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Research Article/Araştırma Makalesi

Effect of roasting temperature and time on some physical and sensory properties of roasted chickpea (leblebi), and kinetic studies of the changes in leblebi color

Farklı sıcaklık ve sürelerinin leblebilerin bazı fiziksel ve duyusal özellikleri üzerine etkisi ve leblebi rengindeki değişim kinetiği

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ABSTRACT

The roasted chickpea, which locally called as leblebi, is a widely consumed traditional snack food in Turkey and Middle Eastern countries. Although leblebi is widely consumed, there is limited research on this product except some of its well-known properties. In this study, the change in texture and color of chickpeas during different roasting temperature and duration were determined. Based on preliminary studies, roasting conditions were selected as 150±5 °C, 180±5 °C and 200±5 °C and 4, 6, and 8 minutes. Textural changes were determined by the force deformation curves obtained from compression tests. Statistical analysis of the data indicated that when the roasting temperature and time increased, hardness of leblebi samples was decreased. During roasting process, L* values decreased meanwhile a* and b* values increased. When correlation coefficients (r^2) were taken into consideration, it was found that L* values followed zero-order reaction kinetics and had 36.81 kj/mol activation energy. Also, the a* and b* values resulted in first-order reaction kinetics and had 14.23 kj/mol and 11.21 kj/mol activation energy, respectively. The lowest value of speckling was determined at 150±5°C for 4 minutes, and the highest value was obtained at 200±5 °C for 8 minutes. Color without speckling was found to be significantly increasing when roasting time and temperature were increased. The lowest value of hardness was observed at 200±5 ºC for 8 minutes of roasting.

Key Words: Chickpeas, Leblebi, Roasting, Hardness, Color

ÖZ

Leblebi, nohudun farklı sıcaklıklarda kavrulması ile elde edilen ve çerez olarak tüketilen Türkiye'ye özgü geleneksel ürünlerden bir tanesidir. Leblebi Türkiye'ye özgü olmasına rağmen, leblebi konusunda çalışma/araştırmalar sınırlıdır. Bu araştırmada farklı kavurma sıcaklığında ve sürelerinde işlenen nohutlarda görülen tekstür ve renk değişimleri araştırılmıştır. Kavurma sıcaklık ve süreleri ön denemeler sonucunda 150±5 °C, 180±5 °C ve 200±5 °C; 4, 6, ve 8 dakika olarak tespit edilmiştir. Tekstür değişimi, sıkıştırma testlerinden elde edilen kuvvet deformasyon eğrisi sonucunda elde edilmiştir. İstatistiksel açıdan baktığımızda, farklı kavurma sıcaklık ve süreleri artan leblebilerin sertliği azalmıştır. Kavurma sıcaklık ve süresinin artması ile birlikte leblebilerin L* değerinin azaldığı, a* ve b* değerlerinin ise arttığı gözlenmiştir. L*, a* ve b* parametrelerinin r2 değerleri incelendiğinde; L* parametresinin renk değişim kinetiği sıfırıncı dereceden ve aktivasyon enerjisi 36.81 kj/mol olarak tespit edilmiştir. a* ve b* parametreleri sıfırıncı dereceden ve sırasıyla 14.23 kj/mol ve 11.21 kj/mol aktivasyon enerjilerine sahip olduğu tespit edilmiştir. En düşük beneklilik değeri 150±5 ºC dakika kavrulmuş leblebide belirlenirken, en yüksek değer 200±5 ºC 8 dakika kavrulan leblebilerde tespit edilmiştir. Beneklilik dışı rengin kavurma sıcaklık ve süresinin artması ile önemli düzeyde arttığı belirlenmiştir. En düşük sertlik değeri 200±5 ºC 8 dakika kavrulan leblebilerde ortaya çıkmıştır.

Anahtar Kelimeler: Nohut, Leblebi, Kavurma, Sertlik, Renk.

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Introduction

Chickpea (*Cicer arientinum* L.) is one of the most important legumes, which can grow in dry or semi-dry soil. Chickpeas, a century old food, have important nutritional quality due to their rich protein, carbohydrate, dietary fiber, minerals and vitamin content (Gülümser 1988).

The chickpea is one of the most common legumes in Turkey in terms of growing area (47.1%) and annual production (43.3 %) and nearly 20 % of total chickpeas production is used to produce roasted chickpea (leblebi) (Aydın 2002). Leblebi is the most popular traditional snack, which is consumed in Turkey and Middle Eastern countries (Mrad et al., 2015).

There are many chickpea processing methods in different countries. Chickpea can be consumed as fresh or as processed into different products. Processing methods include soaking, decortication, grinding, sprouting, fermentation, boiling, mashing, roasting, parching, frying and steam treatment (Deshpande & Damodaran, 1990). Roasting is a worldwide known and used technique that significantly increases the palatability of chickpea by improving its flavor, texture, appearance and color (Özdemir & Devres, 2000; Yıldırım et al., 2012; Mrad et al., 2015).

Chickpeas should meet some quality criteria in order to be processed. These quality criteria include shape, size, color and harvesting time and the shape, size and color of chickpeas change according to chickpea type. For leblebi processing, large-seeded, round and smooth surfaced chickpeas are preferred and the chickpeas' hull should be easily removable from kernels during leblebi production. Harvesting time affects the tempering (preheating and resting) process of chickpea and therefore the quality of the final product. Cleaning and sorting of chickpea (>6 mm radius) are important stages at leblebi production. In order to improve the quality and increase the yield, undeveloped, damaged, shrunken and broken chickpea seeds are removed during cleaning process (Gençkan, 1958; Tekeli, 1965; Bilgir, 1976; Chavan, 1983; Gülümser, 1988; Coşkuner & Karababa, 2004).

Chickpeas hard texture requires severe thermal processing conditions that can damage the nutritional quality and organoleptic properties like color. Cleaned chickpeas are subjected to heat in several stages until the final product is obtained. Following the heat treatment, water is added to increase the moisture content. Chickpeas are rested prior to roasting process due to changes in the physical properties of the chickpea (Bilgir, 1976; Köksel et al., 1998; Coşkuner & Karababa, 2004; Mrad et al., 2015; Sağlam & Seydim, 2017). These physical changes can be defined as the separation of husks, the decrease in moisture content and in hardness, turning yellow, and the chalky appearance.

Today, large-scale industrial production of leblebi is not present. Small-scale manufacturers generally produce it by using traditional methods like "single roasted leblebi". Final roasted chickpea product (Roasted Chickpeas, Sarı Leblebi) is obtained when "single roasted leblebi" is roasted one more time. Roasted chickpeas have bright yellow color, large, soft structure, non-adherent to teeth and have specific flavor. There should not be burnt smell in roasted chickpeas and not have too much black specks (Gülümser, 1998; Aydın, 2002).

Color is one of the most important parameters due to its influence on consumer's acceptance and controlling the process of roasted chickpea (Maskan, 2001; Kahyaoğlu & Kaya, 2006). Roasting process is followed up by the amount of specks. The color and specks on chickpeas are observed in order to decide the roasting degree of the chickpeas.

Browning reactions in food systems are explained by different kinetic models. There are many studies about color kinetic of foods (Avila & Silva, 1999; Özdemir & Devres, 2000; Maskan, 2001; Demir et al., 2002) however; there are not many studies about the color of roasted chickpeas.

Although browning reactions are complex reactions, they are important criterias in "kinetic modelling". In order to follow up the process, the modelling of kinetic parameters (reaction order, reaction rate constant, and activation energy) is necessary (Kahyaoğlu & Kaya, 2006).

The first necessary parameter for describing a kinetic model is the assignment of the reaction degree. Although, generally, it is assumed that reactions in foods are between zero and third order; non enzymatic browning reactions are assumed as zero or first–order reactions (Equation 1, 2). In some studies, reaction kinetic of color change has been calculated as zero order (Rapusas & Driscoll, 1995; Bhattacharya, 1996; Bozkurt et al., 1998; Özdemir & Devres, 2000) or first order (Shin & Bhowmilk, 1995; Maskan, 2001; Demir et al., 2002; Yıldırım et al., 2012) or defined with a different reaction model (Avila & Silva, 1999; Garza et al., 1999; Ibarz et al., 1999; Özdemir, 2001; Demir et al., 2002; Kahyaoğlu & Kaya, 2006). In addition, the Arrhenius relation in the reaction is affected by the temperature (Equation 3) (Labuza, 1982; Özdemir, 2001). Generally, quality reducing non-enzymatic browning reactions is zero-order but oxidative color degradation is a first order reaction (Göğüş et al., 1998; Cemeroğlu, 2005).

$$C=C_0-kt \quad (1)$$

$$C=C_0\exp(-kt) \quad (2)$$

$$k = k_o e^{\frac{-E_a}{RT}} \quad (3)$$

Where;

C: Color dimension after roasting

C_0: Color dimensions before roasting

k: Reaction rate constant (s^{-1})

t: Time (min)

E_a: Activation energy (kg/mol)

T: Temperature (K, kelvin)

R: Universal gas constant (8.314 $jmol^{-1}K^{-1}$)

Since the temperature affects the reaction kinetics, this effect of temperature can be explained by activation energy. Activation energy of a reaction shows the degree of change on the reaction rate depending on the temperature. In other words, E_a is the minimum energy level for the reaction. If the activation energy is high, that means the reaction is sensitive to temperature changes (Cemeroğlu, 2005).

Number of studies about the physical changes during the processing of roasted chickpea is limited and there are not any studies about the roasting time and temperature, which affect the quality of chickpea.

The aim of this study to determine the textural and color changes of leblebi samples that was roasted at different temperatures for different durations. There aren't any studies about the color change kinetics of leblebi, so in this study the kinetics of color change during leblebi production was examined.

Materials and Method

Material

"Single roasted chickpea" samples were obtained from "EROĞLU Leblebi Production Company" (Tavşanlı, Kütahya). In leblebi production, all companies have their own special processing technique. Single roasted chickpeas that was used in this study was produced with the following procedure: Following the cleaning process, chickpeas with a diameter bigger than 9.5 mm were separated with sieving, than subjected to thermal treatment in several stages. First, second and third heat treatments were performed at around 150 °C for 30, 20 and 10 minutes, respectively. The chickpeas were allowed to rest for 24 hours following the first and second heat treatments and 2 months following the third treatment. After this procedure, water was added to increase the moisture content approximately to 10 % and heated so their husks are easily separated from cotyledons. This product is called "single roasted chickpea" and has the characteristics of 482.96 gr a thousand seed weight, 58.93 N stiffness at suture direction, 67.74 N stiffness at cheek direction and 83.23 L*, 3.09 a* and 29.42 b* color values. Single roasted chickpea samples were stored in the polyethylene bag until second roasting process.

Method

Roasting Procedure

Roasting temperatures and time durations were selected as 150±5 °C, 180±5 °C and 200±5 °C and 4, 6 and 8 minutes respectively, based on preliminary studies. Prior to roasting process of “single roasted chickpea”, moisturizing is necessary. Moisture content of the single roasted chickpea was adjusted to 8% by water addition then roasting process was applied at predetermined temperatures and durations. After the roasting process, chickpeas were left to cool at room temperature, than stored in vacuum packages until to the analysis.

Texture Measurements

The textural analysis of the chickpea samples were performed using a LF*Plus* Universal Test Analyzer (Lloyd Insruments, England) with Nexygen Mt. analyzer software. In order to deform and test at least 80 % of the roasted chickpea, a load cell of 100 N with the speed of 1 mm/s was used. The stiffness of roasted chickpea was determined in terms of Newton and ten measurements were taken. During hardness measurements, cheek and suture direction hardnesses were taken into account as shown in Figure 1.

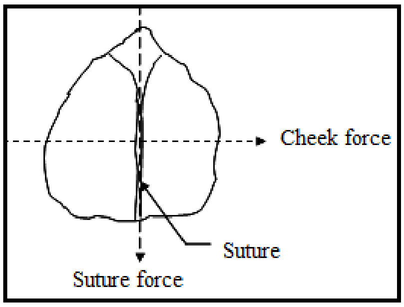

Figure 1. Suture and Cheek Direction of Roasted Chickpea

Şekil 1. Leblebinin Sütür ve Yanak Yönü

Color Measurements

The color of the roasted chickpeas was measured by using a Minolta Chromameter (CR-400) (measuring head (CR-A33f) has an 8 mm diameter measuring area). Prior to color measurement, chickpeas were grinded in a coffee grinder. Five color measurements were taken for each sample, which have different roasting temperature and durations. L*, a* and b* values were determined with these measurements; where L* value is related with the degree of lightness, a-value represents the green-red spectrum (-60 (green) and + 60 (red)), and b* value represents the blue-yellow spectrum (-60 (blue) and +60 (yellow)). Total color change (ΔE) is also used to estimate the total color change during roasting as shown in Eq. 4 (Kaur et al., 2005).

$$\Delta E = [(L^*-L^*_{ref})^2 + (a^*-a^*_{ref})^2 + (b^*-b^*_{ref})^2]^{½} \quad (4)$$

Where;

L*, a* and b*: Color dimensions

ΔE: Total color change

L^*_{ref}, a^*_{ref} and b^*_{ref}: Reference color dimensions

Kinetic model and activation energy was calculated as shown in Equation 1-3.

Sensory Analysis of Roasted Chickpea

“Descriptive Analysis Method” was used for the sensory analysis of roasted chickpea. In order to decide the descriptive parameters of roasted chickpea samples obtained from different markets, 23 panelists were educated. The goal of the education was to introduce the used material in the applications and to form the descriptive parameters. After the education, the roasted chickpea samples from market were placed in special rooms and were served with salted cracker and water to panelists. The analysis was carried out in duplicate for each sample. During the sensory analysis, the panelists who couldn’t determine the differences between the samples in preliminary analysis were excluded from the analysis. Descriptive Analysis Method is a detailed method compared to other analysis methods. In this method descriptive parameters: speckling, color without speckling and hardness were determined by the panelists and these parameters were used for sampling distribution. This method also makes possible to compare the results obtained by sensory analysis and devices.

Statistical Analysis

Analysis of variance with General Linear Model (GLM) was used for statistical analysis to determine the effect of temperature and duration on the stiffness and color of the roasted chickpea samples. Differences between means were compared for significance using the Duncan's test. The statistical analysis was carried out in three replicates using three batches of single roasted leblebi samples (single roasted chickpea). The textural and color measurements for each sample were taken ten and five times respectively.

Results and Discussion

Texture

Statistical analysis indicated that hardness from cheek angle of the single roasted chickpea was statistically greater than the twice roasted chickpea (leblebi). Where the hardness value of single roasted chickpea was 67.74 N, the hardness parameters of twice roasted chickpeas were varied between 59.30-53.41 N due to the applied temperature and duration of the roasting process. According to the obtained results, the chickpea, which was roasted for 8 minutes at 200±5 °C, has the minimum level of the hardness with the value of 53.41 N (Table 1).

Table 1. Hardness of The Chickpeas and Leblebi from Cheek Angle
Tablo 1. Nohut ve Leblebinin Yanak Açısından Sertliği

Sample *Numune* Temperature *Sıcaklık*	Time (Minute) Süre (dakika)	Force (N) *Kuvvet (N)*
150±5˚C	4	59,30±3,56
	6	56,80±1,80
	8	54,06±1,51
180±5 ˚C	4	58,89±5,31
	6	56,10±3,88
	8	54,17±3,36
200±5 ˚C	4	57,14±0,61
	6	56,65±4,93
	8	53,41±2,78
Single Roasted Chickpea *Tek Kavrulmuş Nohut*		67,74±0,42

It can be seen that cheek angle hardness value of the chickpeas roasted at 150±5°C and 180±5 °C were decreased in a similar manner as in the roasting time. Although there was not an important difference in hardness values of the chickpeas that were roasted for 4 and 6 minutes at 200±5 °C, the hardness value of single roasted chickpea at the same temperature for 8 minutes has seen a dramatical decrease. It was seen that the temperature 200±5 °C was the most effective temperature for 4 minutes of processing time; 180±5 °C temperature was effective with 6 minutes processing time. 200±5 °C temperature with 8 minutes of processing time was found to be the most effective method to decrease the hardness of the chickpea.

The hardness of the chickpea from suture angle was decreased with increasing roasting temperature. The hardness value of single roasted chickpea was found as 58.93 N, the hardness values of chickpeas were determined as 51.89 N, 49.98 N and 48.22 N where the processing conditions were 150±5°C for 8 minutes, 180±5 °C for 8 minutes and 200±5 °C for 8 minutes, respectively (Table 2).

Table 2. Hardness of The Chickpeas from Suture Angle
Tablo 2. Nohut ve Leblebilerin Sütür Açısından Sertliği

Sample *Numune* Temperature *Sıcaklık*	Time (Minute) *Süre (Dakika)*	Force (N) *Kuvvet (N)*
150±5˚C	4	56,88±8,32
	6	53,36±2,82
	8	51,89±3,31
180±5 ˚C	4	51,82±0,86
	6	50,06±3,94
	8	49,98±2,61
200±5 ˚C	4	51,38±1,19
	6	52,63±3,80
	8	48,22±4,09
Single roasted chickpea *Tek Kavrulmuş Nohut*		58,93±1,77

As shown in Table 2, the hardness of chickpea processed at 200±5 °C for 6 minutes was greater compared to 4 minutes of roasting process but at the same processing temperature the hardness value was smaller for 8 minutes of roasting process. The minimum hardness of the chickpeas from suture angle was reached with the value of 48.22 N. The suture hardness value of chickpeas roasted at 180±5 and 200±5 °C for 4 minutes were obtained as 51 N whereas the same value for chickpea processed at 150±5 °C was obtained as 57 N approximately. Although the hardness values were decreased similarly in 150±5 °C and 180±5 °C processing temperatures, it was determined that the minimum value of hardness was reached in the samples processed at 200±5 °C for 6 and 8 minutes.

According to the obtained results, when the roasting temperature and time were increased, hardness of leblebi samples from suture and cheek angle were decreased (Figure 1). Since the roasting process decreases the stiffness of chickpea, it becomes possible to consume it as a snack. Stiffness from suture angle was less than cheek angle results because of the physical structure of the chickpea. Having two cotyledons leads to an easy separation of chickpeas. This feature is also the reason for random decrease of stiffness. The minimum value of suture and cheek hardness was obtained at the samples roasted at 200±5 °C for 8 minutes.

In previous studies which compare the chickpeas with roasted chickpeas, it has been found that the roasting process leads to softening the chickpea, so making it possible to be consumed (Köksel et al., 1998; Kaur et al., 2005). Also according to some other studies, with the roasting process, the structure of the hazelnuts was developed, the cell wall of hazelnuts was broken to some extent and the hazelnuts swelled. Structure of the hazelnuts affects the texture, so when they increased in volume, crispness and crackling properties of the products were increased (Saklar et al., 2003). Studies on hazelnut have shown that the roasting temperature and duration change the structure of hazelnuts (Demir & Cronin, 2004; 2005).

Color Analysis

The L*, a* and b* values of roasted chickpeas at different processing temperature and durations were tabulated in Table 3. The statistical analysis indicated that the process temperature and duration significantly ($p<0.05$) affected the color values of roasted chickpeas.

When the L* value 83.23 was determined for single roasted chickpea, this value dramatically decreased with the increase in roasting temperature and time. L* values ranged from 82.51 to 64.59. The value of 82.51 was obtained at 150 °C for 4 minutes processing, the value of 64.59 was obtained at 200 °C for 8 minutes processing (Table 3).

Table 3. The Color Analysis Results of The Samples
Tablo 3. Numunelerin Renk Analizi Sonuçları

Temperature (˚C) *Sıcaklık (˚C)*	L*			a*			b*		
	4 minute *4 dakika*	6 minute *6 dakika*	8 minute *8 dakika*	4 minute *4 dakika*	6 minute *6 dakika*	8 minute *8 dakika*	4 minute *4 dakika*	6 minute *6 dakika*	8 minute *8 dakika*
150±5	82,51 ±0,71 ^{a,x}	80,68 ±0,60 ^{a,x}	77,57 ±2,2^{b,x}	3,13 ±0,30^{a,x}	3,99 ±0,18^{a,x}	5,97 ±1,21 ^{b,x}	28,58 ±0,88^{a,x}	29,6 ±0,75 ^{b,x}	31,09 ±0,89 ^{c,x}
180±5	82,04 ±0,65^{a,x}	78,32 ±3,35 ^{b,y}	71,14 ±2,00^{c,y}	3,44 ±0,34 ^{a,x,y}	5,30 ±1,63^{b,y}	9,0 5±0,96^{c,y}	29,57 ±0,60 ^{a,y}	31,1 ±1,13 ^{b,y}	33,07 ±0,86^{c,y}
200±5	79,26 ±2,45 ^{a,y}	75,52 ±3,18 ^{b,z}	64,59 ±8,31 ^{c,z}	4,15 ±0,58 ^{a,y}	6,87 ±1,41 ^{b,z}	10,9 ±2,79^{c,z}	29,21 ±0,97 ^{a,x,y}	31,3 ±0,80 ^{b,y}	32,80 ±1,08^{b,x}

$^{a-c}$ significant differences in the lines ($p <0.05$)
$^{a-c}$ *satırlardaki önemli farklılıklar($p <0.05$)*
$^{x-z}$ significant differences in the columns ($p<0.05$)
$^{x-z}$ *sütundaki önemli farklılıklar($p <0.05$)*

L* values showed in Table 3. Although there was not an important difference between L* values of chickpeas roasted at 150±5 °C and 180±5 °C for 4 minutes, the value at 200±5 °C for 4 minutes was significantly different. The L* values were different for the samples roasted at different temperature for 6 and 8 minutes. Therefore L* values and roasting time were inversely proportional.

Similar results were observed in the comparison of chickpea and roasted chickpea (Köksel et al., 1998; Mrab et al., 2015) and hazelnuts (Fallico et al., 2003; Özdemir and Devres, 2000; Saklar et al., 2001). In a study of L*, a* and b* values of roasted hazelnuts, it was observed that the most sensitive parameter was the L* value (Demir et al., 2002).

Where the a* value of single roasted chickpea was 3.09, a* values were observed to be significantly increased at different temperatures. Although the a* value was 3.13 for the samples processed at 150±5 ºC for 4 minutes, this value was observed as 3.99 for 6 minutes and 5.97 for 8 minutes at the same temperature. There was not a significant difference between 4 and 6 minutes of roasting process at 150±5 ºC whereas there was a significant increase for 8 minutes of processing duration ($p<0.05$). At 180±5 °C and 200±5 °C, it was observed that the roasting time affected the a* value. There were not important changes in a* values. For the roasting processes of 150±5 °C, 180±5 °C and 200±5 °C for 4 minutes, the a* values were obtained as 3.13, 3.44, and 4.15 respectively. When the roasting temperature was changed for the 6 and 8 minutes of processing times, there was a significant increase in a* values ($p<0.05$). It was concluded that the a* values were ranged from 3.13 to 10.9. The 3.13 value was determined at 150±5 °C for 4 minutes of processing and the 10.9 value was obtained at 200±5 °C for 8 minutes of processing (Table 3).

Similar results for a* values were observed in the comparison of chickpea and roasted chickpea (Köksel et al., 1998; Mrab et al., 2015) and at roasted hazelnuts (Fallico et al., 2003; Özdemir & Devres, 2000; Saklar et al., 2001).

When the statistical analysis of b* value was evaluated, it was seen that the b* value was increased with increasing roasting temperature. When the b* value of single roasted chickpea was 29.42, this value was 32.8 at 200±5 °C for 8 minutes of processing. The b* value was 28.58 at 150±5 ºC for 4 minutes of processing, it increased to 31.06 at the same temperature for 8 minutes of processing. Roasting temperature and time significantly ($p<0.05$) affected the b* values of roasted chickpeas. The b* values ranged from 28.58 to 33.07. The minimum value was observed at 150 °C for 4 minutes, and the maximum value was observed at 180 °C for 8 minutes of processing (Table 3).

Similar results were observed in the comparison chickpea and roasted chickpea (Köksel et al., 1998; Mrab et al., 2015) and at roasted hazelnuts (Fallico et al., 2003; Saklar et al., 2001). However different results were obtained at roasted hazelnuts (Özdemir & Devres, 2000) where b* values of roasted hazelnuts didn't increase.

Total color changes (ΔE) were calculated with Equation 4. The ΔE value at 150±5 ºC for 4 minutes of processing was obtained as 1.11, at 180±5 ºC for 4 minutes was obtained as 1.25, and at 200±5 °C for the same duration, was obtained as 4.11. There was no significant change in ΔE value at 150±5 ºC and 180±5 ºC for 4 minutes of processing. The minimum value of ΔE (1.11) was obtained at 150±5 ºC for 4 minutes and the maximum value of ΔE (20.49) was obtained at 200±5 °C for 8 minutes of processing (Table 4). When chickpea was roasted at different temperature and duration, ΔE values changed significantly ($p<0.05$). As a result, the ΔE values of roasted chickpeas increased when temperature and time increased.

Table 4. Total Color Changes of Roasted Chickpeas
Tablo 4. Leblebilerin Toplam Renk Değişimleri

Temperature *Sıcaklık*	ΔE		
	4 minute *4 dakika*	6 minute *6 dakika*	8 minute *8 dakika*
150±5˚C	1.11	2.71	6.57
180±5˚C	1.25	5.64	13.96
200±5˚C	4.11	8.79	20.49

Köksel et al., (1998) compared chickpeas and roasted chickpeas and found significant ($p<0.05$) color differences in the results of non-enyzmatic reactions. Roasted chickpeas are more attractive than chickpea due to high a* and b* values.

Kinetic Model and Activation Energy

The zero (0°) and first (1°) order equations were applied to the experimental results of L*, a* and b* values in order to determine the model of kinetic of color change during roasting process. The results were tabulated in Table 5. It can be seen that the values of L* for zero order regression results (r^2) was determined in the range of 0.9259-0.9781; and for the first order, it was in the range of 0.9151-0.9757. Since the L* value parameter for zero order was greater than the others; the model of L* parameters was accepted as zero order. While zero order of a* value was in the range of 0.9507-0.9876, first order of a* value was in the range of 0.9799-0.9994. These results show that it is possible to use zero or first order model to describe a* values but for better precisions the first order model was preferred. Zero order of b* value was in the range of 0.9884-0.9911, the first order of b* value was in the range of 0.9878-0.9968. These results show that it is possible to use the zero and first order of b* value but for better precisions model of b* value was taken as first order (Table 5). In conclusion the model of L* value was accepted as zero order, the model of a* and b* values were accepted as first-order.

Table 5. Kinetic Model of Color Changes
Tablo 5. Renk Değişiminin Kinetik Modeli

Model *Model*	Criteria *Kriter*	Roasting Temperature (°C) *Kavurma Sıcaklığı (°C)*								
		L*			a*			b*		
		150	180	200	150	180	200	150	180	200
Zero order	k	1.235	2.725	3.6675	1.6875	1.4025	0.71	1.255	1.75	1.795
	r^2	0.9781	0.9675	0.9259	0.9507	0.9635	0.9876	0.9884	0.9948	0.9911
First order	k	0.0154	0.0356	0.0512	0.1614	0.2418	0.2414	0.021	0.028	0.029
	r^2	0.9757	0.961	0.9151	0.9799	0.9962	0.9994	0.9908	0.9968	0.9878

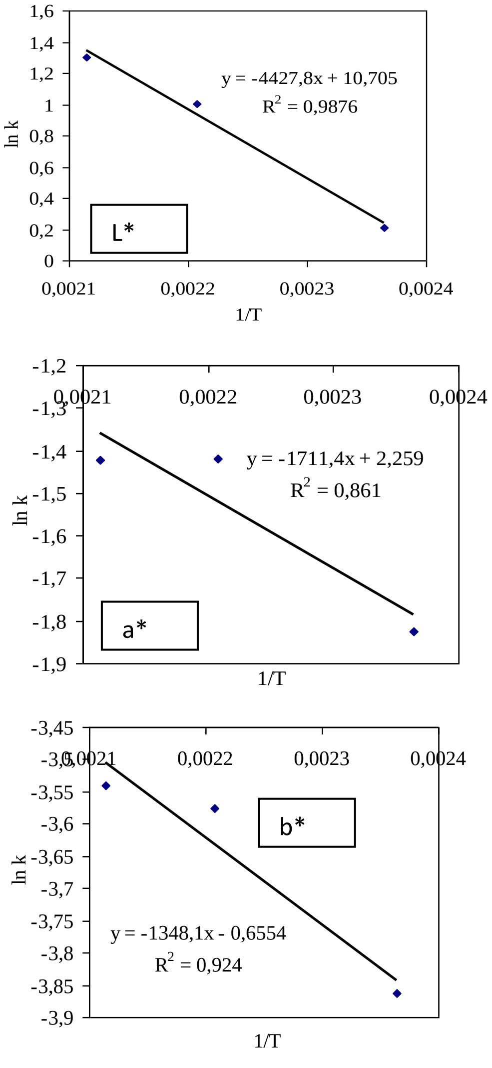

Figure 2. Calculation of Activation Energy
Şekil 2. Aktivasyon Enerjisinin Hesaplanması

Kinetic model of color change can be considered as zero or first order but there were some other studies about different kinetic models (Avila & Silva, 1999; Demir et al.,, 2002; Garza et al., 1999; Ibarz et al., 1999; Kahyaoğlu & Kaya, 2006).

Activation energy of L*, a* and b* values calculated as 36.81 kj mol^{-1}, 14.23 kj mol^{-1} and 11.21 kj mol^{-1}, respectively (Figure 2).

Activation energies of color changes ranged between 41-125 kj mol^{-1} (Cemeroğlu, 2005; Saguy & Karel, 1980) but the activation energies of L*, a* and b* values were determined to be smaller than these values. Reason of this might be due to high temperature during roasting, roasting apparatus and product difference.

The Results of Sensory Analysis

The results of the sensory analysis and statistical evaluation was done according to the answers given by the panelists with descriptive words such as speckling, color without speckling and hardness that were on the sensory evaluation form (Table 6).

The term "speckling" was used to define black speckles that were formed by double roasting of leblebi. The color without speckling as the part of the above-mentioned except for the coloration of leblebi's bright yellow (Figure 3). The hardness feature of roasted chickpea was determined by panelists according to its resistance against biting during sensory evaluation.

Table 6. Speckling, color without speckling and hardness of roasted chickpea
Tablo 6. Leblebinin beneklilik, beneklilik harici kalan renk ve sertliği

Temperature *Sıcaklık*	Time (Minute) *Süre (Dakika)*	Speckling *Beneklilik*	Color without speckling *Beneklilik harici kalan renk*	Hardness *Sertlik*
150±5˚C	4	2,13±1,00	10,90±0,84	8,89±0,54
	6	3,24±1,56	9,68±1,19	7,59±0,41
	8	5,42±2,08	7,77±2,28	6,51±0,83
180±5˚C	4	2,34±0,38	10,93±0,49	7,45±0,50
	6	6,03±3,39	8,12±2,79	6,44±0,42
	8	9,25±0,86	5,13±1,21	6,03±0,74
200±5˚C	4	7,31±3,41	6,23±3,24	6,57±0,36
	6	8,33±2,73	5,88±2,67	6,42±0,68
	8	11,07±2,98	4,07±3,64	5,81±0,61
Single roasted Chickpea *Tek kavrulmuş leblebi*		0,44±0,02	13,33±0,67	11,90±0,46

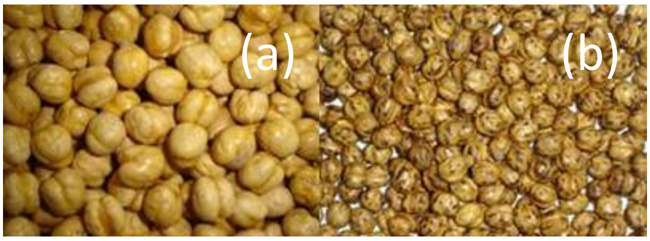

Figure 3. a. Single Roasted Chickpea, b. Speckling and Color Without Speckling of Roasted Chickpea
Şekil 3. a. Tek Kavrulmuş Nohut, b. Leblebinin Beneklilik Durumu

Speckling

The speckling properties of roasted chickpea were observed at the end of the roasting processes at different temperatures and durations. Also, when roasting temperature was increased without increasing the duration or when roasting duration was increased without increasing the temperature, significant changes were observed in the speckling color of roasted chickpea ($p<0.001$). According to the answers given by panelists, it was determined that the speckling value of single roasted chickpea was 0.44. The speckling values of roasted chickpea at different temperatures and durations were obtained between 2.13 and 11.07. The lowest value of speckling was determined in the chickpea sample which was roasted at 150±5°C for 4 minutes, and the highest value was obtained at 200±5 °C for 8 minutes of processing (Table 6).

Color without speckling

Color without speckling was found to be significantly ($p<0.0001$) increasing when roasting time and temperature were increased. It was in the range of 4.07-10.93. The color value without speckling of single roasted chickpea was 13.33, whereas 4.07 at 200±5 °C for 8 minutes of roasting process and 10.93 at 180±5˚C for 4 minutes of roasting process (Table 6).

Hardness

According to the results of sensory analysis, as the roasting temperature increased, the hardness value of the samples decreased. Hardness of single roasted chickpea was determined to be higher than the chickpea samples which were roasted at 150±5 ºC, 180±5 ºC and 200±5 ºC. The value of hardness of single roasted chickpea was determined as 11.90 whereas the hardness of leblebi was ranged from 5.81 to 8.89. The lowest value of hardness was observed at 200±5 ºC for 8 minutes of roasting (Table 6).

By comparing the results of sensory analysis and instrumental analysis, it was found that processing temperature and time affected the chickpea hardness. Our results comply with the results obtained by Szczesniak (2002).

Conclusions

Roasted chickpea is a country-specific snack obtained by roasting chickpeas in different temperatures. During leblebi production, after many heat treatments and resting phases, chickpea becomes single roasted chickpea. The products sold in markets as “leblebi” are double-roasted chickpeas. During the double roasting process by means of the roasting systems, chickpeas are subjected to second heat treatment and therefore chickpea develops in taste, odor and color characteristics.

With increasing roasting temperature and time, it was observed that the L* values of the leblebi's decreased and a* and b* values increased. The color change kinetic model of the L* parameter was determined at zero order and the activation energy was found as 36.81 kJ / mol. The a* and b* values had an activation energy of 14.23 kJ/mol and 11.21 kJ/mol, respectively. The low activation energy values of L*, a* and b* values were due to high temperature application, heating profile and raw material type.

For the hardness analysis, the samples were tested from two different angles, from cheek and suture angle. The results showed that the hardness values obtained from the cheek angle were higher than the corresponding values of the suture angle. The reason of this situation was due to the physical structure of chickpea.

The reason of reducing in the hardness chickpea during roasting process due to the air gaps in the samples. In the second roasting process, the water in the chickpeas evaporated therefore the water vapor pressure increased. During the process, the water in the starch evaporates, hence the porous structure forms. So leblebi reaches to a consumable hardness.

Our study indicates that the temperature and duration of roasting process are the most important steps of roasting process. It was concluded that the increase in temperature and duration of processing leads to increase of chickpea attractiveness and consumer acceptance.

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Conflict of Interest: The authors declare that they have no conflict of interest.

References

Avila, I.M.L.B., & Silva, C.M.L. (1999). Modelling Kinetics of thermal degradation of colour in peach puree. *Journal of Food Engineering*, 39, 161-166.

Aydın, F. (2002). Nohudun Kullanımı ve Leblebi Üretimi. Hububat Ürünleri Teknolojisi Kongre ve Sergisi. Gaziantep.

Bhattacharya, S. (1996). Kinetics on color changes in rice due to parboiling. *Journal of Food Engineering*, 29, 99-106.

Bilgir, B. (1976). Türk Leblebilerinin Yapılışı ve Bileşimi Üzerinde Araştırmalar. Ege Üniversitesi Ziraat Fakültesi Yayınlar No: 232. Ege Üniversitesi Matbaası. Bornova, İzmir.

Bozkurt, H., Göğüş, F., & Eren, S. (1998). Pekmezde Maillard Esmerleşme Reaksiyonlarının Kinetik Modellemesi. *Tr. J. of Engineering and Environmental Science*, 22, 455-460.

Cemeroğlu, B. (2005). Gıda Mühendisliğinde Temel İşlemler. Gıda Teknolojisi Derneği Yayınları No: 29. Ankara Üniversitesi, Mühendislik Fakültesi, Gıda Mühendisliği Bölümü. Ankara.

Chavan, J., K., Jawele, H., K., Shore, D., M., Jadhav, S., J., & Kadam, S., S. (1983). Effect of presoaking treatments on the cooking quality of legume dhals. *Indian Food Packer*, 37, 78-81.

Coşkuner, Y., & Karababa, E. (2004). Leblebi: a Roasted Chickpea Product as a Traditional Turkish Snack Food. *Food Reviews International*, 20, 3, 257-274.

Demir, A., D., Celayeta, J., M., F., Cronin., K., & Abodayeh, K. (2002). Modelling of the kinetics of colour change in hazelnuts during air roasting. *Journal of Food Engineering*, 55, 283-292.

Demir, A., D., & Cronin, K. (2004). Modelling the kinetics of textural changes in hazelnuts during roasting. *Simulation Modelling Practice and Theory*, 13, 97-107.

Demir, A., D., & Cronin, K. (2005). The thermal kinetics of texture change and the analysis of texture variability for raw and roasted hazelnuts. *International Journal of Food Science and Technology*, 39, 371-383.

Deshpande, S., S., & Damodaran, S. (1990). Food legumes: chemistry and technology. In: Pomeranz. Y., ed. Advanced in Cereal Science and Technology, Vol. X. St. Paul, MN: *American Association of Cereal Chemists*, 147-241.

Fallico, B., Arena, E., & Zappala, M. (2003). Roasting of hazelnuts. Role of oil in colour development and hydroxymethyfurfural formation. *Food Chemistry*, 81, 569-573.

Garza, S., Ibarz, A., Pagan, J., & Giner, J. (1999). Non-enzymatic browning in peach puree during heating. *Food Research International*, 32, 335-343.

Gençkan, S. (1958). Türkiye'nin Önemli Nohut Çeşitlerinin Başlıca Vasıfları Üzerinde Araştırmalar. Ege Üniversitesi Ziraat Fakültesi Yayınları:1. Ege Üniversitesi Matbaası. Izmir.

Göğüş, F., Wedzicha, B., & Lamb, J. (1998). Modelling of Maillard reaction during drying of a model matrix. *Journal of Food Engineering*, 35, 445-458.

Gülümser, A. (1988). Nohutun hasattan sonra değerlendirilmesi ve leblebi yapımı. Ondokuz Mayıs

Üniversitesi, Ziraat Fakültesi Dergisi, 3 (2), 251-260.

Ibarz, A., Pagan, J., & Garza, S. (1999). Kinetics model for colour changes in pear puree during heatng at relatively high temperatures. *Journal of Food Engineering*, 39, 415-422.

Kahyaoğlu, T., & Kaya, S. (2006). Modelling of moisture, color and texture change in susame seeds during the conventional roasting. *Journal of Food Engineering*, Volume 75, Issue 2, Pages 167-177.

Kaur, M., Singh, N., & Sodhi, N.S. (2005). Physicochemical, cooking, textural and roasting characteristics of chickpea (*Cicer arietinum* L.) cultivars. *Journal of Food Engineering*, 69, 511-517.

Köksel, H.; Sivri, D.; Scanlon, M., G., & Bushuk, W. (1998). Comparison of physical properties of raw and roasted chickpea (leblebi). *Food Research International*, Vol. 31, No: 9, pp. 659-665.

Labuza, P., P. (1982). Shelf Life Dating of Foods. ISBN 0-917-678-14-1. Minnesota.

Maskan, M. (2001). Kinetics of colour changes of kiwifruits during hot air and microwave drying. *Journal of Food Engineering*, 48, 169-175.

Mrad, R., Assy, P., Maroun, R.G., & Louka, N. (2015). Multiple optimization of polyphenols content, texture and color of roasted chickpea pre-treated by IVDV using response surface methodology. *LWT-Food Science and Technology*, 62, 532-540

Özdemir, M., & Devres, O. (2000). Kinetics of color changes of hazelnuts during roasting. *Journal of Food Engineering*, 44, 31-38.

Özdemir, M. (2001). Mathematical Analysis of color changes and chemical Parameters of roasted hazelnuts. Doktora Tezi. Istanbul Technical University, İstanbul.

Rapusas, R., S., & Driscoll, R., H. (1995). Kinetics of non-enzmatic browning in onion slices during isothermal heating. *Journal of Food Engineering*, 24, 417-429.

Saguy, I., & Karel M., (1980). Modeling of quality deterioration during food processing and storage. *Food Technology*, 37, 78.

Sağlam, H., & Seydim, A.C., (2017). Leblebi Üretiminde İkinci Kavurma Koşullarının Leblebi'nin Fizikokimyasal Özellikleri ve Duyusal Kalitesi Üzerine Etkisi. *Harran Tarım ve Gıda Bilimleri Dergisi*, 21(3):279-292.

Saklar, S., Katnaş, S., & Ungan, S. (2001). Determination of optimum hazelnut roasting conditions. *International Journal of Food Science and Technology*, 36, 271-281.

Saklar, S., Ungan, S., & Katnas, S. (2003). Microstructural changes in hazelnuts during roasting. *Food Research International*, 36, 19-23.

Shin, S., & Bhowmilk, S. (1995). Thermal kinetics of color changes in pea puree. *Journal of Food Engineering*, 24, 77-86.

Szczesniak, A. S. (2002). Texture is a sensory property. *Food Quality and Preference*, 13, 4, 215–225.

Tekeli, S., T. (1965). Ziraat Sanatları. Ankara Üniversitesi Ziraat Fakültesi Yayınları, 237. Yayın No: 77, 477-480.

Yıldırım, A., Bayram, M., & Öner, M. D. (2012). Hydration Kinetics of Ultrasound Treated Chicpeas (*Cider arietinum* L.) During Soaking. *Harran Tarım ve Gıda Bilimleri Dergisi*, Cilt 16, Sayı 4.