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Optimization of Roasting Temperature and Duration for the Preparation of a Coffee-Like Lupin Sheath Beverage using Response Surface Methodology

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Abstract

Objectives: To optimize the roasting time and temperature to prepare a coffee-like beverage from Lupinus albus beans. **Methods:** In this Study, the Response Surface Methodology (RSM) was used to determine the optimal roasting temperature and time. These were roasted at different temperatures between 160 and 240 °C for different times (10-30 min) and then extracted with hot water. **Findings:** The color attributes (L*, a*, b*), pH, yield extract, phenolic compounds, antioxidant activity, total sugars, protein content, ash content, and sensory scores of the lupin seed beverage were affected by the roasting conditions of the seeds (temperature and time). The results of this study revealed that from the surface and contour plots it was determined that the optimal roasting temperature and time were 210°C and 20 min, respectively. **Novelty :** The present work has allowed the valorization of Lupinus albus seeds through the elaboration of a coffee-like beverage considered as a functional food (containing an important protein content, as well as other bioactive substances).

Keywords: Coffeelike Beverage; Lupin seeds; Lupinus albus L; Response surface methodology; Roasting

1 Introduction

Coffee is one of the most popular beverages in the world due to its rich flavor and beneficial effects on human health [1,2]. Nevertheless, excessive caffeine consumption can increase stomach acid secretion, blood pressure, body temperature, and blood sugar levels. Some people may experience palpitations, anxiety, irritability, confusion, insomnia, and change in appetite due to caffeine consumption [3].

Several coffee substitutes are present in the market. They come from different parts of roasted plants (leaves, roots, fruits, and seeds) [3]. Among the plants that contain a myriad of phytoconstituents, legume seeds are an important source of nutrients (protein, unsaturated fatty acids, fiber, minerals, etc.) and bioactive compounds, such as oligosaccharides, flavonoids, and alkaloids [4]. White lupin "Lupinus albus", is a legume that produces seeds rich in protein (35 to 47%), fiber, and fat (6 to 13%), lupin oil contains a high proportion of oleic acid (42.65 to 50.87%), followed by linoleic acid (34.48 to 37.3 %) and linolenic acid (3.35 and 6.58%), respectively.Moreover, lupin has a real health potential, which reduces the risk of dyslipidemia, obesity, and intestinal dysfunction [5,6].

Due to its nutritional composition, white lupin seed is widely used in a variety of potential food applications, including fermented foods (tempeh and miso), milk substitutes, bakery products, pasta, and snacks [6–8].

The production of coffee substitutes from Lupinus albus seeds exposes them to roasting, which is an important step to obtain aroma, color and flavor characteristics similar to those of coffee, this process allows to improve their digestibility, nutritional value, and antioxidant properties [9].

Therefore, this study aims to determine the optimal roasting conditions (temperature and time) obtaining a better sensory and nutritional quality of coffee substitutes. These conditions are attained by using the design of experiment methodology, more precisely the response surface (RSM). Which has the advantage of reducing the number of experimental cycles needed to provide sufficient information to establish the optimal roasting conditions.

2 Methodology

2.1 Materials

Lupinus albus seeds were purchased from the local market of Khemis Miliana in ALGERIA, those of uniform size and without defects were used for roasting. All reagents were purchased from Sigma, Aldrich (France): DPPH, Folin-Ciocalteu reagent, and Gallic acid.

2.2 Experimental design and statistical analysis

A 3-level, 2-factor full factorial design was used as the experimental design, as shown in Table 1. The independent variables were the temperature (x_1) and roasting time (x_2), which varied from 160 °C to 240 °C and from 10 min to 30 min, respectively, with the three levels: -1 (160°C, 10 min), 0 (200 °C, 20 min) and +1 (240°C, 30 min).

The responses: the parameters of color (L*, a* and b*), pH, extraction yield, phenolic content, DPPH scavenging activity, sugar content, protein content, ash content, and sensory properties (appearance, odor, flavor and overall impression) of the roasted beans, were related to the independent variables by a second-degree polynomial equation:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + +\beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2$$

In this equation, β_0 is a constant, β_1 and β_2 are linear coefficients, β_{11} and β_{22} are quadratic coefficients, and β_{12} is the interaction coefficient.

Table 1. Experience matrix including factors and their levels

Run order	Temperature, x_1 (°C)		Temps, x_2 (min)	
	Actual	Coded	Actual	Coded
1	160	-1	10	-1
2	240	+1	10	-1
3	240	+1	20	0
4	240	+1	30	+1
5	200	0	20	0
6	200	0	10	-1
7	200	0	30	+1
8	160	-1	30	+1
9	160	-1	20	0

Multiple regression analysis was applied using MODDE 13 (Umetrics, Sartorius, Germany) to fit the proposed model, including linear (x_1, x_2), quadratic (x_{11}, x_{22}) and interaction (x_1x_2) terms for the predictors (temperature x_1, and time x_2) to determine the regression coefficients and to draw the surface and contour plots. The significance levels of all terms in the proposed equation were determined statistically by calculating the F-value for p-values of 0.001, 0.01 or 0.05.

An ANOVA test was used to determine the effects of independent variables on dependent responses using SPSS software (version 26). The Tukey test was chosen to compare means at the $p < 0.05$ level.

2.3 Roasting and extraction process

Dehulled Lupinus albus seeds were poured into the electric rotary roasting drum (Wintop Wk-1, Wintop Machinery, China) and roasted under the conditions chosen for each experiment. The roasted seeds were cooled to room temperature, then packed in glass jars and stored at 4°C until use. Immediately before the preparation of the beverages, the roasted seeds were ground using a grinder (F2034210 Moulinex Krup France).

The extract was obtained according to the method of Youn and Chung[(10)], crushed seeds (20 g) and distilled water (1500 mL) were introduced into extraction flasks and extracted in a water bath for 1 h at 80 °C. The sample-solvent ratio was selected from preliminary tests, as it ensures effective conditions for good sensory quality. The extract was filtered with filter paper (number 2) and tested for quality indicators.

2.4 The color attributes

L* (darkness/lightness), a* (redness/greenness), and b* (blueness/yellowness) of the lupin seed samples were determined using a Chroma meter (CR400; Konica Minolta). To determine the degree of roasting, the L*-value is a good choice to control the color changes during the roasting process; it is equivalent to the color observation by the operator. The color parameters were measured in triplicate and the results are presented as means and standard deviations.

2.5 Determination of pH

Five grams of roasted seeds were extracted with one volume of distilled water (50 mL) and then filtered through a filter paper (Whatman No. 2). The pH value of the aqueous filtrate was measured with a pH meter (HI 8417, Hanna Instruments, Italy).

2.6 Extraction yield analysis

A portion (10 mL) of each of the hot water extracted beverages was transferred to a weighing pan and dried at 105 °C, until the sample weight was constant. The extraction yield was expressed as the ratio of the weight of extracted solids to the weight of the initial sample.

2.7 Total Phenolic Content (TPC)

The phenolic content of the hot water extracted beverage (previously obtained) was determined according to the Folin-Ciocalteu procedure used by Youn and Chung[(10)]. A 5 mL sample of the beverage was transferred to a volumetric flask. Then 5 mL of Folin-Ciocalteu reagent was added. After 3 min, 5 mL of 10% Na_2CO_3 solution was added and the mixture was left for 1 h. The absorbance of the resulting solution was measured at 760 nm using a spectrophotometer (Shimadzu, UV1601, Japan). Aqueous solutions with known concentrations of Gallic acid in the range of 10 to 500 mg/L were used for calibration. The results were expressed as mg Gallic acid equivalents (GAE) /100 g sample.

2.8 Analysis of antioxidant activity

The free radical scavenging activity of the hot water extracted beverage was determined using the DPPH radical according to the method used by Youn and Chung[(10)]. A 0.2 mL sample of the drink was added to 0.8 mL of 0.4 mmol/L DPPH radical in ethanol.

The mixture was shaken vigorously and left for 10 minutes. The absorbance of the resulting solution was measured at 525 nm with a spectrophotometer (Shimadzu UV-1601, Japan). The radical scavenging activity was calculated using the following formula:

$$\text{Percentage inhibition} = \left[1 - \left(\frac{\text{Abs sample}}{\text{Abs control}}\right)\infty\right] \times 100$$

2.9 Ash and nutrient content

Proximate analysis was performed according to the procedures of the Association of Official Analytical Chemists[(11)], including ash, crude protein, and free sugar content.

2.10 Sensory analysis

Sensory tests were carried out by a panel of 34 volunteers, all non-smokers (employees of the company ALGOFOOD, students and staff of the University Djilali Bounaama Khemis Miliana), and their ages ranging from 22 to 45 years, (14 women and 20 men). The drinks were served as 50 mL samples in white cups, which were coded with three numbers. The panels determined their preference based on sensory attributes such as appearance, odor and taste (flavor), and overall preference. For all attributes, a hedonic scale of 1 to 5 was used (1=low intensity; and 5=extreme intensity) to score the samples. Before the coffee tasting, all panel members were informed about the scoring rules. The data were presented as means and standard deviations.

3 Results and Discussion

3.1 Effect of roasting on color

The effects of roasting on the color properties of Lupinus albus seeds are presented in Table 2. The L* and a* values were found to be dependent on linear effects ($p < 0.05$) at roasting temperature, and the L* value was linearly related to time ($p < 0.05$).

The roasting process and technique affected the seed color values significantly ($p < 0.05$). The L* and b* values decreased while a* value increased with increasing roasting temperature and time (Figure 1). The increase in a* value represents an increase in reddish color and the decrease in L* value represents a darker color of the beans.

During roasting, non-enzymatic chemical browning reactions promote the development of brown pigments that give roasted products a darker color [12].

Yüksel et al. [13] found similar behavior for color values of roasted coffee beans.

Table 2. Values (mean ± standard deviation) for L*, a*, and b* for roasted Lupinus albus seeds

Run order	T (°C)	t (min)	L*	a*	b*	Roasting index[a]
1	160	10	39.04 ± 0.21^{i}	-1.71 ± 0.02^{a}	2.87 ± 1.07^{i}	Medium
2	240	10	25.19 ± 0.01^{e}	1.47 ± 0.01^{g}	0.21 ± 0.02^{a}	Dark
3	240	20	19.64 ± 0.30^{b}	1.70 ± 0.01^{h}	0.58 ± 0.02^{c}	Very dark
4	240	30	16.21 ± 0.02^{a}	2.09 ± 0.02^{i}	0.43 ± 0.01^{b}	Very dark
5	200	20	28.35 ± 0.04^{f}	1.12 ± 0.01^{e}	1.22 ± 0.01^{e}	Dark
6	200	10	29.09 ± 0.02^{g}	0.94 ± 0.05^{d}	1.76 ± 0.02^{f}	Medium dark
7	200	30	21.25 ± 0.02^{c}	1.25 ± 0.02^{f}	0.72 ± 0.01^{d}	Dark
8	160	30	23.44 ± 0.03^{d}	0.57 ± 0.03^{c}	2.16 ± 0.01^{g}	Dark
9	160	20	29.17 ± 0.07^{h}	0.19 ± 0.02^{b}	2.36 ± 0.01^{h}	Medium dark

a [14]: L* ≥57 (Very light), L*= 42–56.99 (Medium-light37–41.99 (Medium), L*= 29–36.99 (Medium dark), L*= 20.1–28.99 (dark),L* ≤20 (Very dark) . Mean of three determinations ± standard error. Means have the same letters in the same line do not differ at $p < 0.05$. $^{a\text{-}i}$Means having a different subscript within a column differ ($P < 0.05$).

3.2 Effect of roasting conditions on the physicochemical properties of the coffee substitute

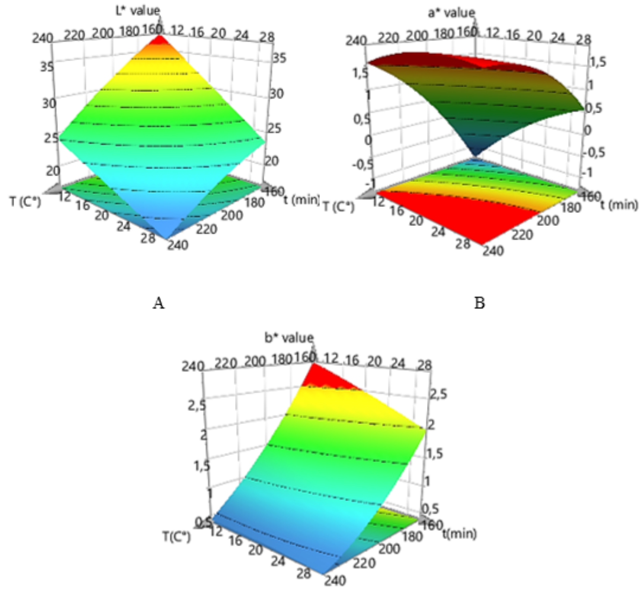
The variation of the brew pH is shown as a function of temperature and roasting time in Table 3. The pH was linearly related to temperature ($p<0.01$), and to roasting time ($p<0.05$) (Table 5). It was observed that increasing the temperature and roasting time resulted in a significant decrease ($P<0.05$) in the pH of the coffee substitute (Figure 1).

Fikry et al. [15] reported similar results for date stone powder extracts. It was suggested that the decrease in pH value could be attributed to the formation of acidic caramelization by-products, such as pyruvic acid, and the formation of acidic Maillard products during the roasting process.

Extraction yield has been defined as the mass of soluble matter in the extract and can thus affect the sensory quality of the coffee-like Lupin beverage. The extraction yield tends to increase with increasing temperature and roasting time. These results can be explained by the softening of the seed texture for material flow and the decomposition of insoluble polymers by the roasting temperature [16].

It can be seen that the highest extraction yield was obtained with a roasting temperature of 240 °C and a roasting time of 30 minutes (Table 3). A similar trend was found for coffee-like corn infusion [10].

The extraction yield was a function of linear ($p<0.001$) and quadratic ($p<0.05$) effects of roasting temperature and also of the linear ($p<0.01$) effect of roasting time, and related to the interaction ($p<0.01$) between temperature and time effect.



A B

C

Fig 1. Response surface for L*-value (A), a*-value (B) and b*-value (C) of Lupinus albus seeds at different roasting conditions

The effects of roasting on the antioxidant activity and total phenolic content of coffee-like Lupinus albus beverages are presented in Table 3. The roasting process significantly ($p<0.05$) increased the antioxidant activity and total phenolic content of the drinks.

Phenolic content was linearly dependent on roasting temperature ($p < 0.001$) and time ($p < 0.05$). Quadratic and interaction effects of time were not significant (Table 5).

The highest levels of phenolic compounds were obtained with a roasting temperature of 240 °C and a roasting time of 30 min (Table 3). The increased production of phenolic compounds during roasting may be related to the increased generation of Maillard reaction products during roasting [17].

According to Ee et al. [18], the increases in total polyphenol content after roasting treatment of Mesembryanthemum forsskalei Hochst seeds is due to the degradation of cellular constituents, the release of free phenolic compounds and the formation of heat-induced phenolic compounds.

The DPPH radical scavenging activity increased with increasing temperatures and roasting times (Figure 2). The radical scavenging activity of DPPH was linearly related ($p < 0.05$) to the roasting temperature (Table 5).

Similar results for antioxidant activity were obtained by [10,19–22]. The increase in antioxidant activity can be explained by the development of new antioxidant materials caused by the Maillard reaction [23,24]. To confirm this result, significant relationships between DPPH values and extraction yield were detected.

Mean of three determinations ± standard error. Means have the same letters in the same line do not differ at $p < 0.05$. $^{a\text{-}h}$ Means having a different subscript within a column differ ($P < 0.05$)

Browning of roasted foods is mainly due to the development of non-enzymatic reactions such as the Maillard reaction and sugar caramelization [23].

According to Youn and Chung [10], the free sugar content is generally considered an indirect measure of the substrate concentration of non-enzymatic browning reactions. Free sugar content was linearly related to temperature ($p < 0.01$) and roasting time ($p < 0.05$), and quadratic and interaction effects were not significant (Table 5). It was observed that the free sugar content, generally decreased with increasing temperature and roasting time (Figure 1).

The highest free sugar content was obtained with the lowest roasting temperature and duration (160 °C, 10 min). The same observation was made for the protein content, which decreased significantly ($p<0.05$) during roasting (Figure 1). Furthermore, the protein contents of the coffee substitute were found to be a function of the linear effects of temperature ($p<0.01$) and time ($p<0.05$) of roasting.

Many researchers [10,22,25,26], claim that free sugar content decreases with increasing roasting temperature and time.

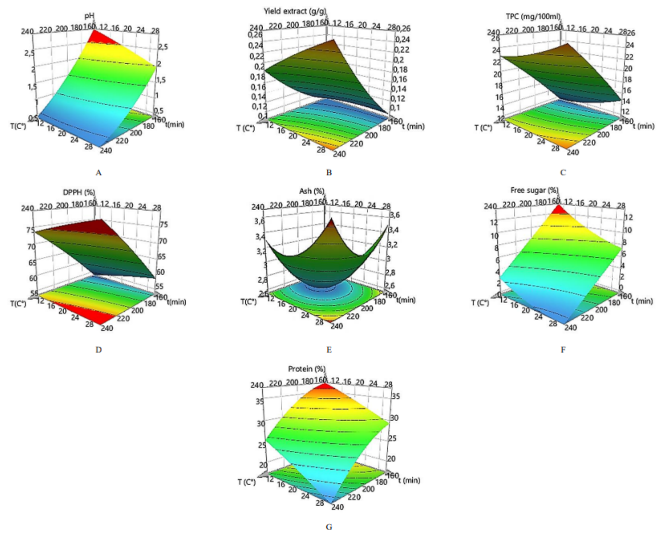


Fig 2. Response surfaces for pH (A), extraction yield (B), content of phenolic compounds (C), DPPH radical scavenging activity (D), Ash (E), free sugar (F), and content of proteins (G) of lupin beverage as a function of roasting temperature and time

Table 3. Physicochemical characteristics of lupin seeds roasted at different temperatures

Run order	T(°C)	t(min)	pH	Yield extract (g/g)	Total phenolic content (mg GAE/100ml)	DPPH scavenging activity (%)	Free sugar (%)	Protein (%)	Ash (%)
1	160	10	5.91 ± 0.01^{c}	0.08 ± 0.02^{a}	11.21 ± 0.04^{a}	55.62 ± 0.2^{a}	12.87 ± 1.42^{d}	37.27 ± 2.03^{e}	2.82 ± 0.10^{a}
2	240	10	4.81 ± 0.49^{abc}	0.18 ± 0.01^{f}	22.65 ± 0.20^{g}	73.64 ± 0.03^{ef}	1.24 ± 0.50^{ab}	25.25 ± 1.01^{bc}	3.20 ± 0.03^{b}
3	240	20	4.46 ± 0.30^{a}	0.23 ± 0.30^{g}	23.31 ± 0.50^{g}	80.23 ± 1.00^{g}	0.89 ± 0.04^{a}	20.73 ± 0.07^{ab}	3.21 ± 0.11^{b}
4	240	30	4.25 ± 0.32^{a}	0.26 ± 0.15^{h}	26.41 ± 0.07^{h}	76.25 ± 0.09^{fg}	0.10 ± 2.14^{a}	17.98 ± 0.08^{a}	3.81 ± 0.01^{c}
5	200	20	5.21 ± 0.72^{bc}	0.14 ± 0.02^{d}	19.05 ± 0.50^{e}	65.01 ± 2.01^{cd}	4.49 ± 1.06^{b}	31.29 ± 1.23^{d}	2.81 ± 0.10^{a}
6	200	10	5.62 ± 0.17^{bc}	0.12 ± 0.03^{c}	17.37 ± 0.02^{d}	61.64 ± 1.20^{bc}	10.17 ± 2.07^{cd}	33.65 ± 2.19^{de}	2.80 ± 0.15^{a}
7	200	30	4.73 ± 0.29^{ab}	0.16 ± 0.30^{e}	20.06 ± 0.30^{f}	74.54 ± 1.30^{f}	1.74 ± 0.04^{ab}	23.28 ± 0.04^{b}	2.87 ± 0.04^{a}
8	160	30	5.76 ± 0.08^{bc}	0.09 ± 0.20^{b}	14.92 ± 0.06^{c}	57.31 ± 0.04^{ab}	8.41 ± 2.19^{c}	30.21 ± 2.17^{cd}	3.74 ± 0.07^{c}
9	160	20	5.72 ± 0.01^{bc}	0.09 ± 0.20^{b}	12.11 ± 0.10^{b}	55.10 ± 0.80^{a}	9.54 ± 0.60^{cd}	32.64 ± 3.12^{de}	2.67 ± 0.08^{a}

However, Waszkowiak et al.[27] observed that increasing the roasting time (16 and 24 min) and temperature (180 and 200 °C) significantly altered the protein profiles of flaxseed. Furthermore roasting treatments (180 °C, >20 min) denatured the protein fractions of peanuts[28].

This shows that the heat applied during roasting and the interaction between the carbonyl group of the reducing sugar and the free amino acid of the protein in the Maillard reaction reduced the protein content.

These results suggest that lupin seeds used for coffee-like beverages should not be subjected to high temperatures and long roasting times during roasting because many nutrients, including carbonyl and amino compounds, are degraded in non-enzymatic browning reactions.

White lupin seeds are a rich source of minerals; their total content is 2.6-4.4 g/100g[4,29,30].

This study shows that the ash content was significantly ($p<0.05$) higher in seeds roasted at 240°C, than in those roasted at 160°C (Table 3).

The significant increase in ash content during the roasting process (Figure 2) may be due to the loss of water during the process. Indeed, during roasting the concentration of mineral matter increases in the beans due to the loss of moisture.

3.3 Organoleptic characterization

Sensory evaluation is very important for new product development. However, appearance, smell, flavor, and general acceptability are the main quality parameters of coffee [(31)].

The results of the sensory evaluation (appearance, odor, flavor, and overall preference) are presented in the Table 4 as averages of scores given by the panel members.

Table 4. Experimental data on sensory attributes of the coffee substitute as a function of roasting temperature and time

Run order	T (°C)	t (min)	Appearance	Odor	Flavor	Overall preference
1	160	10	2.30 ± 0.02^{ab}	2.12 ± 0.02^{a}	3.03 ± 0.01^{a}	2.73 ± 0.21^{ab}
2	240	10	3.40 ± 0.05^{bc}	3.75 ± 0.05^{f}	3.41 ± 0.01^{c}	3.06 ± 0.10^{abc}
3	240	20	3.01 ± 0.08^{abc}	3.14 ± 0.02^{d}	3.31 ± 0.25^{bc}	2.72 ± 0.01^{ab}
4	240	30	2.05 ± 0.50^{a}	2.01 ± 0.07^{ab}	3.07 ± 0.05^{a}	2.70 ± 0.23^{a}
5	200	20	4.89 ± 0.10^{e}	4.81 ± 0.05^{g}	3.87 ± 0.07^{f}	4.10 ± 0.04^{d}
6	200	10	3.75 ± 0.10^{cd}	3.32 ± 0.03^{e}	3.36 ± 0.03^{c}	3.21 ± 0.24^{bc}
7	200	30	3.16 ± 0.40^{bc}	3.67 ± 0.01^{f}	4.21 ± 0.05^{d}	3.49 ± 0.02^{c}
8	160	30	3.81 ± 0.90^{cde}	2.35 ± 0.04^{c}	3.24 ± 0.03^{abc}	3.08 ± 0.09^{abc}
9	160	20	3.05 ± 0.30^{c}	2.26 ± 0.09^{bc}	3.11 ± 0.50^{ab}	2.93 ± 0.40^{ab}

Mean of three determinations ± standard error. Means have the same letters in the same line do not differ at $p < 0.05$. $^{a\text{-}f}$ Means having a different subscript within a column differ ($P < 0.05$)

The degree of roasting (roasting time and temperature) is a determining factor affecting sensory quality. The coffee substitute obtained from lupin beans roasted at 200°C for 20 min achieved the best score ($p < 0.05$) compared to the other beverages.

Coffee-like beverages obtained from beans, roasted at 160°C for 10 and 20 minutes, are light in color, while those roasted at high temperatures (240°C) for a long time (between 20 and 30 min), are very dark in color, and were rated poorly by the sensory panel in terms of odor, flavor and overall acceptability.

Table 5 that the aroma of the coffee substitute is quadratically related to the roasting temperature ($p<0.001$).

The results of the sensory analysis are consistent with the results of Bolek [(26)] and Fikry et al. [(18)] in which the sensory values of roasted legume and date seeds respectively changed as a function of roasting temperature and duration.

Table 5. Regression coefficients of the second order polynomials for response parameters of roasted Lupinus albus seeds

	$\beta 0$	$\beta 1$	$\beta 2$	$\beta 11$	$\beta 22$	$\beta 12$	R2
pH	5.15333***	-0.55858**	-0.23094*	-0.02625	0.0375	-0.0768752	0.966
Yield extract	14.5267***	5.88031***	1.81144**	1.005*	-0.30375	1.27687**	0.997
TPC	18.4178***	4.92624***	1.46647**	-0.29375	0.460001	0.00937476	0.994
DPPH	67.25***	8.96192*	2.48261	-0.52875	-0.21000	0.1725	0.915
Ash	2.62**	0.142894	0.23094	0.31125	0.2325	-0.058125	0.807
Carbohydrate	4.94556*	-4.12661**	-2.02506*	0.03125	0.58625	0.6225	0.937
Proteins	29.593***	-5.2192**	-3.56514*	-1.545	-0.209999	-0.0393753	0.971
Appearance	4.31444**	-0.101036	-0.0620651	-0.7475	-0.42875	-0.53625	0.839
Odor	4.28889**	0.313213	-0.167432	-0.9962*	-0.4	-0.369375	0.854
Flavor	3.84222***	0.0591784	0.103923	-0.46375	-0.0325	-0.103125	0.772
Overall preference	3.73667***	-0.0375278	0.0389711	-0.5475	-0.15375	-0.133125	0.795
L*	26.2411***	-4.41817*	-4.67942*	-0.58625	-0.0124998	1.24125	0.953
a*	1.26*	0.896336*	0.463324	-0.28875	-0.17625	-0.31125	0.928
b*	1.25222*	-0.890563	-0.220836	0.15125	-0.02125	0.174375	0.963

Significance level: *** $p \leq 0.001$; ** $p \leq 0.01$; *$p \leq 0.05$

3.4 Optimizing roasting conditions

To determine the optimal roasting conditions, Bolek and Ozdemir, (2017) [12] stated that the consumer's decision is affected by overall product preference. Thus, in general, overall preference scores can be used to determine the optimal point. Thus, the responses pH, Yield extract, phenols and DPPH, protein, and overall acceptability were chosen to be maximized, while the response L* was minimized.

The results show that the optimal temperature and roasting time for preparing a coffee-like beverage from Lupinus albus seeds was 210 °C and 20 minutes.

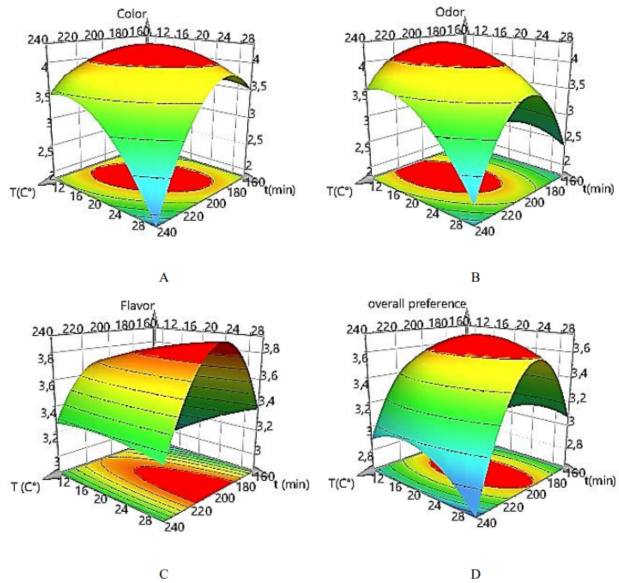


Fig 3. Response surfaces for appearance (A), odor (B), Flavor (C), and overall preference (D) of lupin beverage as a function of roasting temperature and time

4 Conclusion

The coffee substitute prepared from roasted Lupinus albus seeds is considered a bioactive beverage that can be used as a functional drink. White lupin seeds have substantial uses as they are an important source of protein, dietary fiber, minerals, essential fatty acids and active substances, which can be used as ingredients in the preparation of various foods.

The present study, therefore, describes the variations in the attributes of color (L*, a*, b*), pH, dry matter, total polyphenol content, antioxidant activity, sugar content, protein content, ash content, sensory properties, including the overall acceptability of the coffee substitute as a function of roasting conditions (Temperature and time) using a full factorial experimental design.

The results showed that roasting temperature and time significantly affected all parameters. These beverage qualities can be correlated to the roasting conditions using second-order polynomials. The optimal roasting temperature and time (210 °C, 20 minutes), were obtained graphically using contour plots.

In particular, more research is needed to determine the daily dose of the active components reported in these coffee substitutes for best use and to prevent any health hazards from over consumption, especially for long-term consumption.

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