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*Full Length Research Paper*

# Drying kinetic and physical properties of green laird lentil (*Lens culinaris*) in microwave drying

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**The objective of this study was to study the drying kinetics of green laird lentil (*Lens culinaris*) in microwave drying method. The drying data were fitted to the various thin-layer models. All the models were compared using three statistical parameters, that is, coefficient of determination $R^2$, reduced mean square of the deviation $X^2$ and root means square error RMSE. Also, the lentil's physical and mechanical features crude protein, oil and ash parameters were specified under different microwave levels. It was concluded according to these values that the recommended model is the best model, which can define the drying curves at the practices at 300, 400, 550, 700 and 800 W in drying lentil by microwave.**

**Key words:** Microwave, lentil, physical properties, crude protein, drying.

## INTRODUCTION

A green laird lentil grain is a cultivated plant grown for dry consumption and raw material of canned food industry. It contains 26.64% protein, 54.97% carbohydrates, 0.43% fat, 49.11% starch per 100 g (dry) and 197 mg calcium, 53.2 mg sodium, 53.0 mg iron per kilograms (Anonymous, 2006).

Turkey had about 27.697 ha of green laird lentils harvesting area, 24.827 t of green laird lentils production per annum with a yield of 900 kg $ha^{-1}$ of green laird lentils in 2008 (SIS, 2009).

The study of the drying kinetic of foods during microwave heat treatment has recently been a subject of interest for various investigators. Some of the previous studies about microwave drying can be listed as: parsley (Soysal et al., 2006), maize (Velu et al., 2006), bacon (James et al., 2006), mint (Özbek and Dadalı, 2007),spinach (Dadalı et al., 2007; 2008), potato (Gunasekaran and Yang, 2007; Oztop et al., 2007), noodles (Xue et al., 2008), apple (Askari et al., 2008), garlic (Sharma and Prasad, 2006; Souraki and Mowla, 2008), spaghetti (Cocci et al., 2008), red pitaya (Nordin et al., 2008), leek (Dadalı and Özbek, 2008), avocado (Guzmán-Gerónimo et al., 2008), Chilean hazelnuts (Uquiche et al., 2008), basil (Demirhan and Özbek, 2009), tomato (Al-Harahsheh et al., 2009).

This study is on determination of drying kinetics of green laird lentil and selecting proper model in microwave drying method. For this purpose, semi-mathematical models specified before were run with test results; the coefficients in the equations as well as $X^2$, RMSE and $R^2$ values were found and they were compared with the developed model. Also, the green laird lentil's physical and mechanical features at initial and final drying moisture

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**Abbreviations:** $\mathbf{A_s}$**,** Surface area ($mm^2$); $\mathbf{D_a}$**,** arithmetic mean diameter of seed (mm); $\mathbf{D_g}$**,** geometric mean diameter of seed (mm); **D,** diameter of seed (mm); **MR,** moisture ratio, decimal; $\mathbf{M_t}$**,** moisture content at a specific time, g water per dry solids; $\mathbf{M_o}$**,** initial moisture content, g water per g dry solids; $\mathbf{M_e}$**,** equilibrium moisture content, g water per g dry solids; $\mathbf{MR_{exp,I}}$**,** experimental moisture content (%d.b); $\mathbf{MR_{pre,I}}$**,** prediction moisture content (%d.b); **N,** observation number; **RMSE,** root mean square error; $\mathbf{R^2}$**,** coefficient of determination; $\mathbf{X^2}$**,** Chi-square; **Q,** mass of water to added (kg); **T,** thickness of seed (mm); $\mathbf{V_t}$**,** terminal velocity, (m $s^{-1}$); $\mathbf{W_i}$**,** initial mass of sample (kg); **ε,** porosity (%); **α,** angle of tilt, degree; **μ,** static coefficient of friction; $\mathbf{\rho_b}$**,** bulk density (kg $m^{-3}$); $\mathbf{\rho_t}$**,** true density (kg $m^{-3}$); **ϕ,** sphericity of seed (decimal)**; a, k, n, c, k$_o$,b, k$_1$,** experimental constants.

values and post-drying crude protein, crude oil and crude ash were specified.

## MATERIALS AND METHODS

### Drying equipment and drying procedure

The drying procedure was carried out by a microwave oven (Arçelik MD 500, PRC). The values of the oven are 230 V, 50 Hz and 1200 W, the frequency of 2450. The procedure was carried out at 5 microwave powers, which are 300, 400, 550, 700 and 800 W. The size of the oven is 300 × 460 × 280 mm and its rotating glass plate's diameter is 27 mm. In the tests, 250 g of lentil was placed onto the glass plate and the thin layer method was applied. Weight losses were measured at every 10 s through a digital balance (Baster, Istanbul, Turkey) with the sensitivity of 1 g uninterruptedly and recorded. The tests were repeated three times and then, the means were calculated. The tests at different powers were ended up after decrease of 40 g for preventing burning in the product.

### Mathematical modeling of drying data

In order to determine the moisture ratio as a function of drying time, 8 different thin-layer drying models were used. The moisture ratio was calculated using the following equation:

$$MR = \frac{Mt - Me}{Mo - Me} \tag{1}$$

Where, MR is the moisture ratio; $M_t$ is the moisture content at a specific time (g water per g dry solids); $M_0$ is the initial moisture content (g water per g dry solids) and $M_e$ is the equilibrium moisture content (g water per g dry solids).

The equilibrium moisture content ($M_e$) was assumed to be zero for microwave drying as stated by Dadali et al. (2007).

### Statistical analysis

Excel program was employed in obtaining data, their graphical assessment and obtaining regression equations. MATLAB R2008a program was employed in determination of the coefficients, $X^2$, $R^2$ and RMSE values for the said 8 models. Herein, the best model is defined as the one having low $X^2$ and RMSE values and high $R^2$ values. The model, which has these values, is the model, which can estimate the study best (Mengeş et al., 2005). These statistical values are defined as followings:

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

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (MR_{pre,i} - MR_{\exp,i})}{N}} \tag{3}$$

Where, $MR_{exp,i}$, is the experimental moisture ratio in the test with number I; $MR_{pre,i,}$ is the estimated moisture ratio in the test with number I; N, is the observation number; n, number of the constants in the drying model.

### Methods of determination of physical properties

The green laird lentil grains used in this study were obtained from a local market (Marmara region, Bursa, Turkey). The grains were cleaned manually to remove all foreign matter such as dust, dirt, stones and chaff as well as immature, broken grains. The initial moisture content of the grains was determined by digital moisture meter (Pfeuffer HE 50, Germany) reading to 0.01%.

The samples of the desired moisture contents were prepared by adding the amount of distilled water as calculated from the following relation (Ünal et al., 2006):

$$Q = \frac{W_i (M_f - M_i)}{(100 - M_f)} \tag{4}$$

The samples were then poured into separate polyethylene bags and the bags sealed tightly. The samples were kept at 5°C in a refrigerator for a week to enable the moisture to distribute uniformly throughout the sample. Before starting a test, the required quantity of the grain was taken out of the refrigerator and allowed to equilibrate to the room temperature for about 2 h (Singh and Goswami, 1996).

All the physical properties of the grains were determined at initial and final moisture contents (31.86 to 14.02% d.b.). To determine the average size of the grain, their two linear dimensions namely, diameter (D) and thickness (T) were measured using a digital compass (Minolta, Japan) with an accuracy of 0.01 mm.

The average diameter of grain was calculated by using the arithmetic mean and geometric mean of the two axial dimensions. The arithmetic mean diameter $D_a$ and geometric mean diameter $D_g$ of the grain were calculated by using the following relationships:

$$D_a = (2D + T)/3 \tag{5}$$

$$D_g = (D^2 T)^{1/3} \tag{6}$$

The sphericity of grains ϕ was calculated by using the following relationship:

$$\phi = \frac{(D^2 T)^{1/3}}{D} \tag{7}$$

The one thousand grain mass was determined by means of an electronic balance (Radwag, PS 4500, Poland) reading to 0.001 g. The surface area $A_s$ in $mm^2$ of green laird lentil grains were found by analogy with a sphere of same geometric mean diameter, using the following relationship (Ünal et al., 2006):

$$A_s = \pi D_g^2 \tag{8}$$

The projected area $A_p$ was determined from the pictures of green laird lentil grains which were taken by a digital camera (Creative DV CAM 316; 6.6 Mpixels), in comparison with the reference area to the sample area by using the Global Lab Image 2-Streamline (trial version) program (Işık and Güler, 2003).

The average bulk density of the green laird lentil grains was determined using the standard test weight procedure reported by Singh and Goswami (1996) and Gupta and Das (1997) by filling a container of 500 ml with the grain from a height of 150 mm at a constant rate and then weighing the content.

The average true density was determined using the toluene displacement method. The volume of toluene ($C_7H_8$) displaced was found by immersing a weighed quantity of green laird lentil grains in the toluene (Singh and Goswami, 1996). The porosity was calculated from the following relationship (Mohsenin, 1970):

$$P_f = (1 - \frac{\rho_b}{\rho_t})100 \quad (9)$$

The terminal velocities of grain at different moisture contents were measured using a cylindrical air column in which the material was suspended in the air stream (Nimkar and Chattopadhyay, 2001). The air column was 28 mm in diameter. Relative opening of a regulating valve provided at blower output end was used to control the airflow rate. In the beginning, the blower output was set at minimum. For each experiment, a sample was dropped into the air stream from the top of the air column. Then airflow rate was gradually increased till the grain mass gets suspended in the air stream. The air velocity which kept the grain suspension was recorded by a digital anemometer (Thies clima, Germany) having a least count of 0.1 m $s^{-1}$ (Özdemir and Akinci, 2004).

The static coefficient of friction of green laird lentil grains against six different structural materials, namely rubber, galvanized iron, aluminum, stainless steel, glass and MDF was determined. A polyvinylchloride cylindrical pipe of 50 mm diameter and 100 mm height was placed on an adjustable tilting plate, faced with the test surface and filled with the grain sample. The cylinder was raised slightly so as not to touch the surface. The structural surface with the cylinder resting on it was raised gradually with a screw device until the cylinder just started to slide down and the angle of tilt was read from a graduated scale (Yalçın and Özarslan, 2004). The coefficient of friction was calculated from the following relationship:

$$\mu = \tan \alpha \quad (10)$$

Where, μ is the coefficient of friction and α is the angle of tilt in degrees.

#### Methods of determination of crude protein, oil and ash

The experiment was laid out according to randomized complete plot experimental design with three replications. Composition (crude protein, crude oil and ash) of lentils was determined using the Association of Official Analytical Chemists (AOAC, 1990) methods. Standard methods as described in AOAC (1990) were used for the determination of crude protein (ID No. 984.13), ash (ID No. 924.05) and ether extract (EE, ID No. 920.39). Seed samples of plots were ground to pass through a sieve of 0.8 mm diameter. Ground seed samples were analyzed by Kjeldahl method to determine the total nitrogen. Crude protein content was calculated by multiplying total nitrogen value with a coefficient of 6.25. Crude oil percentage was determined by the Soxhlet extraction technique. Approximately, 3 g of sample were extracted with di-ethyl ether for a period of 4 h in Soxhlet device. In order to determine total ash, the samples were ground and 2 g sub-samples were taken. The sub-samples were placed in previously weighed porcelain crucibles and then in a muffle oven at 550°C for four hours. After cooling to ambient temperature inside a desiccator, the crucibles were weighed again and the percentage of ashes was calculated.

## RESULTS AND DISCUSSION

### Drying kinetic of dried lentil

The initial moisture value for the experiments on drying lentil in microwave oven is 31.86% and the experiment was continued until the moisture ratio reached 14.02% corresponding to 40 g of loss in moisture at each practice. During the tests, the moisture ratio of 31.86% reduced to 14.02% in 680, 530, 360, 310 and 300 s at 300, 400, 550, 700 and 800 W respectively. Alteration of the removable moisture ratio in drying lentil versus time is seen in Figure 1. The coefficients obtained in the 8 models by employing the experimental data, $X^2$, $R^2$ and RMSE values are seen on Table 1. According to the table, the best $R^2$ values at 300, 400, 550, 700 and 800 W are obtained as 0.9961, 0.99695, 0.99691, 0.99655 and 0.99421 respectively on Wang and Sing and 0.9933, 0.99154, 0.99541, 0.99357 and 0.99585 in Page 2 when the model recommended in this paper was kept out of the operation. These two modeled $X^2$ and RMSE values are more suitable compared with the other models. However, $X^2$ values for the lentil experiment in the recommended model are 0.00026, 0.00024, 0.00020, 0.00023 and 0.00047 at 300, 400, 550, 700 and 800 W respectively. The values for $R^2$, which is another important parameter in acceptance of the model, are respectively 0.9975, 0.99772, 0.99798, 0.99794 and 0.99588. The root mean square errors of the estimation (RMSE) are 0.01604, 0.01541, 0.0141, 0.01526 and 0.02172 respectively for each test. It may be said according to these values that the model, which has 18 numbered equation and recommended in this paper, is the best model, which can define the drying curves at the practices at 300, 400, 550, 700 and 800 W in drying lentil by microwave.

$$MR = a + bt^2 + ct$$

Figure 2 shows energy consumption values in lentil drying in microwave oven. According to the figure, 0.36, 0.36, 0.32, 0.36 and 0.40 W was consumed per gram ($Whg^{-1}$) at 300, 400, 550, 700 and 800 W respectively for reducing the moisture in lentil from 31.86 to 14.02%. According to these values, the lowest energy was consumed in reducing the moisture in lentil from 31.86 to 14.02% at 550 W and the highest energy was consumed for the same purpose at 800 W.

### Physical and mechanical properties of lentil

Diameter, thickness, arithmetic and geometric mean diameter which define lentil size, are given in Table 2 for

**Table 1.** Mathematical models and constants during microwave treatment and $X^2$, $R^2$ and RMSE values.

| Model | Equation | Reference | Constant | 300 W | 400 W | 550 W | 700 W | 800 W |
|---|---|---|---|---|---|---|---|---|
| Henderson and Pabis | MR = a exp(-kt) (11) | Pehlivan and Toğrul (2004) | a | 1 | 1.20989 | 1.2055 | 1.21686 | 1.22128 |
| | | | k | 0.00216 | 0.00275 | 0.00364 | 0.00456 | 0.00473 |
| | | | $X^2$ | 0.01504 | 0.01509 | 0.01435 | 0.0178 | 0.01766 |
| | | | $R^2$ | 0.8543 | 0.85262 | 0.84973 | 0.83734 | 0.84045 |
| | | | RMSE | 0.1226 | 0.1229 | 0.1198 | 0.1334 | 0.1329 |
| Newton | MR = exp(-kt) (12) | Ayensu(1997),Sarsavadia et al.(1999) | k | 0.07598 | 0.00211 | 0.00274 | 0.00346 | 0.00357 |
| | | | $X^2$ | 0.02086 | 0.0222 | 0.02159 | 0.02566 | 0.02587 |
| | | | $R^2$ | 0.81197 | 0.77901 | 0.76741 | 0.75771 | 0.75818 |
| | | | RMSE | 0.1437 | 0.149 | 0.1469 | 0.1602 | 0.1608 |
| Page 2 | MR = exp(-(kt)$^n$) (13) | Yaldız and Ertekin (2001) | k | 0.00201 | 0.00258 | 0.00358 | 0.00433 | 0.00448 |
| | | | n | 2.7942 | 2.74957 | 2.8458 | 2.97215 | 2.97763 |
| | | | $X^2$ | 0.00069 | 0.00087 | 0.00044 | 0.0007 | 0.00046 |
| | | | $R^2$ | 0.99333 | 0.99154 | 0.99541 | 0.99357 | 0.99585 |
| | | | RMSE | 0.02625 | 0.02943 | 0.02094 | 0.02652 | 0.02144 |
| Logarithmic | MR = a exp(-kt)+c (14) | Saçılık (2007) | a | 23.13862 | 23.07717 | 22.98717 | 24.26689 | 24.09102 |
| | | | k | 0.00007 | 0.00009 | 0.00012 | 0.00014 | 0.00015 |
| | | | c | -21.97304 | -21.92127 | -21.82380 | -23.09486 | -22.91581 |
| | | | $X^2$ | 0.00423 | 0.00436 | 0.00499 | 0.00583 | 0.00571 |
| | | | $R^2$ | 0.95962 | 0.95827 | 0.94927 | 0.9485 | 0.95022 |
| | | | RMSE | 0.9616 | 0.06428 | 0.06901 | 0.07461 | 0.07376 |
| Two term | MR=a exp(-$k_o$t)+b exp(-$k_1$t) (15) | Madamba et al.(1996) | a | 0.61101 | 0.60488 | 0.60271 | 0.60835 | 0.61056 |
| | | | $k_o$ | 0.00216 | 0.00275 | 0.00364 | 0.00456 | 0.00473 |
| | | | b | 0.61102 | 0.60486 | 0.60271 | 0.60834 | 0.61054 |
| | | | $k_1$ | 0.00216 | 0.00275 | 0.00364 | 0.00456 | 0.00473 |
| | | | $X^2$ | 0.0155 | 0.0157 | 0.01521 | 0.01908 | 0.01897 |
| | | | $R^2$ | 0.8543 | 0.85262 | 0.84973 | 0.83734 | 0.84045 |
| | | | RMSE | 0.1211 | 0.1253 | 0.1233 | 0.1486 | 0.1377 |
| Wang and Singh | MR=1+at+bt$^2$ (16) | Özdemir and Devres (1999) | a | -0.0002096 | -0.00031 | -0.00016 | -0.0002 | -0.00022 |
| | | | b | -1.93E-03 | -3.08E-02 | -7.04E-02 | -0.00001 | -0.00001 |
| | | | $X^2$ | 0.0004 | 0.00031 | 0.0003 | 0.00033 | 0.00064 |
| | | | $R^2$ | 0.9961 | 0.99695 | 0.99691 | 0.99695 | 0.99421 |

**Table 1.** Cont

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | RMSE | 0.02003 | 0.01767 | 0.01718 | 0.01827 | 0.02531 |
| | | | a | 0.89166 | 0.90225 | 1.16118 | 0.92261 | 1.17282 |
| | | Midilli et al.(2002) | k | -0.05845 | -0.05872 | -3.01E-15 | -0.07326 | -3.99E-15 |
| | | | n | 0.41705 | 0.42598 | 1.27E-04 | 0.4277 | 1.25E-04 |
| Midilli et al.(2002) | MR=a exp(-kt$^n$)+bt (17) | | b | -0.00312 | -0.00389 | -0.00275 | -0.00679 | -0.00351 |
| | | | $X^2$ | 0.00095 | 0.00112 | 0.00489 | 0.0015 | 0.00563 |
| | | | $R^2$ | 0.9911 | 0.98944 | 0.98734 | 0.98717 | 0.98823 |
| | | | RMSE | 0.03077 | 0.03354 | 0.03589 | 0.03879 | 0.03744 |
| | | | a | 1.035 | 1.02527 | 1.02796 | 1.02846 | 1.03705 |
| | | | b | -1.69E-03 | -2.79E-03 | -6.34E-02 | -9.11E-02 | -9.36E-02 |
| | | This paper | c | -0.0004134 | -0.0005 | 0.00046 | -0.00056 | -0.0007 |
| Recommendation | MR=a+bt$^2$+ct (18) | | $X^2$ | 0.00026 | 0.00024 | 0.0002 | 0.00023 | 0.00047 |
| | | | $R^2$ | 0.9975 | 0.99772 | 0.99798 | 0.99794 | 0.99588 |
| | | | RMSE | 0.01604 | 0.01541 | 0.0141 | 0.01526 | 0.02172 |

**Table 2** . Physical and mechanical properties of green laird lentil.

| **Physical and mechanical property** | **Moisture content (% d.b.)** | |
|---|---|---|
| | **14.86** | **31.86** |
| Diameter(mm) | 6.52 | 6.73 |
| Thicness (mm) | 2.46 | 2.53 |
| Aritmetic mean diameter(mm) | 5.17 | 5.33 |
| Geometric mean diameter(mm) | 4.75 | 4.85 |
| Bulk density (kgm$^{-3}$) | 616.30 | 654.70 |
| True density (kgm$^{-3}$) | 1203.30 | 1266.10 |
| Thousand mass (g) | 63.85 | 72.05 |
| Sphericity (%) | 0.73 | 0.72 |
| Surface area (mm$^2$) | 0.71 | 0.74 |
| Projected area (mm$^2$) | 0.24 | 0.27 |
| Shelling resistance (kg) | 2.70 | 3.25 |
| Terminal velocity (ms$^{-1}$) | 3.95 | 4.65 |
| Porosity (%) | 48.78 | 48.29 |

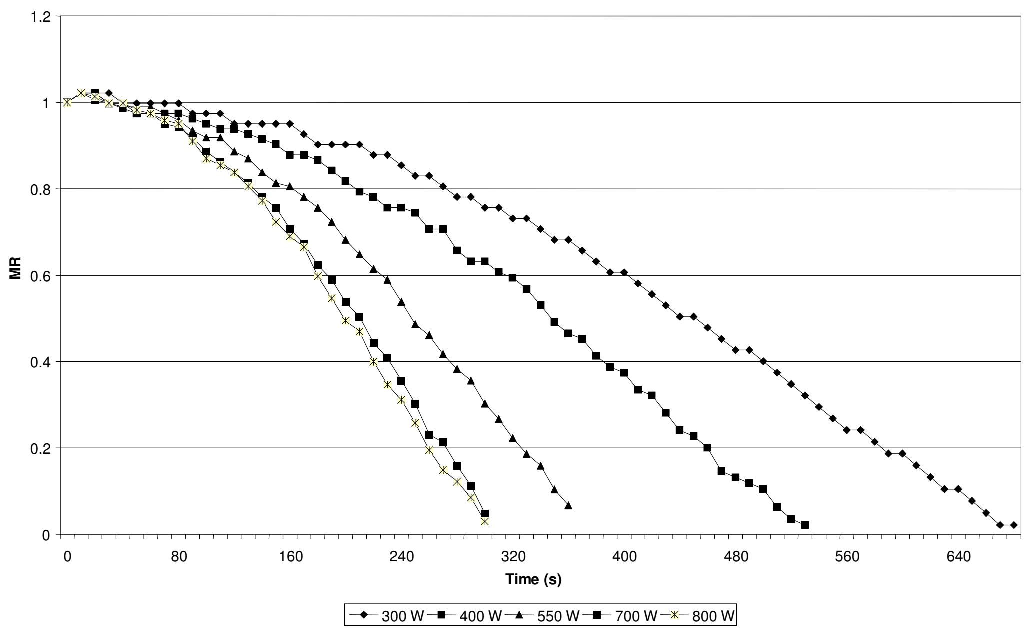


**Figure 1**. Moisture ratio of green laird lentil on 300, 400, 550, 700 and 800 W microwave treatment.

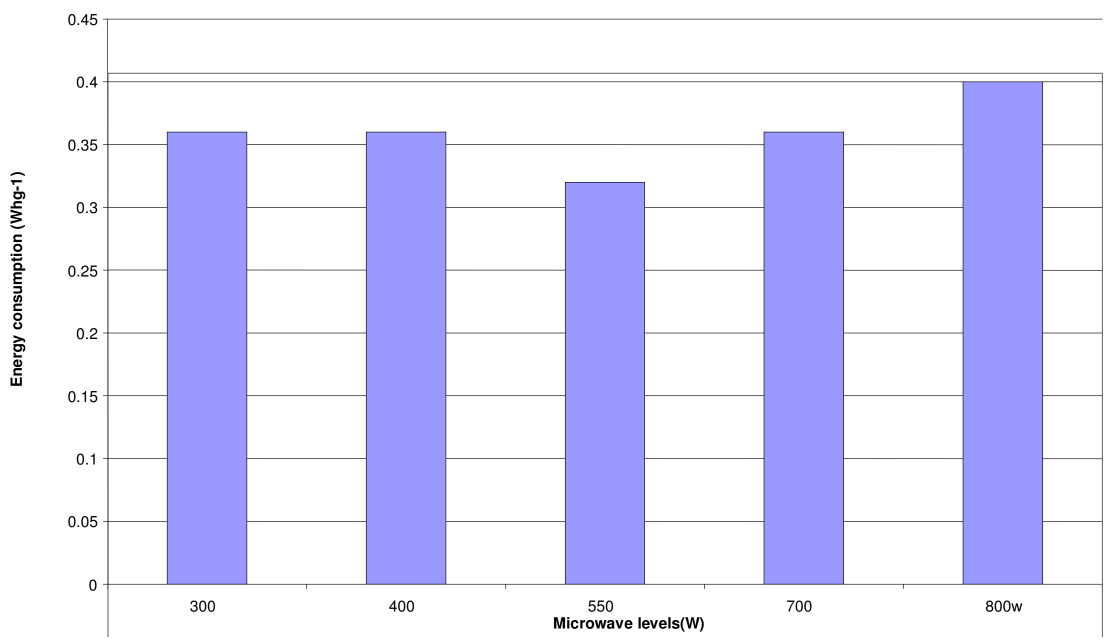


**Figure 2.** Energy consumption of green laird lentil on 300, 400, 550, 700 and 800 W microwave treatment.

two different moisture contents. According to the table, diameter and thickness of the grain decrease as moisture content decreases. This decrease occurred depending on the variation in moisture is seen in arithmetical and geometrical diameter as well as spherical form also. The same affinity is seen between the moisture ratios of 11.36 and 25.08% (Işık and Izli, 2007).

Variations in weight of lentil versus moisture ratio are seen in Table 2. Thousand-grain weight (63.85 to 72.05), bulk density (616.30 to 654.70) and true density (1203.30 to 1266.10), which are especially important in storage of lentil and machinery design, increase depending on the reduction in moisture content (31.86 and 14.02%). Sphericity, surface area and projected area of green laird lentil versus moisture ratio are seen in Table 2. This values are (0.73 to 0.72), (0.71 to 0.74) and (0.24 to 0.27),

**Table 3.** Effect of moisture content on static coefficient of friction of green laird lentil against various surfaces.

| Surface | Moisture content (%d.b.) | |
|---|---|---|
| | 14.86 | 31.86 |
| Stainless steel | 0.40 | 0.46 |
| Rubber | 0.47 | 0.52 |
| Aluminium | 0.40 | 0.45 |
| Galvanised iron | 0.41 | 0.46 |
| Glass | 0.40 | 0.46 |
| MDF | 0.47 | 0.50 |

**Table 4.** Effect of temperature levels on some quality traits in lentil (*Lens culinaris*).

| Microwave level(W) | *Component* | | |
|---|---|---|---|
| | Crude protein content (%) | Crude oil content (%) | Crude ash content (%) |
| 300 | 22.99 | 1.55 $^{b}$ | 2.63 $^{c}$ |
| 400 | 23.55 | 1.62 $^{b}$ | 2.74 $^{ab}$ |
| 550 | 24.93 | 2.06 $^{a}$ | 2.85 $^{a}$ |
| 700 | 23.46 | 1.74 $^{b}$ | 2.80 $^{a}$ |
| 800 | 22.04 | 1.12 $^{c}$ | 2.66 $^{bc}$ |
| Control (24.8%) | 22.64 | 0.80 $^{d}$ | 2.65 $^{bc}$ |
| LSD (0.05) | ns | 0.32 | 0.12 |
| Significance of F-test | ns | ** | ** |

**, F-test significant at p≤0.01; ns, not significant, $^{a,d}$values followed by different letters in same row are significant, P<0.01.

respectively.

The critical rate value, which affects pneumatic transfer, classification by air-flow and cleaning operations, reached 3.95 at moisture content of 14.02% while it was 4.65 at the moisture content of 31.86% db. This value reduced from 25.08 to 11.36% logarithmically (Işık and Izli, 2007). However, porosity, which is an important para-meter in warehouse design, increased depending on the decrease in moisture content while rolling resistance of the lentil grain on steel, rubber, aluminum, stainless steel, glass and MDF reduced depending on the decrease in moisture content (Table 3).

## Crude protein, oil and ash of lentil

Some quality characters of lentil dried under different microwave levels were shown in Table 4. The differences crude oil and ash values between microwave levels have been found to be statistically significant ($p < 0.01$) while it was not significant between crude protein values of lentil. The effects of temperature levels were significant on all attributes, except crude protein content. It was determined that 550 W was suitable for high oil vs. ash ratio. The crude protein ratio of lentil were obtained between 22.04 and 24.93%.

The effects of microwave levels on crude protein content of lentil were found insignificant. In this study, crude protein content showed regular increase from 300 to 550 W (22.99 vs. 24.93%) but tended to lower at treatment 800 W (Table 4). Lentil dried with 550 W had higher crude protein content (24.93%) than other plots which applied different levels.

Crude oil content significantly changed depending on microwave levels. Lentil dried with 550 W produced greatest amount of crude oil content (2.06%) and control plots had the lowest crude oil content (0.80%).

This result shows that the amount of optimum dried microwave level which applied to lentil varies with respect to variety, ecological conditions and dried methods. Microwave levels affected crude ash content of lentil significantly over control. Crude ash content significantly changed depending on the temperature levels like crude oil content. Lentil dried with 550 W had the greatest crude ash content (2.85%) and it was followed by lentil dried with 700 W (2.80%).

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