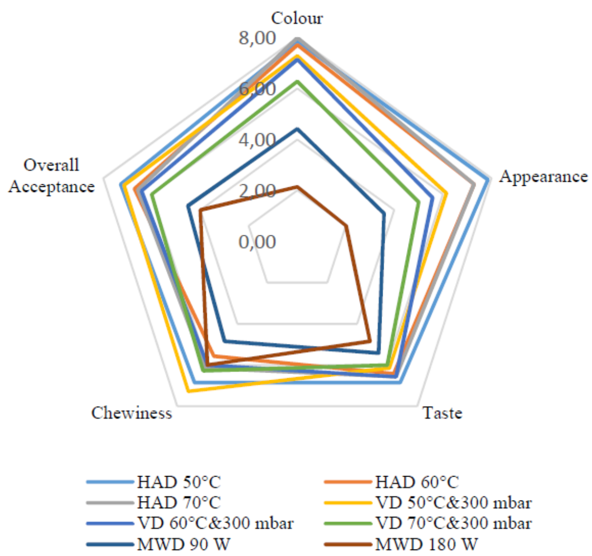

Figure 4. Sensorial profile of pumpkin pestils.

IV. CONCLUSIONS

This research focuses on an overview of the characteristics of pumpkin pestil drying with different methods like HAD, VD and MWD as well as explaining the effective moisture diffusivity (D_{eff}). Mineral content, texture analysis and sensorial features were determined in addition to present nutritional and structural properties. The highest drying rate was recorded from MWD at 180W with the highest reduction ratio (95.37 %) in drying time. Among the seven models, Page and Modified Page models efficiently described the thin layer drying behaviour of pumpkin pestils. Based on the Fick's second diffusion law, the D_{eff} values of pumpkin pestils were found in the range of 2.23×10^{-9}-4.56×10^{-8} m^{2}s^{-1}. Textural properties of pumpkin pestils were significantly affected by the drying conditions ($p<0.05$). Even though HAD and VD methods were more preferred in consideration with sensorial features, MWD method may be advised as most feasible method because it shortened the drying time and increased drying rate and quality attributes of pumpkin pestils. Moreover, it is recommended to use combined methods with microwave (such as hot air – microwave and vacuum – microwave) for best sensorial score, drying time and drying rate in future studies. As a consequence, pumpkin pestil can be considered as a healthy snack food providing the dietary reference intakes (DRIs) of analysed macro and micro elements.

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REFERENCES

Al-Hinai, K.Z., Guizani, N., Singh, V., Rahman, M.S. and Al-Subhi, L. (2013) Instrumental texture profile analysis of date-tamarind fruit leather with different types of hydrocolloids. *Food Sci Technol Res.* **19**, 531–538.

Boris, H., Shrilekha, D. and Sujata, J. (2018) Modelling of vacuum drying of cherry pepper. *Asian J Dairy Food Res*. **37**, 316–320.

Boz, H. (2012) *Dut pestilinin kimyasal, dokusal ve duyusal ozelliklerine bugday unu, sakkaroz şurubu, glikoz şurubu ve pişirme süresinin etkileri* (The effects of wheat flour, sucrose syrup, glucose syrup and cooking time on chemical, textural and sensorial properties of mulberry leather (pestil)). PhD. Thesis. Erzurum: Ataturk University (in Turkish).

Cagindi, O. and Otles, S. (2005) Comparison of some properties on the different types of pestil: A traditional product in Turkey. *Int J Food Sci Technol*. **40**, 897–901.

Compaoré, A., Putranto, A., Dissa A.O., Ouoba, S., Rémond, R., Rogaume, Y., Zoulalian, A., Béré, A. and Koulidiati, J. (2019) Convective drying of onion: modeling of drying kinetics parameters. *J Food Sci Technol*. **56**, 3347–3354.

Concha-Meyer, A.A., D'Ignoti, V., Saez, B., Diaz, R. and Torres, C.A. (2016) Effect of storage on the physico-chemical and antioxidant properties of strawberry and kiwi leathers. *J Food Sci*. **81**, C569–C577.

Dutta, D., Dutta, A., Raychaudhuri, U. and Chakraborty, R. (2006) Rheological characteristics and thermal degradation kinetics of beta-carotene in pumpkin puree. *J Food Eng*. **76**, 538–546.

Ferriol, M. and Pico, B. (2008) Pumpkin and winter squash. *Vegetables 1*. Prohens, J. and Nuez, F. (eds.) Springer, USA, 317-351.

Gamlı, Ö.F., Süfer, Ö. and Eker, T. (2018) Dehydration Kinetics and Infusion Attributes of Microwave Dried Olive Leaves. Turkish *J Agric - Food Sci Technol*. **6**, 963-970.

Goksel, M., Dogan, M., Toker, O.S., Ozgen, S., Sarioglu, K. and Oral, R.A. (2013) The Effect of Starch Concentration and Temperature on Grape Molasses: Rheological and Textural Properties. Food *Bioprocess Technol*. **6**, 259–271.

Gunasekaran, S. (1999) Pulsed microwave-vacuum drying of food materials. *Dry Technol*. **17**, 395–412.

Gunhan, T., Demir, V., Hancioglu, E. and Hepbasli, A. (2005) Mathematical modelling of drying of bay leaves. *Energy Convers Manag*. **46**, 1667–1679.

Gupta, S., Gupta, S.N., Gupta, N. and Jaggi, S. (2016) Economic Analysis of Pumpkin and Papaya as Fruit Leathers and their Utilization as Protective Cover against Cancer in the Medical Science. *Int J Food, Nutr Diet*. **4**, 35–50.

Kacar, B. (2010) *Bitki Analizleri*. Ankara, Turkey: Nobel Akademik Yayıncılık.

Lee, J.H. and Zuo, L. (2013) Mathematical modeling on vacuum drying of Zizyphus jujuba Miller slices. *J Food Sci Technol*. **50**, 115–121.

Limpaiboon, K., Technology, A. and Thammarat, N.S. (2011) Effects of Temperature and Slice Thickness on Drying Kinetics of Pumpkin Slices. *Walailak J Sci Tech*. **8**, 159–166.

NIH (2021) *National Institutes of Health*. Available at: https://www.ncbi.nlm.nih.gov/books/NBK56068/table/summarytables.t3/?report=objectonly.

Özkan Karabacak, A. (2019) Effects of different drying methods on drying characteristics, colour and in-vitro bioaccessibility of phenolics and antioxidant capacity of blackthorn pestil (leather). *Heat Mass Transf und Stoffuebertragung*. **55**, 2739–2750.

Panchariya, P.C., Popovic, D. and Sharma, A.L. (2002) Thin-layer modelling of black tea drying process. *J Food Eng*. **52,** 349–357.

Praveen Kumar, D.G., Hebbar, H.U. and Ramesh, M.N. (2006) Suitability of thin layer models for infrared-hot air-drying of onion slices. *LWT - Food Sci Technol*. **39**, 700–705.

Süfer, Ö., Demir, H. and Sezer, S. (2018) Convective and microwave drying of onion slices regarding texture attributes. *Czech J Food Sci*. **36**, 187–193.

Süfer, Ö. and Palazoğlu, T.K. (2019) A study on hot-air drying of pomegranate: Kinetics of dehydration, rehydration and effects on bioactive compounds. *J Therm Anal Calorim*. **137**, 1981–1990.

Suna, S. and Özkan-Karabacak, A. (2019) Investigation of drying kinetics and physicochemical properties of mulberry leather (pestil) dried with different methods. *J Food Process Preserv*. **43**, e14051.

Suna, S., Tamer, C.E., Incedayi. B., Sinir, G.O. and Copur, O.U. (2014) Impact of drying methods on physicochemical and sensory properties of apricot pestil. *Indian J Tradit Knowl*. **13**, 47–55.

Surendhar, A., Sivasubramanian, V., Vidhyeswari, D. and Deepanraj, B. (2019) Energy and exergy analysis, drying kinetics, modeling and quality parameters of microwave-dried turmeric slices. *J Therm Anal Calorim*. **136**, 185–197.

Szczesniak, A.S. (2002) Texture is a sensory property. *Food Qual Prefer*. **13**, 215–225.

Tontul, I. and Topuz, A. (2017) Effects of different drying methods on the physicochemical properties of pomegranate leather (pestil). *LWT - Food Sci Technol*. **80**, 294–303.

TUIK (2019).*Turkish Statistical Institute. Plant production statistics*. Available at: https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr .

Tüfekçi, S. and Özkal, S.G. (2017) Enhancement of drying and rehydration characteristics of okra by ultrasound pre-treatment application. *Heat Mass Transf und Stoffuebertragung*. **53**, 2279–2286.

USDA (2021a). *United States Department of Agriculture. Agricultural Research Service. USDA Food Composition Databases*. Available at: https://fdc.nal.usda.gov/fdc-app.html#/food-details/167540/nutrients .

USDA (2021b). *United States Department of Agriculture. Agricultural Research Service. USDA Food Composition Databases*. Available at: https://fdc.nal.usda.gov/fdc-app.html#/food-details/401314/nutrients .

Vatthanakul, S., Jangchud, A., Jangchud, K., Therdthai, N. and Wilkinson, B., 2010. Gold kiwifruit leather product development using quality function deployment approach. *Food Quality and Preference*. **21**, 339–345.

Yadav, M., Jain S., Tomar, R., Prasad, G.B.K.S. and Yadav, H. (2010) Medicinal and biological potential of pumpkin: An updated review. *Nutr Res Rev*. **23**, 184–190

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