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The Influence of Drying on Some Physical Properties of Laurel Berry

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Abstract: In this study Laurel berries (*Laurus nobilis* L.) were dried by hot air and microwave method. The power levels for microwave application were 180, 360, 540, 720 and 900 W, respectively. The temperature levels for hot air drying were 60, 70 and 80 ºC, respectively. The drying time, moisture content, energy consumption, oil yield, some physical properties such as size, weight, volume, true density, geometric diameter, arithmetic diameter, sphericity, and mechanical behavior was measured in this study. Drying time of laurel berries by hot air at the temperature of 80 °C was 12 hours. By using microwave energy at the power of 900 W the drying time was only 10 minutes. To calculate the moisture ratio for different mathematical models the coefficient of determination (R^2), standard error of estimate (SEE) and residual sum of squares (RSS) were calculated. The results show that Midilli-Kucuk and Verma model were best proper equations to predict thin layer drying behavior of laurel berries. The results of this study show that this three steps technique could be easily applied in industrial scale.
Key words: Laurel berry, drying, hot air, microwave

INTRODUCTION

Laurel berry (*Laurus nobilis* L.) is evergreen, large shrub tree and it reaches 8-10 m high as forest plant. It grows wild in the coastal area of Mediterranean and the Black Sea. The used plant parts of laurel are leaves and berries. The leaves ripen in May-June and they are manually collected from wild flora. Except direct usage of leaves as fresh or dried for flavoring, the essential oil is also an important product gained by steam distillation. The second used part of laurel is round, grape-sized berries having purplish black color. Laurel berries are picked up also manually in November-December. They are used to produce berry oil which differs from leaf oil and it is only used for soap making. Traditionally, laurel berry oil is extracted from fresh berries by boiling for several hours in an open drum of water using a wood fire. After the cooling the oil floating over the water is collected. As the amount of oil gained by traditional method is not too much, it is usually sold in domestic markets to produce daphne soap. The laurel berry oil could be also gained by organic solvent extraction or mechanical expression known as cold pressing. In practice oil yield by traditional method is about 10% (w/w). In laboratory scale the oil yield could increase till to over 20% by super critical CO_2 extraction method (Beis and Dunford, 2006).

In frame of this study a new processing method for laurel berries was investigated. Each step of this method is actually well known from other crops. But, applying of these one by one for laurel berries was studied first time in this research. The suggested method for laurel berry processing consists of following three steps;

1. Drying laurel berries till to 9% of moisture
2. Cold pressing
3. Extraction of oil cake gained from cold press

The preliminary tests in this study show that the oil gain from laurel berries by cold press is approximately 10 %. But gaining whole oil of berries by cold press technique is not possible. To gain remaining oil in the cake after pressing the solvent extraction method known from oil industry could be used. By implementing both techniques together the total oil yield from laurel berries could reach over 25%, which is two times higher than that of traditional boiling method. In order to apply this new strategy the drying of laurel berries plays a curious role.

From the drying point of view it should be mentioned three morphological parts of single berry, which are skin, flesh and an inner kernel, namely seed. The whole berry, flesh, skin, and kernel contain 26, 38.8, and 18 % oil, respectively (Yazicioglu and Karaali, cited by Beis and Dunford, 2006). The outer skin and flesh with the 64.8 % of oil content are actually very important parts of berry with regard to drying. That means; any drying energy applied to laurel berries should be sufficient to get the moisture from inside, but parallel to this it shouldn't cause any quality or quantity loss in oil. The fulfilling of two controversy demands is not very easy task. Generally, there are two ways for applying drying energy to the berries. First one is hot air drying technique where heat is produced in outside and transferred to inside of crop. After the moisture is evaporated in inside, it is transferred back to outside and moist air is removed by forced convection. The second option is the microwave technique where heating energy is created in inside of crop and transferred to outside. Both techniques have been already well studied for drying of some other agricultural crops. However, research on laurel berry processing is scarce. Moreover no published report is available for laurel berry drying. Therefore aims of this study are to dry the laurel berries by hot air and microwave techniques and to investigate the influences of drying method on some physical properties of laurel berries.

MATERIAL and METHOD

Drying Experiments

Laurel berries were provided from Antakya province of Turkey. The manually picked fruits were stored at ±4 ºC prior to experiments. The moisture content of material was determined by standard oven method at 105º C for 24-h. The sample mass was measured with precision balance (Sartorius, GM 1502; accuracy: 0.01 g). Electric consumption was used by electric meter (Vi-Ko).

Moisture content of samples was determined with following equation;

$$M = \frac{m_w}{m_w + m_d} \qquad (1)$$

Where;

M= Moisture content % (wet basis),

m_w= Mass of water (g),

m_d = Mass of dry material (g)

Microwave drying tests were carried out by using domestic microwave oven (Arçelik ARMD 594) having five output levels which are 180W, 360W, 540W, 720W and 900W, respectively. On the other hand hot air drying tests was carried out by using laboratory scale drying oven where the temperatures of 60, 70 and 80ºC were selected.

During drying tests the glass turn-table having a diameter of 325 mm in the microwave oven was filled up by 250 g of laurel berries homogeneously. Moisture losses during microwave drying were measured in two minutes intervals. For hot air drying the measuring intervals was 2 hour.

Berry oil was extracted by using Soxleth extraction method. The ether was used as organic solvent. The data's was evaluated by using multiple range tests. The used software for statistical evaluation was SPSS 17.0.

Mathematical Modeling

Drying curves were fitted with eleven thin-layer drying models (Table 1). The moisture ratio and drying rate of laurel berries were calculated using the following formulas:

$$MR = \frac{M - M_e}{M_0 - M_e} \qquad (2)$$

$$\text{Drying rate} = \frac{M_{t+dt} - M_t}{dt} \qquad (3)$$

where MR, M, M_0, M_e, M_t and M_{t+dt} are the moisture ratio, moisture content at any time, initial moisture content, equilibrium moisture content, moisture content at the time of *t* (min) and moisture content at the time of *t*+d*t* (kg [H_2O] kg^{-1} dry matter), respectively.

The coefficient of determination (R^2), standard error of estimate (SEE), residual sum of square (RSS) were used to decide on best proper equation.

In order to determine the size, weight and volume a hundred of berries were randomly selected. For each berry three principal dimensions namely length (*L*), width (*W*) and thickness (*T*), which are shown in Fig.1 were measured by using a digital vernier caliper (*BTS*, accuracy; 0.01 mm (Çalışır *et al*, 2004).

The geometric mean diameter (D_g), arithmetic mean diameter (D_a) and sphericity (ϕ) of the fruits were calculated using the following equations.

Table 1. The mathematical models used for variation of moisture ratio

	Model name	Model equation	References
1	Newton	MR=exp(-kt)	Ayensu (1997)
2	Page	MR=exp(-kt^n)	Agrawal and Singh (1977)
3	Modified Page	MR=exp(-$(kt)^n$)	White *et al.*(1981)
4	Henderson and Pabis	MR=a exp(-kt)	Akpınar *et al.*(2006)
5	Logarithmic	MR=a exp(-kt)+c	Yaldız *et al.* (2001)
6	Wang and Singh	MR=1+at+bt^2	Wang and Singh (1978)
7	Diffusion Approach	MR=a exp(-kt)+(1-a)exp(-kbt)	Toğrul and Pehlivan (2003)
8	Verma	MR=a exp(-kt)+(1-a)exp(-gt)	Verma *et al.*(1985)
9	Two Term Exponential	MR=a exp(-kt)+(1-a)exp(-kat)	Sharaf-Elden *et al.*(1980)
10	Midilli-Kucuk Equation	MR=a exp(-k(t^n)+bt	Sacilik and Elicin (2006)

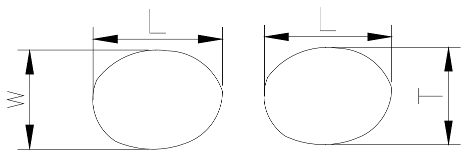

Figure 1. Principal dimensions of laurel berry fruits; L, W and T are the length (major axis), width (intermediate axis) and thickness (minor axis)

$$D_g = (LWT)^{1/3} \quad (4)$$

$$\phi = \frac{(LWT)^{1/3}}{L} \quad (5)$$

$$D_a = \frac{L + W + T}{3} \quad (6)$$

A scanner was used to project the image of the fruit in its natural rest position. Then, the projected area was calculated by using Auto-CAD 2007. The volume and true density of each fruit were determined by the water displacement method (Mohsenin, 1978). The true density was then computed by dividing the weight to volume.

The static coefficients of friction of laurel berry were determined by using three materials, which are galvanized sheet, chrome steel and plywood. A group of bound fruit was placed on the tilting surface. The surface was gradually raised up by the screw. Vertical and horizontal height values were read from the ruler when the fruit started the sliding. The static coefficient friction then calculated (Ertekin *et al*, 2006).

For the determination of angle of repose (θ) of fruit, a specially constructed prism in dimensions of 300*190*130 mm with a movable wall was used. After filling the box with fruits, the movable wall was pulled carefully. Therefore the fruits flowed along the horizontal line in the volume and the angle between static bulk main line and horizontal plane was measured (Akcalı *et al*, 2006)

Quasi-static compression tests were done with a Lloyd Material Testing Machine (model LRX Plus) equipped with a 5000 N load cell and computer. Two loading positions which are parallel to the principal dimensions of the fruit were used in compression tests. Each sample was placed between two plates and compressed at 8 mm min^{-1} speed until the fruit was initiated. Rupture force was read directly from graphics. Each test was repeated 20 times.

RESULTS

The data's on final moisture content, drying time, energy consumption and oil yield for hot air and microwave drying were presented in Table 2. The drying time was reduced by 82 % by increasing microwave output power from 180W to 900W. The consequent of this is the reduction of energy consumption by % 36.5. In that stage no negative sensory changes such as burning smell etc. on dried berries were observed.

However, the oil yield was significantly reduced by increasing of microwave power ($p<0.05$). In fact the oil yield at the microwave output of 180 W was obtained just by CO_2 extraction method in laboratory scale (Beis and Dunford, 2006). Even at the level of 900 W the oil yield was still higher than 25 % which was seemed promising in favor of microwave drying. On the other hand an increase in drying time is expected at hot air drying due to morphological properties of laurel berries which complicates the heat transfer between outside and inside of single berry.

Table 2. Drying parameters of laurel berry

Drying Methods & Levels		Drying Time (min)	Energy Consumption (kWh)	Initial Moisture Content (%, d.b.)	Final Moisture content (%, d.b.)	Oil Yield (%, w/w)
Microwave output (W)	180	66	0.361	0.61	0.091	28^{a}
	360	21	0.245	0.64	0.082	27.6^{ab}
	540	18	0.248	0.64	0.092	27.4^{b}
	720	15	0.238	0.64	0.10	25.8^{d}
	900	12	0.229	0.64	0.065	25.8^{d}
Hot Air temp. (ºC)	60	1680	2.315	0.65	0.12	25.8^{d}
	70	1320	2.308	0.65	0.11	27.8^{ab}
	80	720	1.529	0.65	0.12	27^{c}

Table 3. Non-linear regression analysis results for microwave drying of Laurel Berry; SEE Standard error of estimate; R^2, coefficient of determination; RSS, residual sum of square

	180W			360W			540W			720W			900W		
No	R^2	SEE(±)	RSS	R^2	SEE(±)	RSS	R^2	SEE(±)	RSS	R^2	SEE(±)	RSS	R^2	SEE(±)	RSS
1	0.991	0.057	0.073	0.987	0.079	0.044	0.980	0.100	0.059	0.982	0.096	0.0553	0.972	0.112	0.0763
2	0.999	0.008	0.001	0.996	0.047	0.013	0.999	0.006	0.000	0.999	0.006	0.0002	0.999	0.009	0.0004
3	0.999	0.017	0.006	0.999	0.025	0.003	0.997	0.042	0.007	0.998	0.035	0.0049	0.994	0.060	0.0144
4	0.995	0.040	0.034	0.989	0.079	0.037	0.984	0.095	0.045	0.987	0.090	0.0409	0.979	0.108	0.0586
5	0.999	0.019	0.072	0.999	0.024	0.002	0.997	0.043	0.007	0.998	0.035	0.0050	0.994	0.063	0.0162
6	0.998	0.026	0.014	0.999	0.023	0.003	0.996	0.042	0.009	0.998	0.035	0.0063	0.993	0.060	0.0185
7	0.998	0.027	0.015	0.987	0.094	0.044	0.999	0.022	0.002	0.997	0.041	0.0067	0.999	0.022	0.0021
8	0.999	0.008	0.001	0.9997	0.0133	0.0009	0.999	0.022	0.002	0.999	0.021	0.0019	0.999	0.022	0.0021
9	0.999	0.008	0.001	0.992	0.083	0.028	0.995	0.065	0.012	0.999	0.025	0.0019	0.995	0.066	0.0134
10	0.9999	0.0072	0.0010	0.998	0.034	0.004	0.9999	0.0076	0.0002	1.000	0.0072	0.0002	0.9999	0.0072	0.0002

The convenient drying temperature for medicinal and aromatic crops varies between 50 and 70 ºC (Martinov *et al*, 2007). The drying time to reach the crop moisture under 10% was 12 hours at the drying air temperature of 80°C. Such a longer drying times and lower capacities are not accepted in practice due increased operational costs. Therefore to use of the hot air alone could not be suggested. Moreover the decrease in oil yield by increasing of air temperature from 70 °C to 80 °C was significantly important ($p<0.05$).

The results of non-linear regression analyses for hot air and microwave drying were given in Table 3 and Table 4. The highest values of R^2 were obtained by Midilli-Kucuk model. The change of moisture depending on time was obtained as follows:

$$MR=a.\exp(-kt^{n})+b.t$$

The best proper model at the microwave power of 360 W was the Verma Model which gives the highest values of R^2. The change of moisture depending on time was calculated according to following formula:

$$MR=a.\exp(-kt)+(1-a)\exp(-gt)$$

It was found that the highest coefficient of determination varied between 0.9984-1.0000 for Midilli-Kucuk and 0.9997 for Verma equations. The obtained results were showed that these models are reliable to predict the variation moisture ratio of laurel berry.

The classical degradation force and degradation graphics were given in Figure 2. The effects of drying process on the physical properties and mechanical behaviors of material were given in Table 5. The density and degradation force of the hot air dried samples higher than that of microwave dried berries. The real density values of the samples dried by hot air in 60, 70 and 80°C were determined as 0.98, 1.00 and 1.12 g cm^{-3}, respectively (Table 5). This density values increases by 21% at 80°C in compare to fresh berries. According to these results, the degradation force of hot air dried laurel berries was higher than that of the fresh samples which was by 413 % in vertical axis and by 213% in horizontal axis. The degradation force of microwave dried berries at the power of 180 W was increased by 217 % in horizontal axis and by – 28 % in vertical axis. The degradation force at the level of 900 W was increased by 42% in vertical axis and decreased by 19% in horizontal axis. Similar tendencies were also confirmed at microwave drying at the level of 360, 540, 720 W.

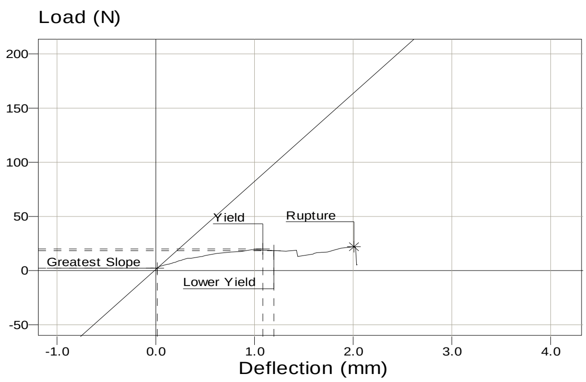

Figure 2. Classical degradation force

Table 4. Non-linear regression analysis results for hot air drying of Laurel Berry under hot air; SEE Standard error of estimate; R^2, coefficient of determination; RSS, residual sum of square

	60ºC			70ºC			80ºC		
No	R^2	SEE(±)	RSS	R^2	SEE(±)	RSS	R^2	SEE(±)	RSS
1	0.9984	0.02182	0.0066	0.9935	0.0425	0.0198	0.9964	0.0357	0.0076
2	0.9984	0.0226	0.0066	0.9948	0.0399	0.0159	0.9964	0.0390	0.0076
3	0.9994	0.6286	4.7416	0.8406	0.2206	0.4868	0.9964	0.0390	0.0076
4	0.9994	0.6064	4.7798	0.9936	0.0444	0.0197	0.9965	0.0386	0.0074
5	0.9772	0.0900	0.0971	0.8410	0.2323	0.4858	0.9971	0.0392	0.0061
6	0.9992	0.0164	0.0035	0.9959	0.0352	0.0124	0.9983	0.0271	0.0037
7	0.8184	0.1462	0.0085	0.9936	0.0465	0.0195	0.9968	0.0411	0.0068
8	0.9990	0.0188	0.0043	0.9936	0.0465	0.0195	0.9968	0.0411	0.0068
9	0.9984	0.0231	0.0069	0.9935	0.0445	0.0198	0.9963	0.0392	0.0077
10	0.9998	0.0091	0.0009	0.9984	0.0244	0.0048	0.9995	0.0193	0.0011

Table 5. Physical properties of laurel berry

		Microwave Drying					Hot Air Drying		
Physical Properties	Fresh	180 W	360 W	540 W	720 W	900W	60°C	70°C	80°C
Moisture Content (% w.b.)	40	8.55	7.57	8.48	9.2	7.18	8.3	9.36	9.81
Extracted oil		28^{a}	27.6^{ab}	27.4^{b}	25.8^{d}	25.8^{d}	25.8^{d}	27.8^{ab}	27^{c}
Length (mm)	14.26	14.08	14.23	14.18	14.18	14.16	13.78	13.49	13.78
Width(mm)	12.22	11.07	11.37	11.44	11.17	11.39	10.42	10.46	10.61
Thickness (mm)	10.86	10.65	10.99	10.99	10.75	11.01	9.94	9.98	10.08
Geometric Mean Diameter (mm)	12.36	11.87	12.11	12.18	11.93	12.24	11.25	11.20	11.37
Arithmetic Mean Diameter (mm)	12.44	11.97	12.20	12.27	12.03	12.35	11.38	11.31	11.49
Sphericity	0.86	0.84	0.85	0.85	0.84	0.84	0.82	0.83	0.83
Weight (g)	1.27	0.74	0.73	0.67	0.70	0.70	0.80	0.76	0.82
Volume (cm^3)	1.38	0.82	0.82	0.91	0.86	0.91	0.81	0.76	0.79
True Density (g/cm^3)	0.92	0.90	0.88	0.73	0.81	0.77	0.98	1.00	1.12
Projected Area (mm^2)	149.31	106.63	112.07	108.72	102.43	108.54	93.49	90.90	91.01
Rupture Force Major Axis (N)	52.91	113.25	59.11	79.52	79.14	74.85	204.89	215.86	215.96
Rupture Force Minor Axis (N)	97.99	125.74	84.75	85.17	85.37	79.04	179.17	177.87	209.94
Angle Of Repose (º)	29.54	24.15	21.61	22.59	22.01	23.62	19.96	21.54	25.04
Static Coefficient Of Friction									
Galvanized Steel	26.57	29.66	28.07	30.06	29.22	30.68	29.86	31.73	30.46
Chrome Steel	25.06	29.11	29.09	32.60	28.75	27.17	31.98	31.12	31.83
Plywood	25.32	30.94	31.25	32.36	29.22	30.68	33.48	37.00	37.53

CONCLUSION

Laurus nobilis L. is an indigenous forest plant which is the main income source for local people in the growing region of this plant. The demand for laurel berry oil in domestic and international market is very promising due to its usage as ingredient in daphne soap. As by using current traditional boiling method the demand of market could not be covered, new methods are required. The three steps processing method which is implemented in this study would contribute to increase the quantity of laurel berry oil. In terms of quality the drying is the key step. Although only hot air and microwave drying were tested in this study, there are still many options to apply the hot air efficiently. Moreover the investment capacity of entrepreneur is also very important factor to decide on drying system. On the other hand combined usage of microwave and hot air technique in belt driers could be also another option. Microwave energy application may result the quality losses due to burning of oil in high initial moisture levels. Therefore the hot air could apply firstly, than the rest of moisture could be easily taken by microwave energy. But all of these options require detailed studies where the influences of drying technique on oil quality and quantity should be investigated in detail.

The cold press as a second step has been already used to produce other seed oil such as pomegranate, grape seed etc. Regarding to laurel berry the market potential of cold pressed oil differs from extracted oil. Due to necessity of organic solvent on extraction method, the removing of whole used solvent from extracted oil is usually not possible which means that a small part of solvent stays in oil. The potential consumers of cold pressed oil are those who don't want to use such seed oil containing organic solvent. They prefer to use pure cold pressed oil. On the other hand the consumers have also no information whether it is really cold pressed. Actually the term "cold" does not mean that there is not any temperature rise during pressing. Just the opposite the temperature of laurel berry oil increases over 100 ºC during the pressing. Normally, the consumers do not have any information about process temperature anyway. The usage of seed oils in the market could be evaluated as a trend or habit of consumers, where they believe that cold pressed oil is healthy.

The third step as solvent extraction has been also used since a long time in food oil production. The improvement of both press and extraction process is out of the aims of this study. The both techniques are just used to increase the quantity of laurel berry with acceptable losses in quality.

The results of this study show that this three steps technique could be easily used in industrial scale. Thus one entrepreneur in growing area of laurel in east Mediterranean region has been already invested for such system which is working very efficiently. Thoroughly an important aim of applying the research results to industry and collaboration between research institutes and industry was realized.

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