

Optimisation of *Senna Occidentalis* L. Seed Roasting Using the Response Surface Method

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Abstract

The aim of the study was to define the optimum conditions for roasting *Senna occidentalis* seeds for the production of coffee substitute; ground 'negro coffee'. A centred composite design was used to assess the effects of roasting temperature and time on secondary metabolites (polyphenols and flavonoids), antioxidant potential and the colour of 'senna coffee'. The roasting temperature and time were varied from 190 to 210°C and 10 to 20 minutes respectively. Multiple regression models were developed using response surface methodology (RSM). The results visualised with the response surface graphs show that temperature and time significantly influence the recorded responses. The optimum conditions for roasting the seeds to produce 'senna coffee' are 194.206°C and 14.33 minutes. Under these conditions, the predicted polyphenol content, free radical scavenging activity, and colour difference were 2.419 mg EAG.g⁻¹, 53.89%, and 24.98 respectively.

Keywords

Roasting; seed; *Senna occidentalis*; coffee

1. Introduction

Plants used in traditional medicine contain a wide range of substances that can be used to treat chronic illnesses [1]. Studies have shown that the seeds of *Senna occidentalis*, also known as café nègre or false kinkeliba, are used therapeutically and as food [2, 3]. The seeds contain numerous anthracene derivatives and a toxalbumin [4]. The plant also contains sugars and fatty acids, phytosterols, an alkaloid (N-methyl-morphine) [4], chrysophanic acid, emodin, tannins, and anthraquinones [5]. A volatile oil has been reported in the seeds and leaves [6]. Previous studies have shown that many seeds, such as baobab seeds, can be used as coffee substitutes [7]. The coffee we drink today contains caffeine, which is not recommended for certain people with health problems (high blood pressure, heart problems, etc.) [8]. Some manufacturers offer decaffeinated coffee to overcome this problem. The other solution is to produce coffee substitutes by roasting suitable seeds, including those of *S. occidentalis*. In recent years, the response surface method has been widely used, as it allows maximum information to be obtained with minimum experimentation. This methodology has been used in a number of studies to determine the optimum conditions for roasting Robusta coffee [9], Arabica coffee [10], maize coffee [11], sesame seeds [12], and extracting oils from Moringa [13], *Cannabis sativa* L. [14] and dried calyxes of *Paeonia lactifolia* 'roselette' [15]. The aim of the study is, therefore, to produce a coffee substitute from *S. occidentalis* using the

response surface method in order to define the optimum roasting conditions while maximising the secondary metabolite content.

2. Material and methods

2.1 Plant material

The *Senna* seeds used were harvested in December 2021 and January 2022 in Kounkané in the Kolda region of southern Senegal. Seeds are non-homogeneous with different sizes. The water content is 9.47%.

2.2 Methods

2.2.1 Experimental design

Response surface methodology was used to study the effect of independent *Senna occidentalis* bean roasting factors, i.e. temperature (X1) and time (X2), on the colour difference (Y1), polyphenol content (Y2), flavonoid content (Y3) and antiradical activity (Y4) of the *Senna* coffee substitutes obtained. The experimental design selected was a centred and starred composite design comprising thirteen (13) trials with the sample taken (Table 1). The temperature (X1) and time (X2) were varied from 190 to 210°C and from 10 to 20 minutes respectively. These two experimental factors are relatively close to those used in conventional coffee roasting [16]. The effect of the two independent variables X1 and X2 on 4 response variables Y1, Y2, Y3, and Y4 was evaluated.

2.2.2 Roasting of *Senna occidentalis* seeds

Cassia seeds were roasted in an oven (Memmert). Beforehand, the temperature of the oven was raised to the desired temperature, then a mass of seeds was introduced and quickly spread out in a thin layer of aluminium foil. The roasted seeds obtained were then ground using a blender and sieved to a mesh size of 1mm. The substitute obtained was conditioned and then stored in a dry place before the analyses began.

2.2.3 Determination of total polyphenol content

The total polyphenol content was determined using the Folin-Ciocalteu method [17]. The results are expressed in milligram equivalents of gallic acid per gram of dry matter (mg EAG/g DM) using a calibration curve.

2.2.4 Determination of flavonoid content

The flavonoid content of cassia seed coffee is determined using the colorimetric method [17]. The results are expressed in milligrams of catechin equivalent per gram of dry matter (mg EC/g DM) using a calibration curve.

2.2.5 Determination of antioxidant activity

Antioxidant activity was assessed with 2, 2-diphenyl-1-picrylhydrazyl (DPPH) using the method reported by Oliveira *et al.* [18]. A mass of 2.5 g of *Senna occidentalis* coffee was diluted in 100 mL methanol to obtain a solution with a concentration of 25 mg/mL. Thus, 2.5 mL of DPPH (2500 µL) prepared in methanol was introduced into a test tube containing 0.4 mL of the coffee solution. The mixture was stirred for five (5) minutes and then incubated in the dark at room temperature for 30 minutes. After this incubation period, the absorbance was read at 517 nm against a blank (0.4 mL methanol in 2.5 mL DPPH) using a UV spectrophotometer (SPECORD 200 PLUS). This activity was compared with a control antioxidant (vitamin C). The free radical scavenging activity is expressed as a percentage of DPPH reduced according to equation 1:

$$PI (\%) = \frac{A_{co} - A_{ex}}{A_{co}} \times 100 \quad (1)$$

PI: percentage of inhibition

A_{co}: Absorbance of the control

A_{ex}: Absorbance of extract

2.2.6 Colour determination

A colorimeter (CM-5, Konica Minolta Sensing Americas Inc., US) was used to determine the colour parameters L*, a*, b*, ΔC of the different Cassia coffees. The L* component indicating brightness or luminance varies from black to white; the a* component corresponds to the green-red antagonist pair; the b* component corresponds to the blue-yellow antagonist pair; ΔC corresponds to the colour difference. Beforehand, calibration was carried out using unroasted seeds (L₀ = 48.74; a₀ = 8.04; b₀ = 22.71). The colour difference is calculated from equation:

$$\Delta C = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2} \quad (2)$$

3. Results and discussion

3.1 Statistical analysis

The results of the analyses are shown in Table 1 and the analysis of variances is in Table 2. Table 1 shows that the parameters monitored vary greatly. Colour variance ranged from 22.591 to 34.563; polyphenol content from 0.0146 to 2.69615 mg GAE/g; flavonoid content from 0.0155887 to 0.58171 mg EC /g and anti-free radical activity from 1.04907 to 76.3414 %.

Table 1. Centred composite design with 5 repetitions in the centre: real variables (temperature and time) and responses

No. of roasting tests	X ₁ : Temperature (°C)	X ₂ : Time (min)	Browning	Polyphenols (mg EAG/g)	Flavonoids (mg EC/g)	DPPH PI (%)
1	200	15	30.5971	2.0109	0.453426	18.568
2	200	15	28.461	1.82202	0.33567	19.3678
3	200	15	28.1472	2.04209	0.386002	18.7575
4	214	15	34.563	0.014652	0.0365588	-5.5544
5	200	15	28.3331	2.03474	0.360531	17.5031
6	210	10	31.2459	0.8391	0.0761	1.4089
7	190	10	21.0017	2.64487	0.442109	74.2432
8	200	22	29.2041	0.99145	0.0155887	2.457
9	200	8	22.591	2.26325	0.420463	68.7833
10	200	15	28.9171	1.88932	0.35716	74.1368
11	186	15	20.6744	2,69615	0.581719	76.3414
12	210	20	33.2202	0.58376	0.071842	1.04907
13	190	20	26.183	2.02449	0.402128	69.7152

The coefficient estimate represents the expected change in response per unit change in the value of the factor when all other factors are held constant. Temperature (x_1) and time (x_2) are the factors with terms significantly influencing the model equations for colour difference and antioxidant activity at the 95% confidence level. Temperature (x_1), time (x_2), quadratic contributions (x_1^2 , x_2^2), and interaction (x_1x_2) are the factors with terms that significantly influence the model equation for polyphenol and flavonoid content. In ANOVA, F is the ratio of the mean square of the error to the mean square of the model. The P value is the probability, if the means of the different populations are equal, of a higher value of F than that observed. Thus, a factor is influential on a parameter if $p < 0.05$.

Table 2. Analyse de la variance des réponses avec les valeurs de F (FV) et de P (PV)

Factors	Colour différence		Polyphenols		Flavonoïdes		DPPH-PI	
	FV	PV	FV	PV	FV	PV	FV	PV
X ₁ (°C)	81.51	< 0.0001	234.78	< 0.0001	42.47	0.0003	22.51	0.0008
X ₂ (min)	16.29	0.0024	33.89	0.0006	7.51	0.0289	3.31	0.0988
X ₁ X ₂			1.26	0.298	0.0503	0.8289		
X ₁ ²			22.84	0.002	1.64	0.2417		
X ₂ ²			6.61	0.037	7.77	0.027		
R ²	0.9072		0.9769		0.8934		0.7208	
Probability	0.001		0.001		0.0027		0.0017	

3.2 Effects of temperature and time

3.2.1 Variation in colour difference

The R^2 value obtained is 0.907 (Table 2). The response surface plot of the interaction is shown in Figure 1 and a polynomial regression model was used to describe the relationship between the roasting parameters (temperature and time). The colour difference is proportional to the roasting temperature (with $p < 0.05$). Similar results were obtained for the roasting of peanuts [19], nutsedge (*Cyperus esculentus*) [20], and baobab seeds (*Adansonia digitata*) [7]. The equation associated with the model is as follows:

$$\Delta C \text{ (Colour difference)} = 27.93 + 4.62X_1 + 2.06X_2 \quad (3)$$

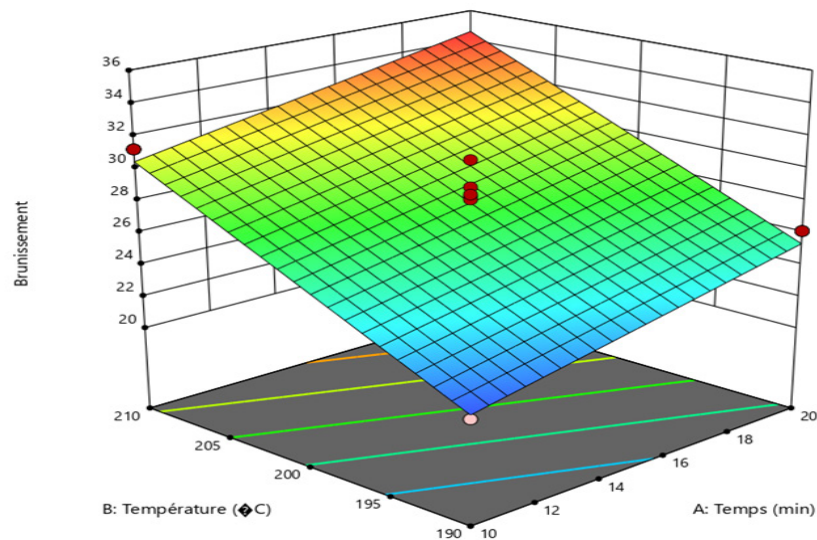


Figure 1. Response surface for colour difference.

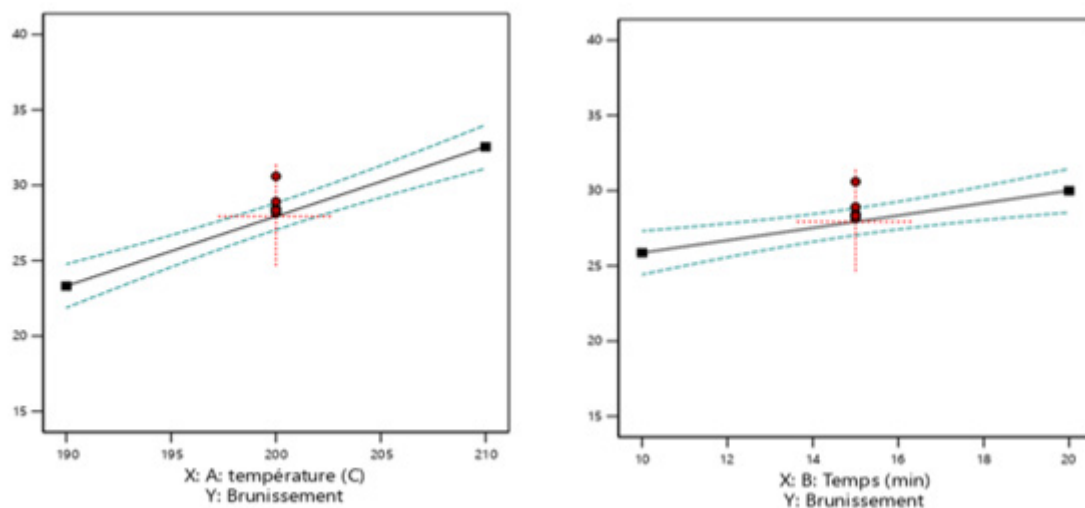


Figure 2. Variation in colour difference as a function of temperature and time compared to unroasted seeds.

The quadratic effect and the interaction effect had no significant effect. This colour difference became more pronounced with increasing roasting temperature: the highest was recorded for a roasting temperature of 214.142°C and a roasting time of 15 min (Table 1). According to Votavová *et al.* [21], pyrolytic reactions begin at 190°C, causing oxidation, reduction, hydrolysis, polymerisation, decarboxylation, and many other chemical changes. These lead to the formation of a number of aromas that characterise the sensory qualities of roasted foods such as coffee.

3.2.2 Variation in polyphenol content

The results show that polyphenol content is proportional to roasting temperature and time according to the model in equation 4 (with R^2 equal to 0.97). Thus, the quadratic effects are significant ($p < 0.05$) and the interaction effect is not significant ($p > 0.05$) (Table 2). The response surface plot is illustrated in Figure 3 and shows that the polyphenol content decreases with increasing temperature and roasting time Figure 4. In these tests, the highest polyphenol content was obtained with a roasting temperature of 185.85°C and a roasting time of 15 min. Phenolic compounds are destroyed at cooking temperatures [22]. According to Votavová *et al.*, pyrolytic reactions begin at 190°C, causing oxidation, reduction, hydrolysis, polymerisation, decarboxylation, and numerous other chemical changes [21]. Moreover, this content is higher than that obtained with unroasted seeds, which is 0.358 mg EAG/g [23]. This increase can be explained by the fact that roasting partially destroys the cellular structures, resulting in the release of certain phenolic compounds which could then become more extractable [24, 25]. On the other hand, compounds derived from Maillard reactions, such as pyrroles and furans that can react with the Folin-Ciocalteu reagent [26] and other compounds with polyphenolic structures [27] could increase the phenolic compound content. We can also add the availability of certain phenolic compounds released from certain polymers and in free form [26].

The model equation is:

$$\text{Polyphenols content} = 1.96 - 0.8798X_1 - 0.3343X_2 - 0.2943X_1^2 - 0.1583X_2^2 + 0.0913 X_1X_2 \quad (4)$$

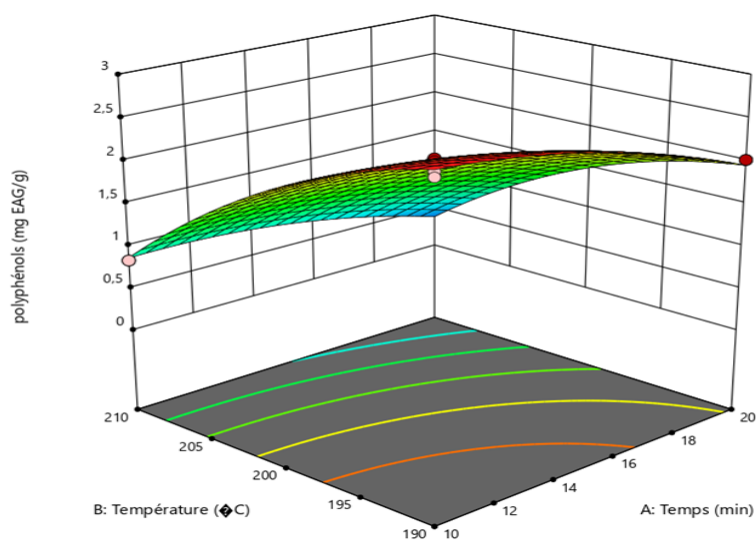


Figure 3. Response surface for polyphenol content.

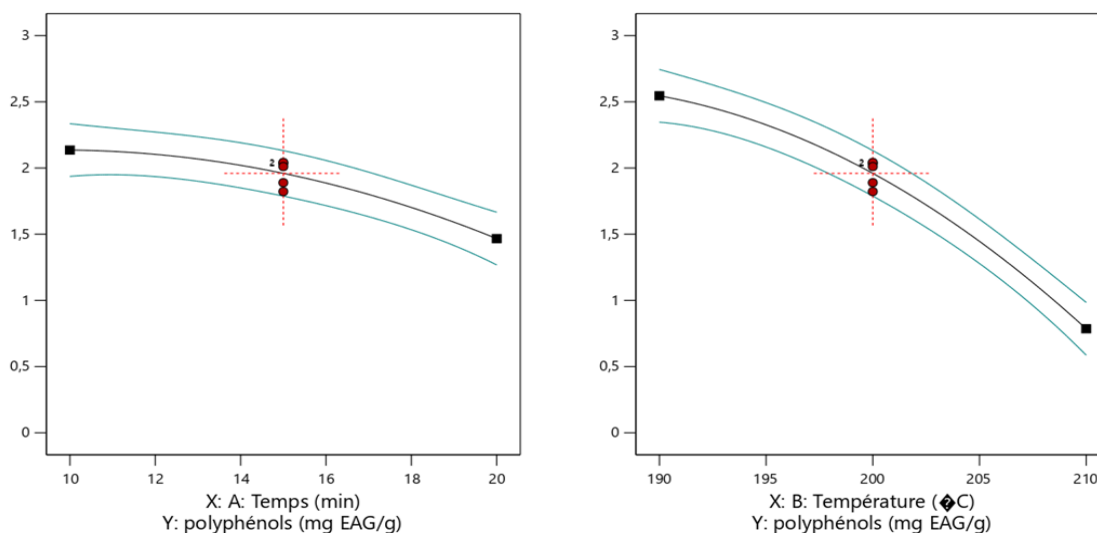


Figure 4. Variation in polyphenol content as a function of time and temperature.

3.2.3 Variation in flavonoid content

The model in equation 5 shows that flavonoid content is inversely proportional to roasting temperature ($p < 0.05$) and roasting time ($p < 0.05$). Analysis of variance showed an R^2 value of 0.89. The response surface curve is shown in Figure 5. The quadratic and interaction effects were not significant ($p > 0.05$) (Table 2). The largest value is obtained at a roasting temperature and time of 185.850°C and 15 minutes. However, for the roasting temperature, the flavonoid content decreases constantly (Figure 6). This decrease may be due to the sensitivity of phenolic compounds to high temperatures [28].

$$\text{Flavonoids content} = 0.3786 - 0.1834X_1 - 0.0771X_2 - 0.0386X_1^2 - 0.0842X_2^2 + 0.0089X_1X_2 \quad (5)$$

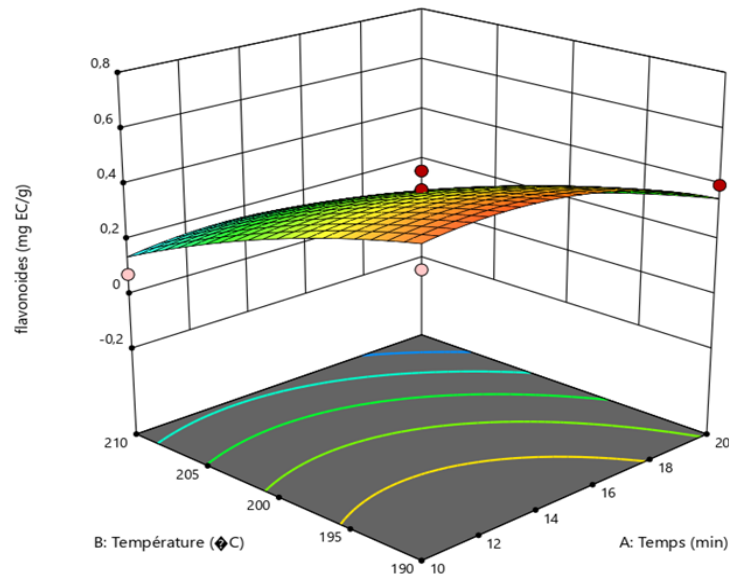


Figure 5. Response surface curve for flavonoid content.

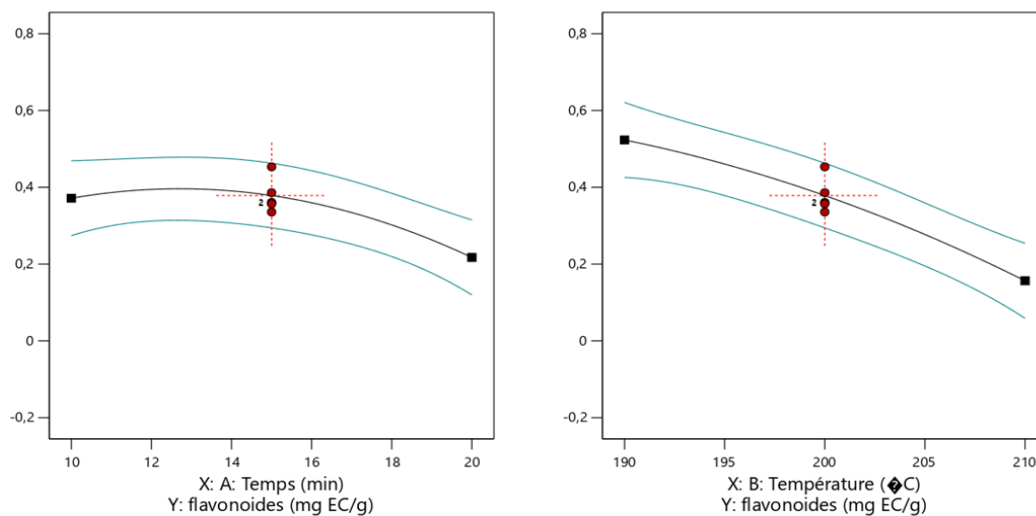


Figure 6. Variation in flavonoid content as a function of time and temperature.

3.2.4 Variation in antioxidant activity

The R^2 value obtained for antioxidant activity was 0.72 (Table 2). The response surface curve for the interaction is shown in Figure 7. Analysis of variance shows that the model is significant ($p < 0.05$). The results show that the percentage of DPPH inhibition in processed coffees is inversely proportional to the roasting temperature ($p < 0.05$) according to the model in equation 6. The time factor, quadratic, and interaction effects were not significant ($p > 0.05$). The variations noted for the temperature and time factors are shown in Figure 8. The highest antioxidant activity was obtained for a

roasting temperature and time of 185.85°C and 15 minutes. These values are very close to those reported by Chung *et al* [10] on roasted coffee beans (*Coffea arabica* L.), which were 182°C and 7 minutes. These results confirm the existence of a correlation between phenolic compound content and anti-free radical activity [11, 29]. The two response surfaces (total polyphenols and antioxidant activity) do not show the same trends. This may be explained by the fact that, after roasting, the antioxidant properties of coffee may be maintained or enhanced by the appearance of compounds with antioxidant activity, such as Maillard reaction products [30]. The equation for the response model is:

$$PI = 33.60 - 32.16X_2 - 12.34X_1 \quad (6)$$

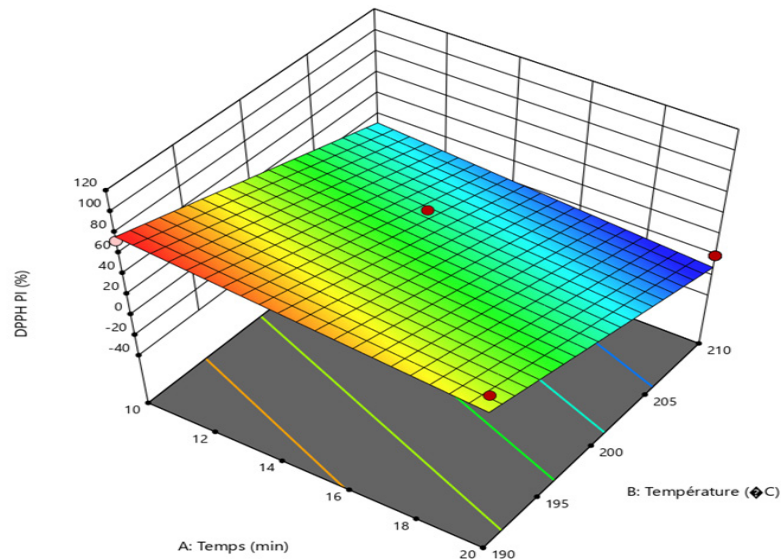


Figure 7. Response surface curve for the percentage of DPPH inhibition.

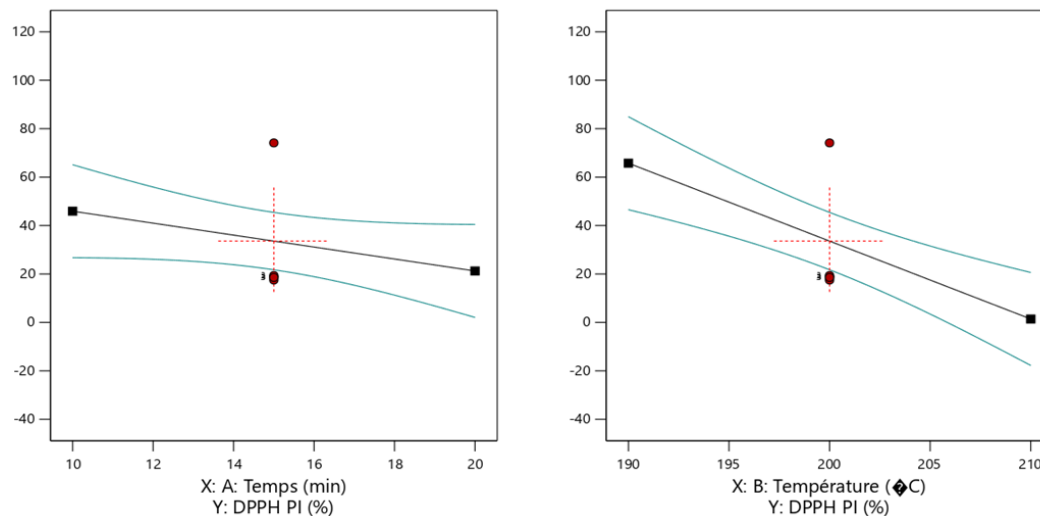


Figure 8. Variation in the percentage of DPPH inhibition as a function of time and temperature.

3.3 Optimising roasting conditions

The conditions for roasting *S. occidentalis* seeds to produce ‘senna coffee’ would be considered optimal when the difference in colour between roasted and unroasted seeds, the polyphenol and flavonoid content, and the antiradical activity reached maximum values. The optimum roasting temperature and time were thus obtained by superimposing the response contour curves. Figure 9 shows the area of optimal roasting conditions for the production of coffee fromenna seeds. The results show that the optimum temperature and roasting time for producing the coffee substitute from *Senna occidentalis* are 194.206°C and 14.32 minutes. These roasting conditions (194°C/14 min) were used to produce *Senna occidentalis*

coffee. Under these conditions, the colour difference, polyphenol content, flavonoid content, and free radical scavenging activity predicted by the model were respectively 24.98; 2.42 mg.EAG.g⁻¹; 0.48 mg.EC.g⁻¹; 53.89% with a desirability of 0.638.

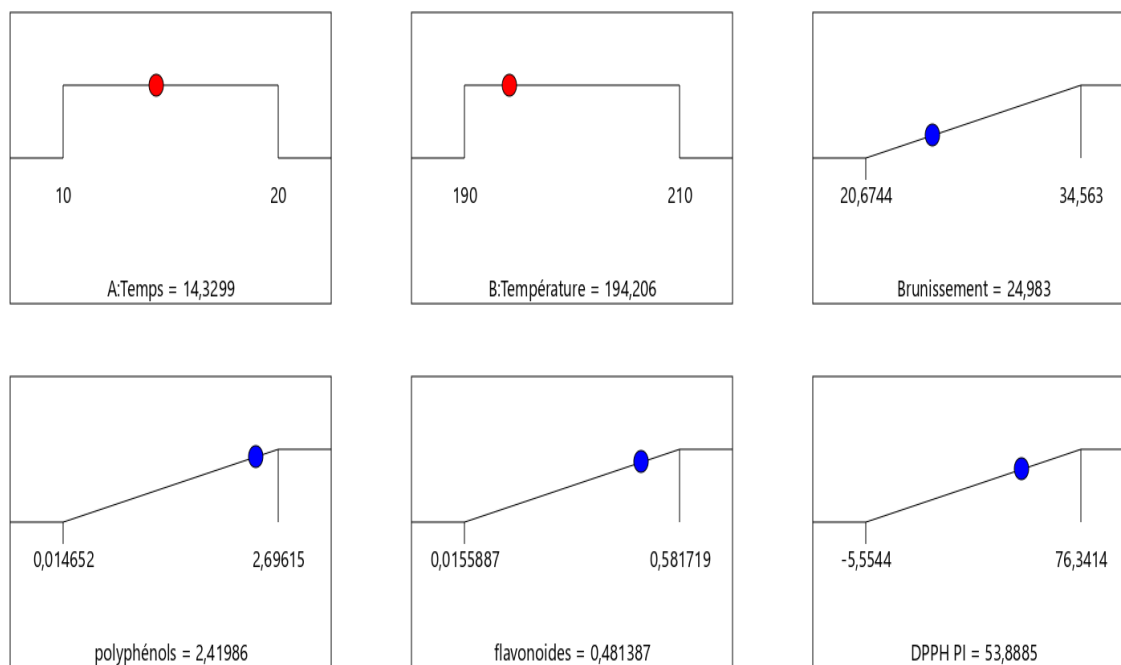


Figure 9. Superimposing the contours of the different responses to determine optimum conditions.

Depending on the temperature/time combination and the plant material used, the optimum conditions may vary. Using the response surface method, the superimposed contour lines indicated that the optimum roasting temperature and time was (182°C/7 min), which favoured good antioxidant activity and better sensory quality of green coffee (*Coffea arabica L*), such as browning index, colour, aroma, taste and overall acceptability of the coffee [10]. The optimum temperature and roasting time for baobab seed coffee is 204°C and 14 minutes [7]. Comparative analysis with conventional coffee roasting parameters revealed that “senna coffee” requires slightly lower temperatures and longer durations, which can be explained by differences in seed composition and the desired result.

The experimental data were compared with the predicted values (Table 3) to check agreement with the predicted values for optimization. The results show agreement within the given limit with 95% confidence.

Table 3. Predicted values of actual values over a 95% confidence interval

Analysis	Predicted Mean	Data Mean	Limit inferior at 95%	Limit superior at 95%
Brunissement	24,7518	22,145	21,3318	28,1719
polyphénols	2,45325	2,036	2,03378	2,87272
flavonoïdes	0,487835	0,402	0,282242	0,693428
DPPH PI	55,3643	50,632	10,0094	100,719

4. Conclusion

In this study, the parameters for roasting *Senna Occidentalis* seeds to obtain a coffee substitute called ‘senna coffee’ were determined. They enable the biochemical and functional characteristics of the product obtained to be maintained, particularly in terms of anti-radical activity. Control of the process guarantees the availability of a new, stable product. Future studies should include sensory evaluations through consumer tasting panels to determine the acceptability and taste profile of “senna coffee” compared to conventional coffee, and then the identification and quantification of consumer aroma

compounds are necessary steps for the validation of this new product. For economic benefits, studies on environmental impact, plant cultivation method, and scalability considerations should be addressed in future work to ensure the viability of “senna coffee” as a commercial product.

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References

- [1] Duraipandiyan V, Ayyanar M, Ignacimuthu S. Antimicrobial activity of some ethnomedicinal plants used by Paliyar tribe from Tamil Nadu, India. *BMC Complement Altern Med.* 2006;6:35-41.
- [2] Badock EA, Ndiaye AY, Drame A, Drame M, Ayessou NC, Cisse M. Ethnobotanical survey of a medicinal plant *Cassia occidentalis* Linn in Senegal. *Afrique SCIENCE.* 2023;22(4):79-87.
- [3] Ruffo CK, Birnie A, Tengnas B. Edible wild plants of Tanzania. Nairobi: Regional Land Management Unit; 2002. p. 588-591.
- [4] French Pharmacopoeia Committee. Medicinal plants and essential oils - CP022016023. Séance n°10 du 5 avril 2016. p. 6-7.
- [5] Bagayogo M. Botanical quality control of the plants of the Improved Traditional Medicines of the Traditional Medicine Department of Mali [Doctoral thesis in Pharmacy]. USTTB; 2020. p. 57.
- [6] Daniel F, Modou L, Maynard G. Medicinal plants of the Sahel. *Environnement africain: cahiers d'étude du milieu et d'aménagement du territoire.* Dakar: Enda-Editions; 2000. p. 187-189.
- [7] Sow A, Cissé M, Ayessou NC, Cissé OI, Niane K, Sakho M, Diop CM. Optimization of the roasting of baobab seeds cake (*Adansonia digitata* L.) using the response surfaces methodology. *J Soc Ouest-Afr Chim.* 2018;045:42-48.
- [8] Bruère MP. Remarks about a coffee substitute, *Cassia Occidentalis*, toxic before roasting. *J Pharm Chem.* 1942;9(2).
- [9] Mendes LC, Menezes HC, Aparecida M, Silva AP. Optimization of the roasting of robusta coffee (*C. canephora conillon*) using acceptability tests and RSM. *Food Qual Prefer.* 2001;12:153-162.
- [10] Chung HS, Kim DH, Youn KS, Lee JB, Moon KD. Optimization of roasting conditions according to antioxidant activity and sensory quality of coffee brews. *Food Sci Biotechnol.* 2013;22:23-29.
- [11] Youn KS, Chung HS. Optimization of the roasting temperature and time for preparation of coffee-like beverage using the response surface methodology. *Food Sci Technol.* 2012;46:305-310.
- [12] Kahyaoglu T, Kaya S. Determination of optimum processing conditions for hot-air roasting of hulled sesame seeds using response surface methodology. *J Sci Food Agric.* 2006;86:1452-1459.
- [13] Mani S, Jaya S, Vadivambal R. Optimization of Solvent Extraction of Moringa (*Moringa Oleifera*) Seed Kernel Oil Using Response Surface Methodology. *Food Bioprod Process.* 2007;85:328-335.
- [14] Kostić MD, Joković NM, Stamenković OS, Rajković KM, Milić PS, Veljković VB. Optimization of hempseed oil extraction by n-hexane. *Ind Crop Prod.* 2013;48:133-143.
- [15] NGouadjo LC, Youmssi A, Desogbo ZSC, Kayem J. Optimizing juice extraction from dried roselle calyxes (*Hibiscus sabdariffa* L.). *Int J Innov Appl Studies.* 2013;2:500-511.
- [16] Pérez JAH. Study of roasting: modeling and determination of the degree of roasting of coffee in real time. *Sciences du Vivant [q-bio]. ENSIA (AgroParisTech);* 2002. NNT: 2002EIAA0124. pastel-00003699.
- [17] Georgé S, Brat P, Alter P, Amio MJ. Rapid Determination of Polyphenols and Vitamin C in Plant-Derived Products. *J Agric Food Chem.* 2005;53:1370-1373.
- [18] Oliveira RT, Junior JM, Nascimento DV, Stefani R. Phytochemical screening and comparison of DPPH radical scavenging from different samples of coffee and Yarpa Mates Beverages. *Int J Sci Res Publ.* 2014;4(5):1-7.
- [19] Rakesh KR, Rohit U, Hari NM. Optimization of Microwave Roasting of Peanuts and Evaluation of Its Physicochemical and Sensory Attributes. *J Food Sci Technol.* 2017;54:2145-2155.
- [20] Ndiaye B, Sow A, Faye S, Cisse OI, Dieye F, Faye PG, Sakho M, Ayessou NC. Optimization of Tiger Nut (*Cyperus esculentus*) Roasting Process Using Response Surface Methodology. *Food Nutr Sci.* 2022;13:811-825. <https://doi.org/10.4236/>
- [21] Votavova L, Voldřich M, Ševčík R, Čížkova H, Mlejnecka J, Stolař M, Fleišman T. Changes of antioxidant capacity of robusta coffee during roasting. *Czech J Food Sci.* 2009;27:S49-S52.
- [22] Wani SM, Riyaz U, Wani TA, Ahmad M, Gani A, Masoodi FA, Dar BN, Nazir A, Mir SA. Influence of processing on physicochemical and antioxidant properties of apricot (*Prunus armeniaca* L. variety Narmo). *Cogent Food Agric.* 2016;2:1-12.
- [23] Badock EA, Niang L, Dramé A, Nkounkou-Loumpangou C, Touré O, Sokhna O, Ayessou NC, Cissé M. Phytochemical

- Screening and Assays of Phenolic Compounds in *Senna occidentalis* L. Leaf and Seed Extracts. *Food Nutr Sci.* 2024;15:499-508. <https://doi.org/10.4236/fns.2024.157033>
- [24] Ghazzawi HA, Al-Ismail K. A Comprehensive Study on the Effect of Roasting and Frying on Fatty Acids Profiles and Antioxidant Capacity of Almonds, Pine, Cashew, and Pistachio. *J Food Qual.* 2017;Article ID: 9038257. <https://doi.org/10.1155/2017/9038257>
- [25] Chethan S, Malleshi N. Finger Millet Polyphenols: Optimization of Extraction and the Effect of pH on Their Stability. *Food Chem.* 2007;105:862-870. <https://doi.org/10.1016/j.foodchem.2007.02.012>
- [26] Win MM, Abdul-Hamid A, Baharin BS, Anwar F, Sabu MC, Pak-Dek MS. Phenolic Compounds and Antioxidant Activity of Peanut's Skin, Hull, Raw Kernel and Roasted Kernel Flour. *Pak J Bot.* 2011;43:1635-1642.
- [27] Boublenza I, Lazouni HA, Ghaffari L, Ruiz K, Fabiano-Tixier AS, Chemat F. Influence of Roasting on Sensory, Antioxidant, Aromas, and Physicochemical Properties of Carob Pod Powder (*Ceratonia siliqua* L.). *J Food Qual.* 2017;Article ID: 4193672. <https://doi.org/10.1155/2017/4193672>
- [28] Sheng Z, Zhao J, Muhammad I, Zhang Y. Optimization of Total Phenolic Content from *Terminalia chebula* Retz. Fruits Using Response Surface Methodology and Evaluation of Their Antioxidant Activities. *PLoS ONE.* 2018;13:e0202368. <https://doi.org/10.1371/journal.pone.0202368>
- [29] Djeddi S, Yannakopoulou E, Papadopoulos K, Skaltsa H. Anti-free radical activities of essential oil and crude extracts of *Thymus numidicus*, Poiret., Algérie. *Afr Sci.* 2015;11:58-65.
- [30] Castillo MD, Ames JM, Gordon MH. Effect of roasting on the antioxidant activity of coffee brews. *J Agric Food Chem.* 2002;50:3698-3703.