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Colour optimisation of ground pistachio during roasting

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RESEARCH PAPER

Abstract

In this research, 'Ahmad Aghaei' pistachio cultivar harvested from Iran in 2011 was supplied by the Pistachio Research Institute. The effect of roasting times (5, 10, 15, 20, 25 and 30 min) and temperatures (120, 130, 140, 150 and 160 °C) on the colour of pistachio nuts was investigated. Initially, the L value (lightness) decreased for all temperatures and then increased for 120 and 130 °C with increases in roasting temperature and time. Values of a (redness) and ΔE (colour difference) for pistachio samples showed an increase while b decreased. Changes in L, a and b (yellowness) values of pistachio were used to develop and to validate a numerical dynamic model. The developed prediction models satisfactorily described the colour development as a function of roasting temperature and time for L, a, b and ΔE of ground-state measurements. As a result of variance analysis, the effects of the roasting process on colour values of pistachios were found to be statistically significant. In addition, changes in colour values gave high R^2 and the obtained nonlinear equations may be utilised to determine the optimum roasting degree based on time and temperature. A reverse approach for modelling is used in order to establish that it is possible to obtain the optimal condition directly from the experimental data modelling step.

Keywords: colour, pistachio nuts, roasting

1. Introduction

Pistachio (*Pistacia vera* L.) product as a commercial output has a special importance in the agricultural production of some countries like Iran and represents a large share of non-petroleum exportation. Iran ranks first in the world in terms of pistachio production and harvested area but it does not enjoy such a high position in global marketing due to exporting challenges (Koshteh and Urutyan, 2005). The pistachio is a nut with peculiar organoleptic characteristics. It is widely consumed as a raw or toasted ingredient of many desserts, ice cream, cake, pastry and for the production of some sausages (Arena *et al.*, 2007). Roasting is the very important technological operation in the processing of nuts that causes significant physical, chemical, structural and sensorial changes (Özdemir and Devres, 2000b; Pittia *et al.*, 2001; Saklar *et al.*, 2001). The roasting is carried out to promote more flavour, desired colour and textural changes that ultimately increase the overall palatability (Kahyaoglu and Kaya, 2006b). Nevertheless, this process is highly complex, since the quantity of heat transferred to the nuts is crucial. During roasting, evaporation is not limited, water moves from the inner part to the outer surface and the temperature remains at boiling point. The boiling point rises slowly, due to an increase in solid content caused by water evaporation (Saklar *et al.*, 2001) that is to say moisture loss and chemical reactions as well as major changes (to colour, volume (swell), form, mass, density and volatile components) occur (Hernández *et al.*, 2008). In order to improve the quality of roasted pistachio nut products, it is necessary to understand the physical and chemical changes that occur during roasting. Knowledge of temperature and moisture distribution in the product is vital for equipment and process design, quality control, choice of appropriate storage and handling practices (Özdemir and Onur Devres, 1999).

One of the most important quality attributes of dehydrated foods for consumers is colour (Driscoll and Madamba, 1994). Hazelnut is roasted to become a desired product with a range of colours: white, pale-yellow, golden-yellow,

dark and very dark. However, there is a problem of internal browning (development of a darker colour inside the kernels, namely brown centres, compared to the outside colour of the kernels, during roasting). The internal browning makes the product unpleasant for consumers, as whole kernels (Özdemir and Devres, 2000a). Empirically, colour is also an effective quality indicator because the brown pigments increase as the browning and caramelisation reactions progress (Cammarn *et al.*, 1990; Moss and Otten, 1989). Colour measurement with a colorimeter is one of the most widely used techniques and has been applied by some authors to determine colour characteristics (Simsek, 2007). In addition many authors have found a good relationship between colour parameters and the roasting process used for products such as cocoa beans (Krysiak, 2006), hazelnut (Demir *et al.*, 2002; Fallico *et al.*, 2003; Özdemir and Devres, 1999; 2000a,b; Özdemir *et al.*, 2001; Saklar *et al.*, 2001; Simsek, 2007), peanut (Moss and Otten, 1989), macadamia nuts (Wall and Gentry, 2007), sesame seed (Kahyaoglu and Kaya, 2006a,b) and coffee (Hernández *et al.*, 2008). There are several researchers that have studied the effect of roasting on pistachio nut quality (Gezginc and Duman, 2004; Koroglu *et al.*, 2000; Yeganeh and Trystram, 2013) and the chemical component (Caglarirmak and Batkan, 2005; Luh *et al.*, 1982). In addition, the sorption behaviour and drying process of pistachio (Aktas and Polat, 2007; Midilli and Kucuk, 2003) and optimisation of the pistachio roasting process using response surface methodology (Kahyaoglu, 2008) was studied. Another study examined the effect of frying on pistachio nut quality and proposed a comparison between hot air and frying roasting (Yeganeh and Trystram, 2013). Hence, knowledge of the quality control system and determination of the effect of roasting conditions on the main quality attributes for pistachio nut is necessary. It also requires prediction of roasting conditions for a desired colour with an acceptable level of storage duration. Therefore, in this study the effect of temperature and time on the colour of pistachio during roasting was investigated. This research will contribute to the establishment of an objective quality control system for pistachio roasting and determine the optimum roasting degree.

2. Materials and methods

Materials

For the present study, samples of 'Ahmad Aghaei' pistachio (*P. vera*) nut were used for all the experiments. Samples were supplied from the Pistachio Research Institute, Rafsanjan, Iran (harvest season 2011). The samples were manually cleaned to remove foreign matter and broken and immature nuts. The nuts were cracked and the kernel separated from the shell by hand. The nuts were kept at 4 °C in a refrigerator until analyses were performed.

Methods

Experimental procedure

The pistachios were roasted in a pilot spouted bed roaster as indicated in Figure 1. The roaster has a roasting cell, which is Pyrex and equipped with a metal grid in its lower part that holds the pistachio nuts. It delivered hot air to the cell at a speed of 7.45 m/s, measured by an electronic anemometer (Lutron company, Taipei, Taiwan). Pistachio nuts were manually placed in the chamber before roasting. The samples were roasted at 120, 130, 140, 150 and 160 °C (Özdemir and Devres, 2000b). The roasting times were determined to be 5, 10, 15, 20, 25 and 30 min. The

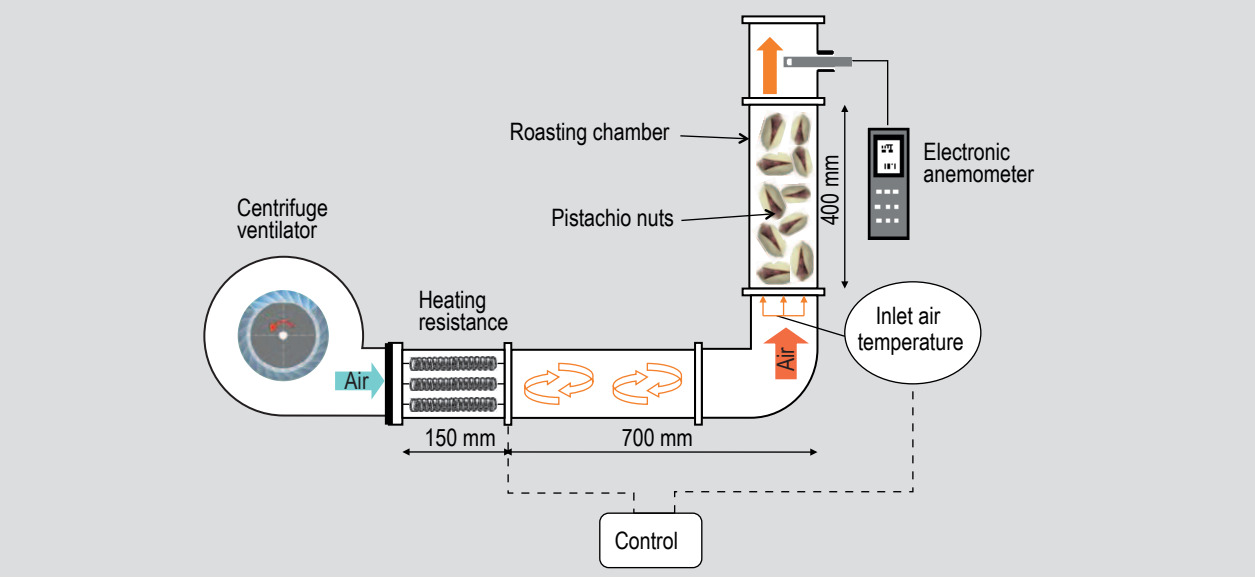

Figure 1. Schematic drawing of the pilot spouted bed roaster used in this study for pistachios.

error intervals were determined by replication. They are represented on curves.

Colour measurement

Colour can be expressed by visually uniform terms of the Commission Internationale d'Eclairage (International Commission on Illumination). The colours of unroasted and roasted pistachio in terms of L, a and b values (lightness, redness and yellowness, respectively) were measured in the ground state with a MINOLTA CR-200 colorimeter (Lutron company, Taipei, Taiwan). Before the colour measurements, the colorimeter was calibrated using a white surface where L=97.91, a=-0.49 and b=1.91 (Davidson *et al.*, 1999). The roasted pistachios in each set were then ground in a mill and kept separately in small beakers. The ground pistachios were spread on a plate. The colour measurements were repeated by taking many readings from the different regions of ground pistachio. Ground pistachios were not of uniform size (longest edge <3 mm).

Statistical analysis

The L, a and b values obtained from the experiments were analysed to find out the effect of time and temperature on those reactions. These values were dependent variables and the independent factor was the roasting process (i.e. temperature and time). Analysis of variance (ANOVA) of the MINITAB statistical program (version 12.2, Paris, France) was used with the colour measurements. Pistachio colour vs. time curves, available at five different temperatures, were fitted to the model presented in Equation 1. Differences in colour were assessed by an evaluation of the total colour difference parameter (Equation 2). The fit of the model to the data was assessed at each temperature by determining the square of the correlation coefficients (R^2) and the standard error values (SE), applying one-step regression (Simsek, 2007).

$$C = C_0 + a \times T + b \times t + c \times T^2 + d \times t^2 + e \times T \times t \quad (1)$$

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (2)$$

Where, C is the dependent variable (colour values as L, a, b and ΔE), C_0 the intercept, a, b, c, d and e the partial regression coefficients, T and t are the independent variables (temperature and time) and ΔE the colour difference.

3. Results and discussion

In ground pistachio roasted with different roasting processes dependent on increasing temperatures and times, variations in the colour were observed. The moisture content of the raw pistachio was between 48-50% (dry basis). The L, a and b values of unroasted (control) and roasted ground pistachio for different times and temperatures are shown in Figures 2-7.

The change of colour in ground pistachio is presented in Figure 2. At high temperature and time, the colour of ground is near to black due to the darkening. In general, the a (redness) values for all samples increased, while L (lightness) and b (yellowness) values decreased with the roasting time and temperature. The L values of pistachio control samples changing between 46.06 and 50.92 decreased with increasing roasting temperatures and times and reached the lowest value (33.55) at 160 °C in 30 min (Figure 3). During roasting, the a value showed an increase from approximately -9.28 to 2.78 with high roasting times and temperatures. The highest a values were determined 2.78 at 160 °C in 30 min. The differences among values for maximum roasting times at 120, 130, 140, 150 and 160 °C were not significant (Figure 4). One other significant result, among the colour parameters (L, a and b), was that a values had the highest sensitivity for temperature and time change, followed by b and L, respectively. The lowest b values changed between 25.14 and 24.61 at maximum times of 150 and 160 °C which have the same effect (Figure 5).

To study the effect of the roasting temperature and time on the colour of pistachio and determined R^2 and SE values, a three-dimensional nonlinear regression analysis was employed. The regression equalities with maximum R^2 and least SE were accepted to be mathematic models. The analysis results for R^2 values and SE of mathematical equalities are shown in Table 1. The parameters for

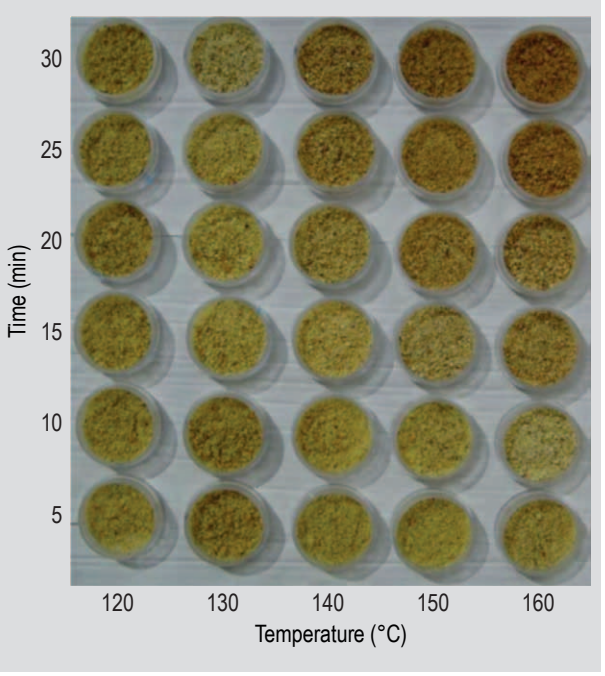

Figure 2. Changes in colour of ground pistachio during roasting, depending on time and temperature.

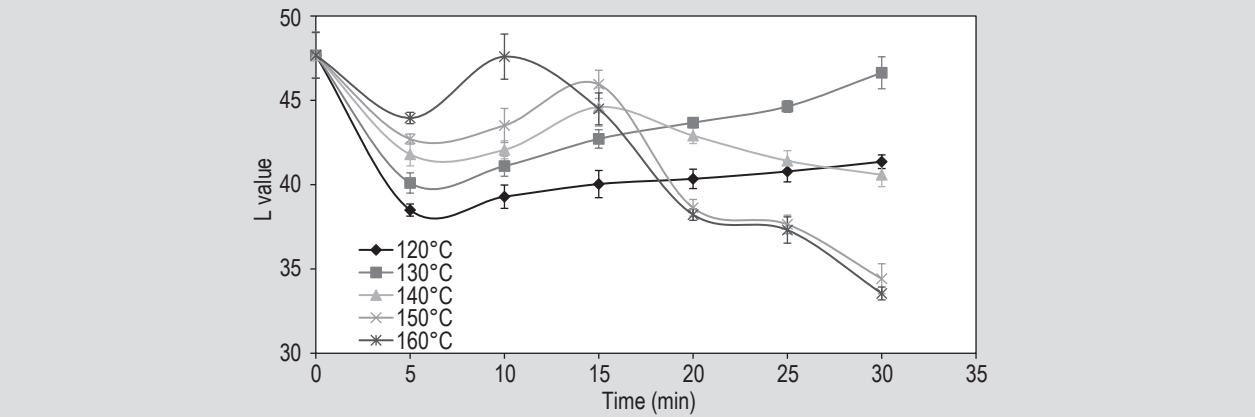

Figure 3. Changes in L-value (lightness) of ground pistachio during roasting.

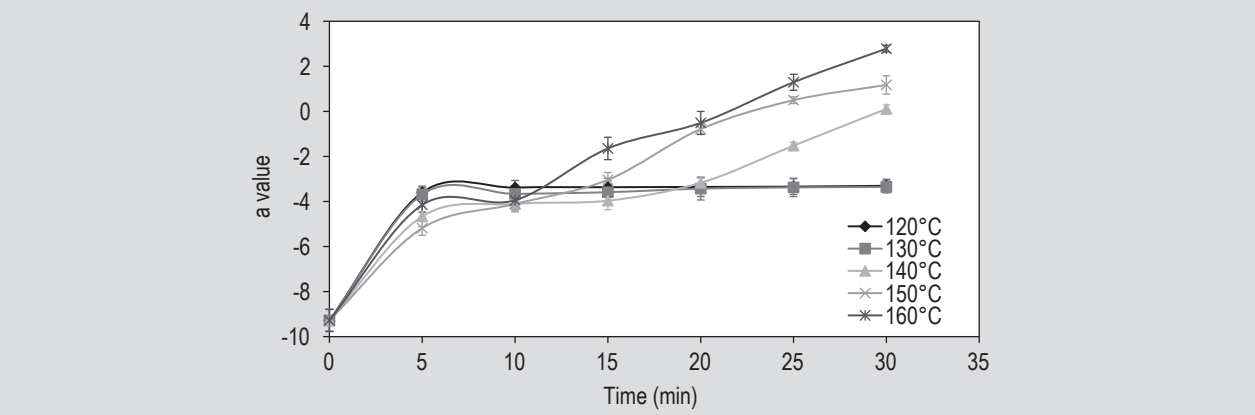

Figure 4. Changes in a-value (redness) of ground pistachio during roasting.

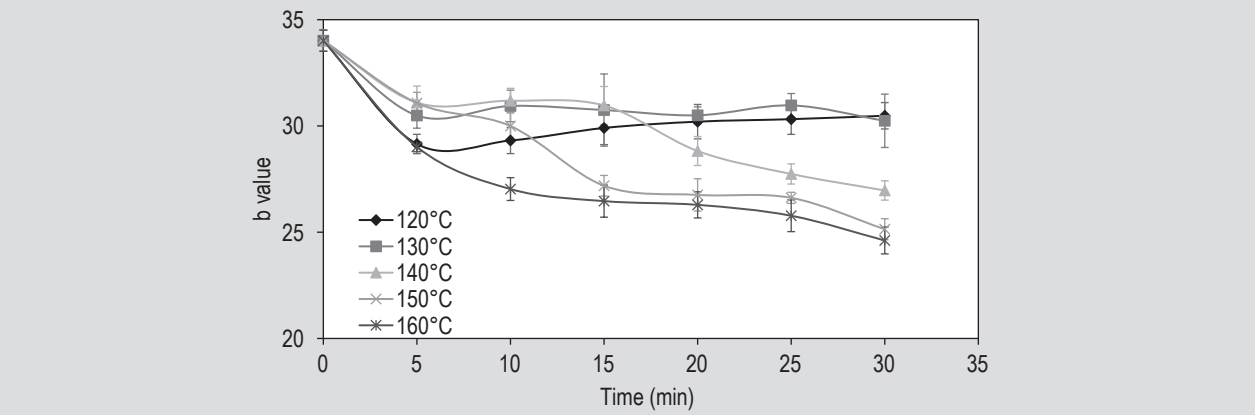

Figure 5. Changes in b-value (yellowness) of ground pistachio during roasting.

mathematical equations (temperature and time) of colour values are significant factors that are understood from high R^2 values. For this parameter (colour, time, temperature), the use of simulated graphics can be a very practical and easy way to determine the optimum roasting degree of roasted pistachio. These graphics were shown to be representing models obtained from mean data of milled state in Figure 6. Differences in colour between ground nuts can be assessed by evaluating the total colour difference parameter, as shown in Figure 7. These results indicate that nut colour at a low temperature tends to become more uniform towards the end of the roasting process for high temperature.

In addition, the changes in the mean values of L, a and b and the processes having the same effect with pistachio forms can be discerned as different areas on 3D-simulation

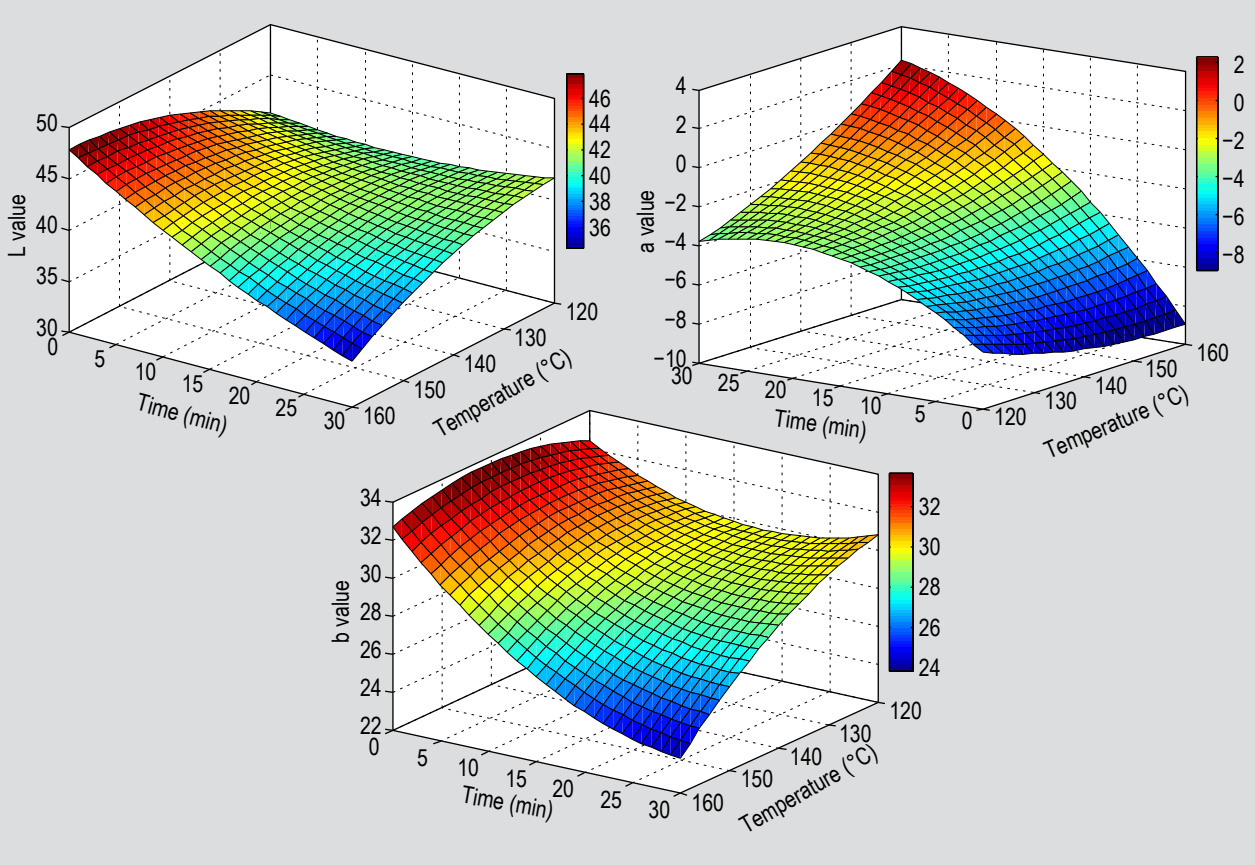

Figure 6. 3D-graphics obtained from mean data of L, a and b values (lightness, redness and yellowness, respectively) belonging to milled state (ground) of pistachio as a function of the combined effects of temperature and time.

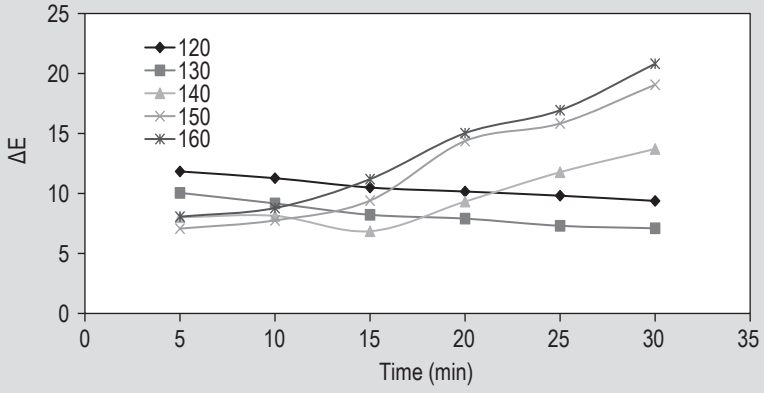

Figure 7. Changes in total colour (ΔE) of ground pistachio during roasting.

graphics. Constructed simulation graphics of pistachio forms for L values show that when pistachios were roasted between 140 and 160 °C for 15-25 min, they reached the optimum roasting degree. On the other hand, Figure 6 shows that the optimum temperature for a value belonging to the measurement of the pistachio was between 140 and 160 °C for 10-25 min. The process of critical roasting by b value simulation graphic was determined as 25-30 min at 160 °C and 30 min at 150 °C. Eventually pistachio can be burnt and have a negative colour which is the criterion of continuity of standardised roasting. The control of roasting by colour values at more than 160 °C may be difficult because the roasting time was decreased. On the other hand, under 30 min, there is no point in roasting below 120 °C because increasing the time may increase not only the rancid taste but also deterioration and contamination due to high moisture content. These processes are not considered economical because they take more time.

Table 1. Analysis results for square of the correlation coefficients (R^2) and the standard error (SE) values of mathematical equalities for the colour values of roasting pistachio.

	R^2	SE
L value (lightness)	0.711	2.206
a value (redness)	0.964	0.6222
b value (yellowness)	0.882	0.9799
ΔE value (colour difference)	0.889	1.343

The ground pistachios and kernels are consumed as snack foods and the region with highest possible desirability could be acceptable as optimum operating conditions for roasting systems. For example, the chocolate industry uses the pistachios extensively in kernel form so the degree of roasting is important for better quality.

4. Conclusions

The colour of roasted pistachio greatly depends on the roasting process (temperature and time). The coefficients of determination R^2 for a and b were reasonably high (>88%) and had the least SE. The 3D-nonlinear model can be used as a mathematic model in roasted pistachio. Moreover, the roasting temperature and time were obtained as a function of mathematical equations. Mathematical equations showed in particular that determining colour change was more practical for a and b values than L values due to high R^2 values and least deviation. These equations and simulation graphics can be used to determine the optimum roasting degree based on time and temperature. As a result of this study, process, temperature between 140 and 150 °C and a time of 15-25 min were determined as the optimum roasting conditions for pistachio nuts. These equations can identify the degree of pistachio roasting and may be used to standardise roasting.

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