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Research Article

Optimization of Olive Oil Extraction by Oleo-Doser Using Response Surface Methodology

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Abstract

Background and Objective: The increase of olive oil production, known for its nutritional and therapeutic quality, need adequate extraction processes dependent on the influence of controllable independent parameters. The objective of this study is to contribute to an improvement of extraction rate by oleo-doser of the laboratory by optimizing the effect of ultrasound and minorised natural talc on oil yield using response surface methodology. **Materials and Methods:** Olive oil was extracted from olive drupes using a laboratory oleo-doser. The sonication was carried out by an ultrasound apparatus set at 25 kHz and 100 watts for power. The effects of micronized natural talc (1-3%), the temperature malaxation (30-90°C), time malaxation (30-120 min) and sonication temperature (40-80°C) on oil yield were studied using the factorial design. **Results:** Statistical analysis revealed that data were adequately fitted in the second-order polynomial model. The linear terms of malaxation temperature, sonication temperature and micronized natural talc (MNT) had significant effects on the oil yield ($p<0.05$). **Conclusion:** The optimal conditions to obtain the maximum oil yield (23.28%) were found to be: Malaxation temperature = 90°C, sonication temperature = 60°C, for malaxation time = 30 min and MNT concentration = 1% .

Key words: Olive oil, extraction, oleo doser, response surface methodology, micronized natural talc, sonication, malaxation, temperature, time

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In Algeria, the cultivation of olive tree (*Olea europaea*) occupies an area of 471,657 ha. with a production evaluated at around 700 000 hectoliters of oil olive yearly. Oil olive known for its health benefits was the subject of several research works. Among these studies, we cite the investigations realized on malaxation, ultrasound and micronized natural talc to optimize the oil extraction. The studies carried out on malaxation are focused essentially on the effect of malaxation temperature and time on the virgin olive oil yield and quality[1-3]. Ultrasound is often applied as pretreatment of olive paste before the extraction process to increase the extraction rate and also to preserve the organoleptic and nutritional quality of virgin olive oil[4-6]. On the other hand addition of micronized natural talc in the olive paste during the extraction process has been the subject of study which has shown an increase in oil yield without modifying its quality[7].

So in this context and to improve the olive oil extraction process, the present study aims to optimize the oil extraction using an oleo-doser by studying the effect of malaxation temperature and time, sonication temperature and micronized natural talc concentration on the oil yield and acidity of olive oil extracted from the Azeradj variety using the response surface methodology.

MATERIALS AND METHODS

Study area: The study was carried out at the Food Sciences Laboratory of High National School of Agronomy Algiers and at Laboratory for Quality Control Algiers from October, 2017 to April, 2019.

Sampling: Olives fruits of an Azeradj variety used for the experimentation were harvested from adults trees. The sampling was carried out by hand. Every sample is constituted of three kilograms of olives picked from five trees. Maturity indices were determined using the method based upon the colouration of skin and pulp[8]. The maturity index (MI) was calculated by the following Eq. 1:

$$M.I = \frac{a.0+b.1+c.2+d.3+e.4+f.5+g.6+h.7}{100} \quad (1)$$

where, the numbers represent the colour from 0: Green to 7: Blacks and the letters from a to h represents the number of olives for each olive colour during the evolution of their maturity.

Analytical methods: All analytical determinations were performed in triplicate for each sample with the standard deviation.

Sample preparation for oil olive extraction by oleo-doser: Oil was extracted from olives drupes using laboratory oleo-doser. Oleo-doser constituted by a grinder, mixer and centrifuge is presented in Fig. 1. After the washing process, the olives were crushed and olive pastes obtained (700 g for each test) were sonicated, then the micronized natural talc was added to the kneading operation. The samples were sonicated at 25 kHz with a puissance of 100 watts for 15 min. The experiments were performed in triplicate. The samples of olive oil obtained after centrifugation were stored at a temperature of 4°C in dark glass flasks for their chemical analysis. The extraction yield was defined as the percentage of the extracted olive oil from the total weight of the fruit (g). The extraction yield was calculated using the following Eq. 2:

$$\text{Yield} = \frac{\text{Extracted oil (g)}}{\text{Olive fruit (g)}} \times 100 \quad (2)$$

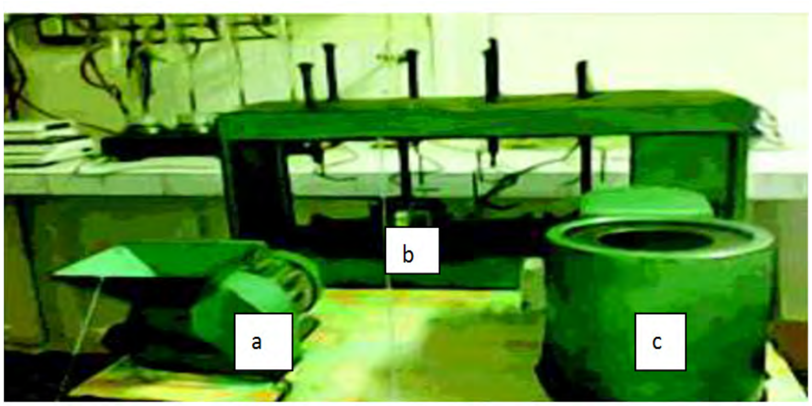

Fig. 1: Laboratory oleo doser manufactured by Leroy-Somer Society, (a) Grinder, (b) Mixer and (c) Centrifuge

Table 1: Coded and uncoded levels of different process variables used in factorial design

	Symbol		Levels	
Independent variables	Coded	Un-coded	Coded	Un-coded
Malaxation temperature (°C)	A	T	-1	30
			0	60
			+1	90
Malaxation time (min)	B	T	-1	30
			0	90
			+1	120
Sonication temperature (°C)	C	Ts	-1	40
			0	60
			+1	80
MNT (%)	D	M	-1	1
			0	2
			+1	3

Determination of physico-chemical characteristics of olive oil

Total oil content: Total oil content was determined from 10 g of ground seeds by a soxhlet extractor using hexane as a solvent. The result is expressed as the percentage of lipids in the dry matter of seeds.

Fatty acids composition: The methyl esters have been analyzed using a gas chromatograph equipped with a flame ionisation detector and capillary column. The separation of fatty acid methyl esters was carried out at 190°C. The temperature of the detector was 230°C and the injection block was recorded as 210°C. Peaks were identified by comparing the retention times with those of a mixture of standard methyl esters[9]. Peroxidizability index (PI) was evaluated using the equation of Song *et al.*[10]:

$$PI = (\text{Monoenoic }(\%)\times 0.025)+(\text{Dienoic }(\%)\times 1)+(\text{Trienoic }(\%)\times 2)+(\text{Tetraenoic }(\%)\times 4)+(\text{Pentanoic }(\%)\times 6)+(\text{Exaneoic }(\%)\times 8)$$

Experimental design: Response surface methodology was used to optimize the oil extraction from olive by an oleo-doser. The effect of independent variables, malaxation temperature (30-90°C), malaxation time (30-120 min), sonication temperature (40-80°C) and micronized natural talc (1-3%) on oil extraction was studied using the factorial design. The coded and uncoded levels of different process variables are shown in Table 1.

The second response surface model used to fit the experimental data has the following form Eq. 3:

$$Y = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \beta_{ii} x_i^2 + \sum_{i=1}^{n} + \sum_{i=1}^{n-1} \times \sum_{J=i+1}^{n} \beta_{ij} x_i x_j \quad (3)$$

where, Y is the response (oil yield in %), β_0 and are constant coefficients of intercept, linear, quadratic and interaction terms, respectively x_i and x_j are coded independent variables[11,12]. Analysis was conducted using Statistica v. 10. The quality of the fitted model was evaluated by the Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

Physico-chemical proprieties of olive fruits and its oil of Azeradj variety: Results of Physico-chemical proprieties of olive drupes of a variety Azeradj are shown in Table 2. The maturity index (MI) evaluated at 4.5 is similar to values reported by El Yamani *et al.*[13]. It is noted that olive drupes are characterized by a weight of 3.59±0.2 g and a calibre of 1.70±0.22 cm. The moisture content of whole olive fruits was de 48.02±1.27%. Oil yield evaluated at 39.95±0.42% show the importance of using Azeradj variety for oil production. Basing on the results of Abaza *et al.*[14], who reported that generally the olive varieties are classified according to their oil contents as follows: High content (46%), average content (36-46%) and low content (<38%), we can concluded that Azeradj variety is characterized by average content oil. Values of specific extinction at 232 nm inform us of accumulation primary oxidation products. For this study extracted oil by oleo-doser the value of specific extinction at 232 nm was evaluated at 1.31±0.3 which is less than the standard of the international olive council (IOC) which is $\leq$2.60. The value 0.15 of specific extinction of oil olive at 270 nm show that there is not a decomposition of peroxides because is inferior to norms of IOC ($\leq$0.22). The values of the peroxide number do not exceed the limit fixed by IOC at 20 meq of O_2 kg^{-1}. The peroxide index is directly linked to autoxidation and evolves similarly to acidity because oxygen by attacking triglycerols causes their degradation leading to the release of free fatty acids[15]. The values of the acidity, the peroxide index and the values of absorbances at 232 and 270 nm make it possible to classify the oil of the Azeradj variety in the category of extra virgin oil.

Fatty acids: The fatty acid composition of oil olive of variety azeradj and their percentages identified in order of their elution time in the column is shown in Table 3. The fraction of saturated fatty acids is represented by palmitic acid (C16:0) (11.44%), stearic acid (C18:0) (3.63%) and arachidic acid (C20:0) (0.52%). Unsaturated fatty acids are oleic acid (C18:1) (76.97%), followed by linoleic acid (C18:2) (6.66%), linolenic acid (C18:3) (0.47%), gadoleic acid (C20:1) (0.31%). The results show a clear predominance of oleic acid and linoleic acid. The content of unsaturated fatty acid was evaluated at 83.63% total fatty acids with a predominance of oleic acid which is considered an important essential fatty acid for the therapeutic quality of oil olive[16]. On the other hand, Al-Bachir and Sahloul[17] have reported that oleic acid is associated with an oxidative

Table 2: Physico-chemical proprieties of Azeradj variety oil

Proprieties physicochemical of olive drupes and oil	Values
Weight (g)	3.59±0.2
Caliber (cm)	1.70±0.22
Content water (%)	48.02±1.27
Content oil (MS (%))	39.95±0.42
Maturity indice	4.5
Acidity (En ac.oléique (%))	0.27±0.01
I.P (meq d'O_2 kg^{-1})	7.80±0.35
Absorbance à 232 nm	1.31±0.03
Absorbance à 270 nm	0.15±0.01

Table 3: Fatty-acids composition of the olive oil (Unit: Relative peak area)

Fatty acids		Percentage	Retention time (min)
Palmitic acid	C16:0	11.44±0.5	8.5
Stearic acid	C18:0	3.63±0.079	12.50
Oleic acid	C18:1	76.97±0.18	13.17
Linoleic acid	C18:2	6.66±0.06	14.74
Linolenic acid	C18:3	0.47±0.03	17.07
Arachidic acid	C20:0	0.52±0.03	19.56
Gadoleic acid	C20:1	0.31±0.01	20.66
	ΣUFA/ΣSFA	5.61	
Peroxy disability index		9.53	

Table 4: Experimental conditions and observed response values of factorial design

Run	A	B	C	D	Yield (%)	Acidity (%)
6	-1	0	1	-1	17.96	0.73
8	-1	1	0	-1	15.94	0.49
11	0	-1	0	0	17.97	1.53
12	0	-1	1	-1	18.92	1.21
9	-1	1	1	1	18.60	0.54
19	1	-1	-1	0	22.21	0.95
7	-1	1	-1	0	15.25	0.50
20	1	-1	0	-1	20.45	0.99
21	1	-1	1	1	23.28	1.06
26	1	1	0	0	20.60	1.03
23	1	0	0	1	22.54	1.75
13	0	0	-1	0	16.50	0.76
27	1	1	1	-1	20.97	1.50
3	-1	-1	1	0	17.00	0.55
5	-1	0	0	0	16.00	0.66
15	0	0	1	1	22.43	1.07
24	1	0	1	0	21.92	1.80
4	-1	0	-1	1	19.28	0.64
1	-1	-1	-1	-1	10.51	0.60
14	0	0	0	-1	17.42	0.85
16	0	1	-1	-1	15.49	1.54
2	-1	-1	0	1	16.25	0.64
25	1	1	-1	1	18.91	1.08
18	0	1	1	0	21.30	0.95
17	0	1	0	1	22.22	1.04
10	0	-1	-1	1	17.00	1.02
22	1	0	-1	-1	20.88	0.99

A: Malaxation temperature, B: Malaxation time, C: Sonication temperature, D: MNT (%)

Table 5: Effect of malaxation temperature, sonication temperature and MNT (%) on oil yield (%)

Variables	Wilks lambda	F(4.34)	p-value
Malaxation temperature	0.155	13.074	0.00001
Sonication temperature	0.478	3.78	0.01187
MTN (%)	0.620	2.293	0.0794

stability oil olive during storage. Moreover, the values of the peroxidizability index and the unsaturated/saturated ratio, evaluated, respectively at 9.53 and 5.41% show that the olive oil of variety Azeradj is stable to the rancidity of auto-oxidation during storage. These observations are in agreement with those of Kaskoos *et al.*[18], who reported that the stability of oil olive depends on polyunsaturated fatty acid content.

Response surface analysis: Firstly we research the real influence of the four factors with 3 levels on the variation of the response. For this, a screening analysis is carried out using fractional factorial design (3^{4-1}). The study of a fractional design consists in studying all the possible combinations of the factors concerning the analysis. All factors have 3 levels each so the number (N) of experiments necessary for the set of combinations can be easily calculated by the expression $N = 3^{k-1}$, where, k is the number of factors, i.e., for this study $N = 3^{4-1} = 27$.

Table 4 shows the twenty-seven generated experiments with the values of various responses to different experimental combinations for coded variables. A large variation for oil yield, between 10.51 and 23.28% and for acidity values between 0.49-1.80%, were observed for different experimental combinations. The experiments were conducted following the factorial design to find the optimal combination of temperature and malaxation time, sonication temperature and micronized natural talc content for maximum oil yield and optimal acidity.

Analysis of screening: The fractional factorial design is theoretically perfect for a screening study. In this study, we found that the 4 factors studied influence the response. Figure 2 and 3 present the Pareto diagram which shows the influence of each of the 4 factors analyzed for the yield of oil and acidity. The most influential is the factor A (malaxation temperature) followed by C (sonication temperature), D (MNT (%)) and interaction A×B (malaxation temperature× malaxation time). It is noted that the acidity is influenced only by the mixing temperature.

Table 5 presented that, the results were confirmed by effective hypothesis decomposition using the Wilks lambda method. The results of effective hypothesis decomposition of factors influencing oil yield show that the malaxation temperature is the most influential followed by sonication temperature and MNT (%).

The results of effective hypothesis decomposition of factors influencing oil acidity show that the malaxation temperature is the most influential followed by sonication temperature and MNT (%) (Table 6).

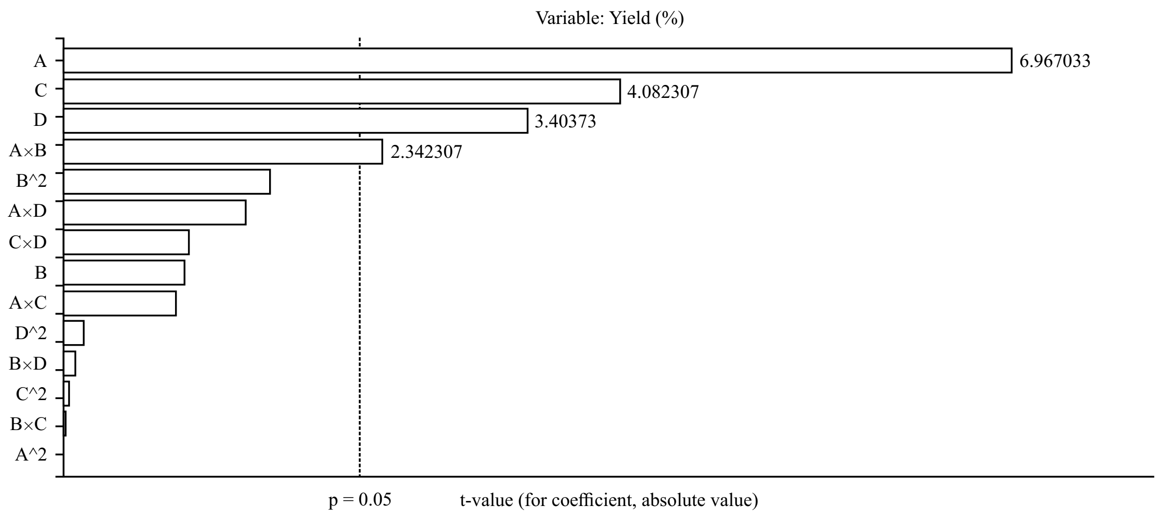

Fig. 2: Pareto diagram of factors influencing the oil yield

A: Malaxation temperature, B: Malaxation time, C: Sonication temperature, D: MNT (%), as independent factors represented in the y-axis by their linearity, interaction and quadratic

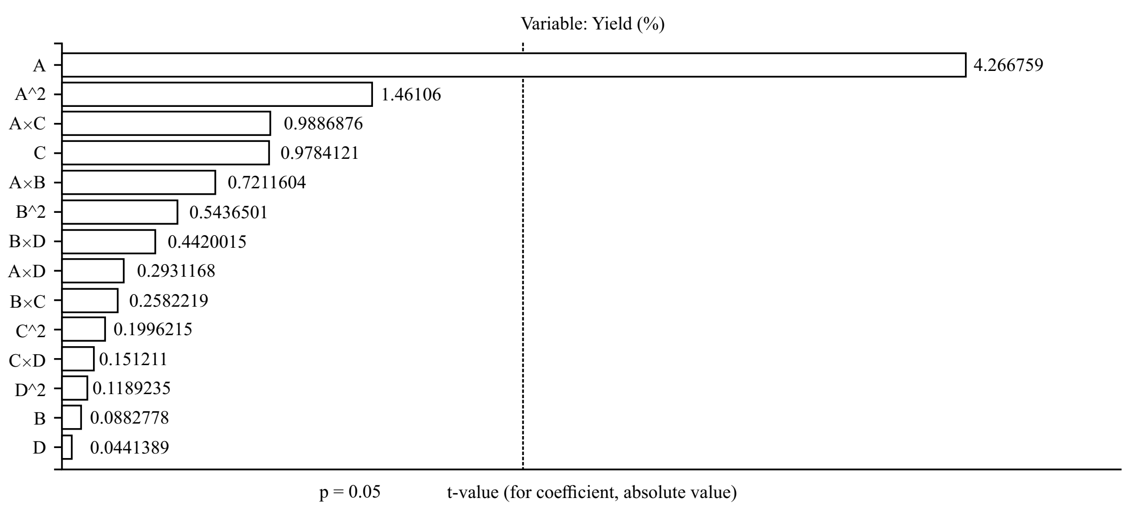

Fig. 3: Pareto diagram of factors influencing oil acidity

A: Malaxation temperature, B: Malaxation time, C: Sonication temperature, D: MNT (%) as independent factors represented in the y-axis by their linearity, interaction and quadratic

Table 6: Effect of malaxation and sonication temperature on oil acidity (%)

Variables	Wilks lambda	F(4.34)	p-value
Malaxation temperature	0.155	13.074	0.00001
Sonication temperature	0.478	3.78	0.01187

Analysis of variance of factors influencing the yield and acidity of olive oil

Oil yield: Results of analysis of variance carried out to estimate the quality of the fitted second-order response surface model is shown in Table 7. Model F-value of 487.359 reveals that the model is significant. Values of "Prob>F" less than 0.0500 indicate that model terms are significant. In this study A, C, D, AB are significant model terms. The value of the determination coefficient (R^2) at 0.880 shows that the fit of the model is good. In conclusion, the final mathematical model for the response variable oil yield is as follows:

$$\text{Oil yield (\%)} = 19.391+2.49xA+0.31xB+1.46xC+1.22xD+0.002xA^2-0.94xB^2-0.02xC^2+0.086xD^2-1.06xAxB-0.37xAxC-0.007xB\times C-0.6xA\times D-0.03xB\times D-0.41xC\times D \quad (4)$$

Taking into account only the p significant values, the equation becomes:

$$\text{Yield (\%)} = 19.391+2.49xA+1.46xC+1.22\times D-1.06xAxB \quad (5)$$

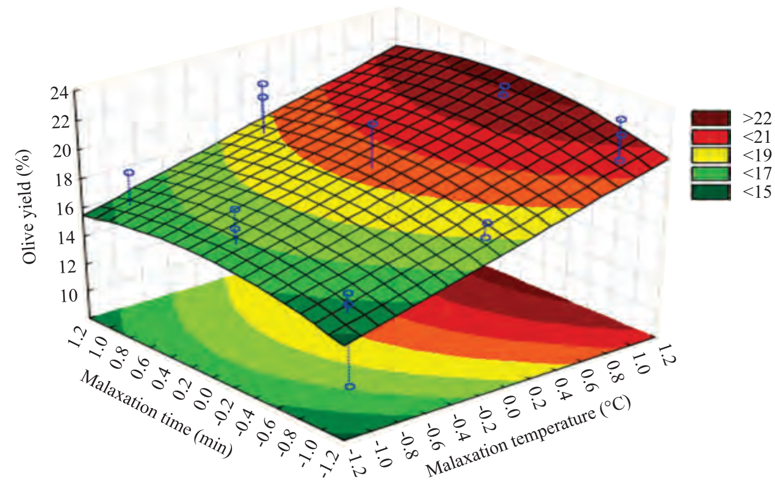

Fig. 4: Combined effect of malaxation temperature and malaxation time on the oil yield (%)

Table 7: Analysis of Variance (ANOVA) for response surface quadratic model of olive oil yield (%)

Source	Coefficient	Sum of squares	Df	Mean of squares	F Value	Prob >F
Model	19.39	203.93	14	14.56	487.359	<0.0001
Malaxation temperature (A)	2.49	112.35	1	112.35	48.5396	<0.00015
malaxation time (B)	0.31	1.79	1	1.79	0.0000	0.395
Sonication temperature (C)	1.46	38.57	1	38.57	0.7771	0.0015
MNT (D)	1.22	26.81	1	26.81	2.3095	0.005
A^2	0.002	0.00	1	0.00	16.6652	0.996
B^2	-0.94	5.34	1	5.34	0.0011	0.154
C^2	-0.02	0.003	1	0.003	11.5854	0.974
D^2	0.08	0.04	1	0.04	0.0192	0.892
A×B	-1.06	12.69	1	12.69	5.4864	0.037
A×C	-0.37	1.55	1	1.55	0.6710	0.428
B×G	-0.007	0.001	1	0.001	0.0003	0.987
A×D	-0.60	4.17	1	4.17	1.8046	0.204
A×D	-0.03	0.015	1	0.015	0.0064	0.937
C×D	-0.41	1.98	1	1.98	0.8565	0.372
Residual		27.77	12	2.31		
Pure error		0.93				
R-squared		0.88				
Adj R^2		0.74				

Response surface plots of oil yield: The results of analysis variance reveal clearly that the malaxation temperature, sonication temperature and MNT (%) have linearly a high effect on the olive oil yield (Table 6). The effect of malaxation temperature and time, sonication temperature and MNT (%) on the oil yield (%) are confirmed by the response surfaces plots shown in Fig. 4-6. Indeed these figures show that the oil yield increased with an increase in malaxation temperature, sonication temperature, malaxation time and MNT (%). The increase in oil yield at high temperature is explained by a decrease in viscosity leading to the formation of the oily phase allowing an increase of oil yield using the centrifugation process.

The positive effect of ultrasound on the increase of yield oil (%) agree with the results reported by Achat *et al.*[19], who have explained the effect of ultrasound on oil extraction by the cell membrane disruption leading to an important mass transfer. Figure 6 shows clearly that the addition of micronized natural talc increase oil yield confirmed also by the results of analysis of variance (p = 0.005). The increase of oil yield is due to the effect of micronized natural talc which destabilizes the oil-in-water emulsion during the extraction process of virgin oil olive[20].

Olive oil acidity: The results of the analysis of variance carried out to estimate the quality of the fitted second-order response

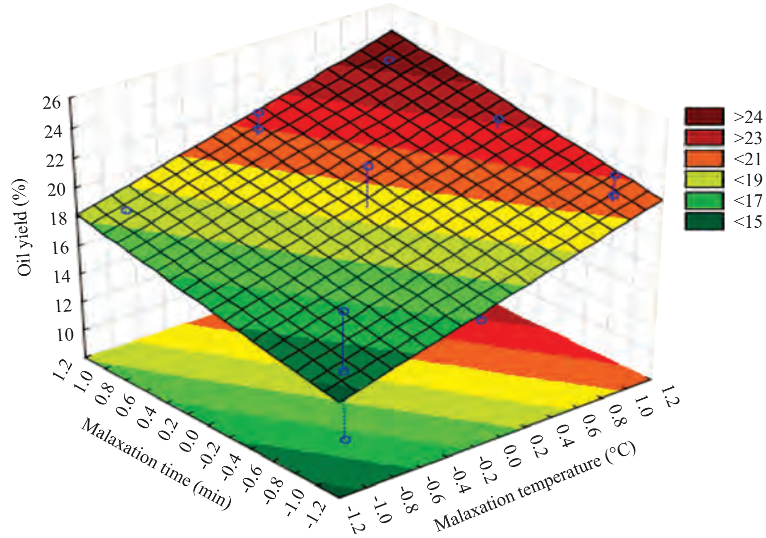

Fig. 5: Combined effect of malaxation temperature and sonication temperature on the oil yield (%)

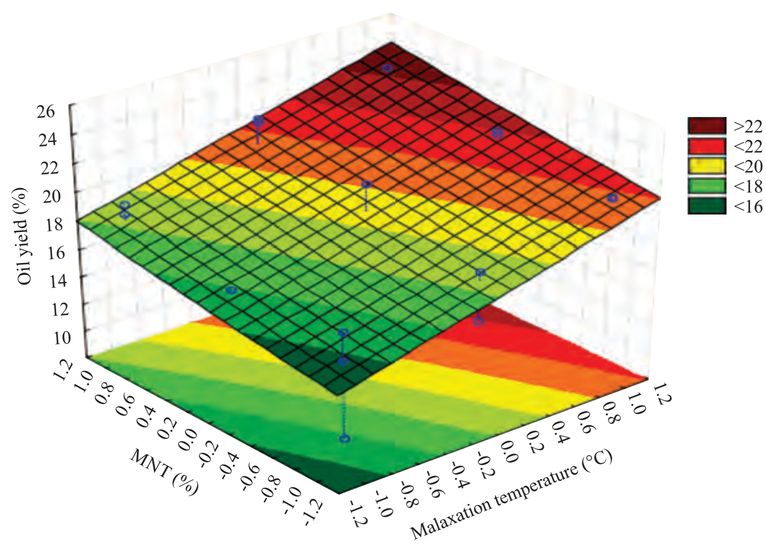

Fig. 6: Effect of malaxation temperature and MNT (%) on the oil yield (%)

surface model are presented in Table 8. The model F-value of 39.474 shows that the model is significant. Values of "Prob>F" less than 0.0500 indicate that model terms are significant. In this study, only A is the significant model term. The high coefficient of determination (R2) which is 0.660 shows that the fit of the model is good. The final mathematical model for the response variable oil yield is as follows:

$$\text{Acidity (oleic acid (\%))} = 4.05+1.868\text{xA} \quad (6)$$

Response surface plots olive oil acidity: The effect of malaxation temperature and time, sonication temperature and MNT on acidity are indicated in Fig. 7-9. It is noted that the acidity increased with an increase in malaxation temperature. The three surface plots show that the sonication temperature, MNT (%) and malaxation time don't modify the acidity.

Given that the surface plot shows the significant effects of temperature, sonication and micronized natural talc on the oil yield and the acidity and knowing that olive oil of quality was often obtained at low temperature and low acidity, it would be interesting to investigate from the contour plot the optimal conditions to extract the olive oil at low malaxation temperature. Hence, the importance

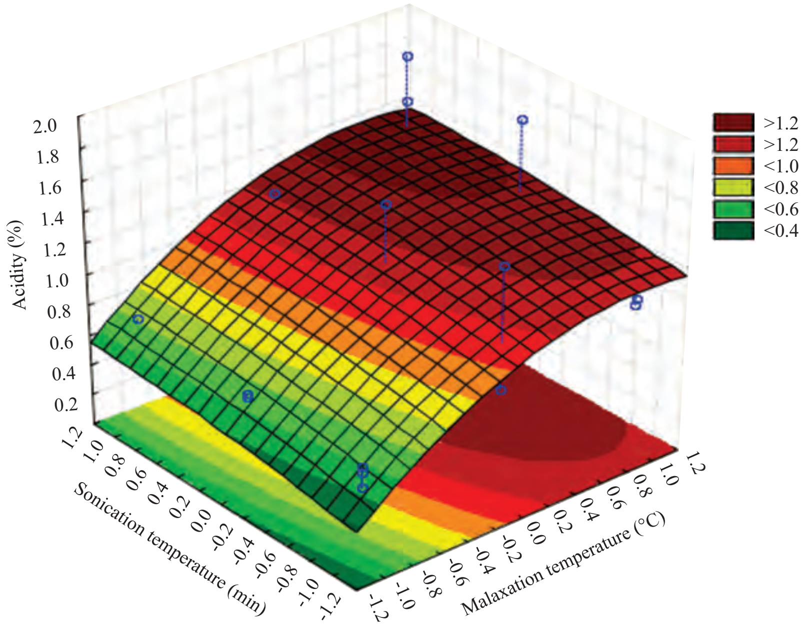

Fig. 7: Combined effect of malaxation temperature and sonication temperature on the olive oil acidity

Table 8: Analysis of Variance (ANOVA) for response surface quadratic model of olive oil acidity

Sources	Coefficient	Sum of squares	Df	Mean of squares	F-value	Prob>F
Model	1.162222	4.052	1	4.052	39.474	0.0000
Malaxation temperature (A)	0.322222	1.868	1	1.868	18.205	0.0010
Malaxation time (B)	-0.191111	0.0008	1	0.0008	0.007	0.9311
Sonication temperature (C)	0.006667	0.098	1	0.098	0.957	0.3471
MNT (%) (D)	-0.071111	0.0002	1	0.0002	0.001	0.9655
A^2	0.073889	0.219	1	0.219	2.134	0.1696
B^2	-0.026111	0.030	1	0.030	0.295	0.5966
C^2	-0.003333	0.004	1	0.004	0.039	0.8451
D^2	0.015556	0.0014	1	0.0014	0.014	0.9073
A×B	0.068889	0.053	1	0.053	0.520	0.4846
A×C	0.094444	0.100	1	0.100	0.977	0.3423
B×C	-0.024667	0.006	1	0.006	0.066	0.8006
A×D	0.028000	0.008	1	0.008	0.085	0.7744
B×D	-0.042222	0.020	1	0.020	0.195	0.6663
C×D	-0.014444	0.0023	1	0.0023	0.022	0.8823
Residual		1.231	12	0.102		
Pure error		0.816				
R-squared		0.666				

importance of using contour plots to predict the optimal conditions during the extraction process of oil from olives.

Contour plot of the effects of different interactions of malaxation temperature and time, sonication temperature and MNT (%) on yield oil (%) and acidity (%).

Evaluation for oil yield: The effect of different interactions on oil yield, namely malaxation temperature×sonication temperature, malaxation temperature×MNT (%) and malaxation temperature×malaxation time are shown, respectively in Fig. 10-12.

The optimal conditions at low temperature for maximum oil yield are shown in Table 9.

Evaluation for olive oil acidity: Concerning the effect of different interactions, namely malaxation temperature×malaxation time, malaxation temperature×sonication temperature and malaxation temperature×MNT, on olive oil acidity, are shown, respectively in Fig. 13-15.

The optimal conditions predicted at low temperature for minimum acidity (%) are presented in Table 10.

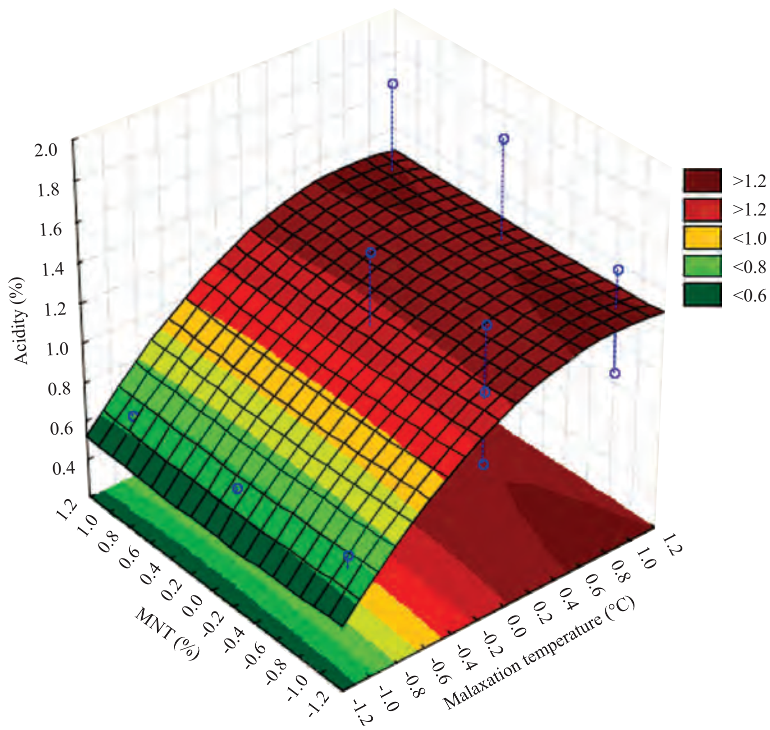

Fig. 8: Combined effect of malaxation temperature and MNT (%) on olive oil acidity

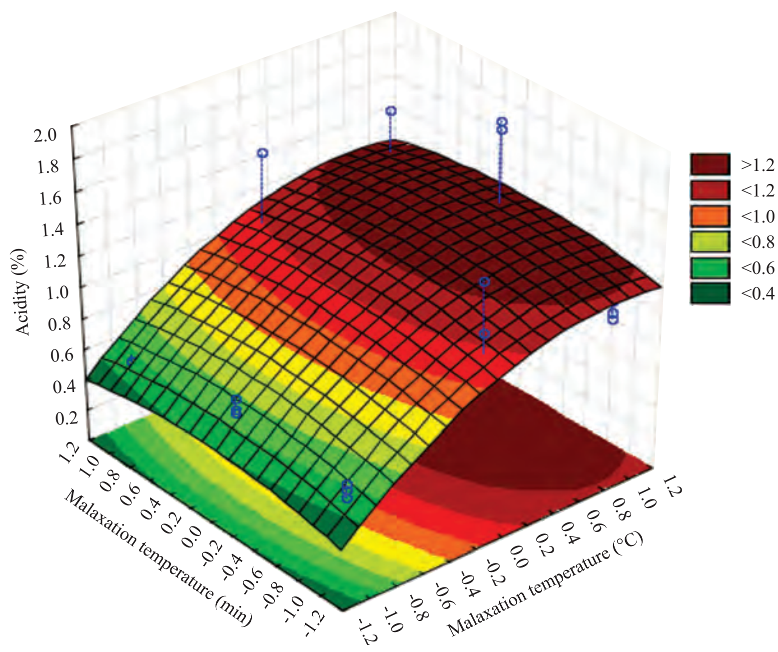

Fig. 9: Combined effect of malaxation temperature and malaxation time on olive oil acidity

Table 9: Optimal conditions for maximum oil yield (%) determined from contours plots

Interactions	T_M (°C)	T_S (°C)	t_M (min)	MNT (%)	Oil yield (%)
Malaxation temperature × malaxation time	30	-	60	-	17.96
Malaxation temperature × sonication temperature	30	80	-	-	17.96
Malaxation temperature × MNT (%)	30	-	-	3	18.6

T_M: Malaxation temperature, T_S: Sonication temperature and t_M: Malaxation time

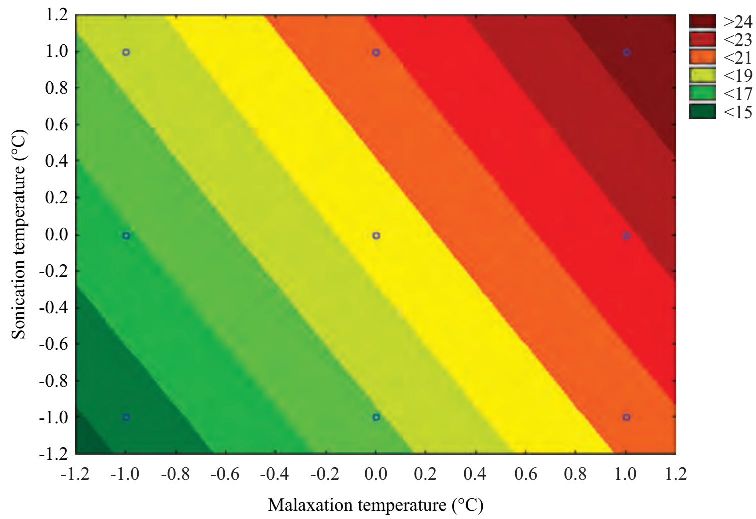

Fig. 10: Effect of interaction of malaxation temperature and sonication temperature on oil yield (%)

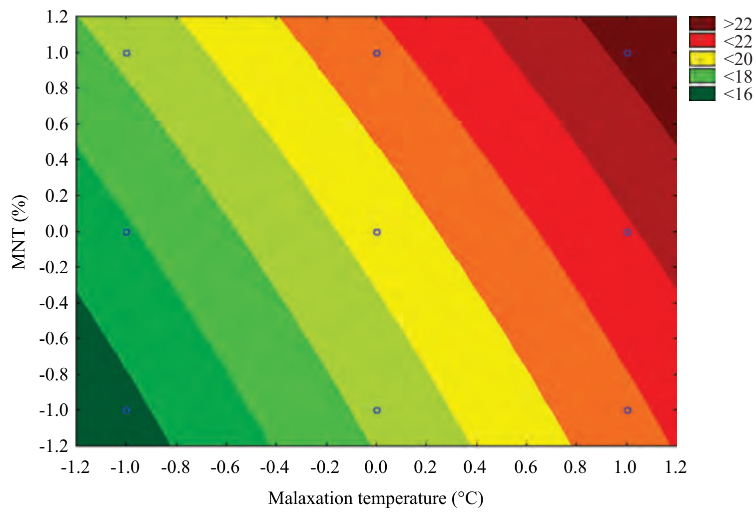

Fig. 11: Effect of the interaction of malaxation temperature and MNT (%) on oil yield (%)

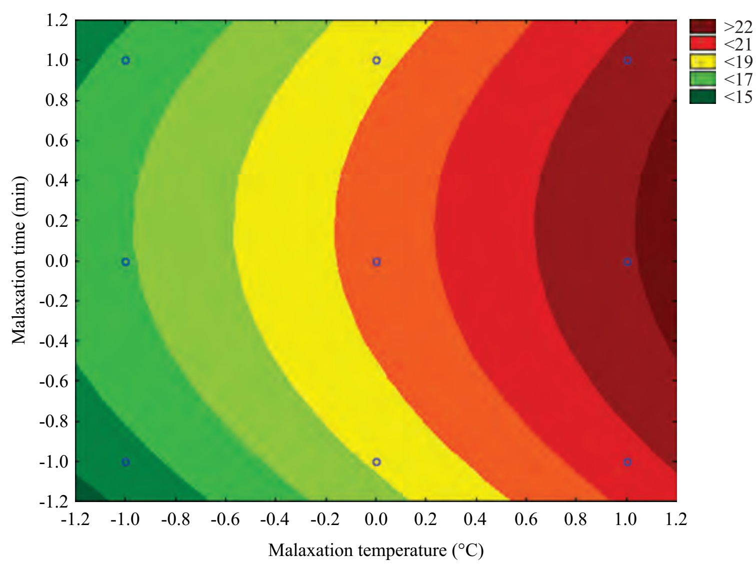

Fig. 12: Effect of the interaction of malaxation temperature and malaxation time on oil yield (%)

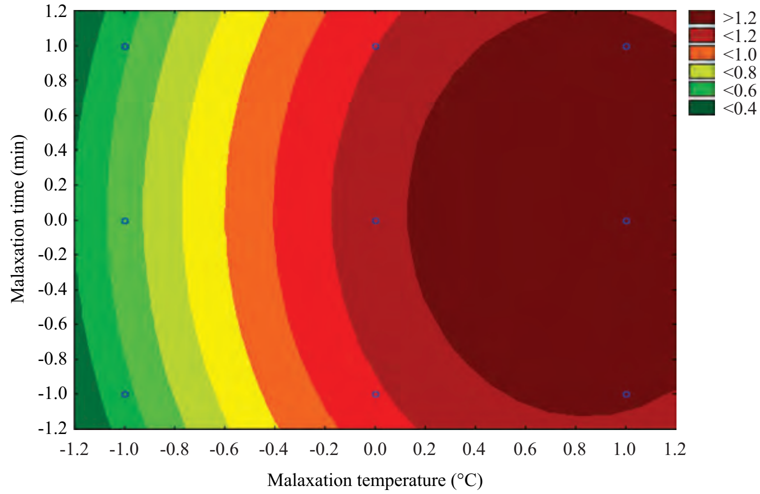

Fig. 13: Effect of interaction of malaxation temperature and malaxation time on olive oil acidity (%)

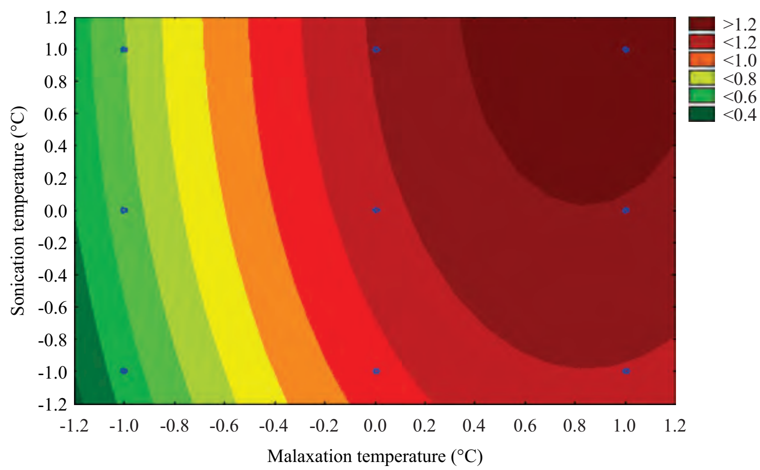

Fig. 14: Effect of interaction of malaxation temperature and sonication temperature on olive oil acidity (%)

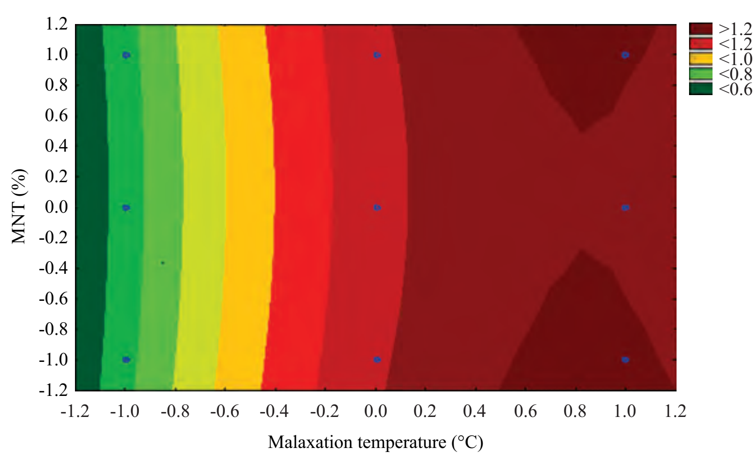

Fig. 15: Effect of interaction of malaxation temperature and MNT (%) on olive oil acidity (%)

Table 10: Optimal conditions for minimum acidity (%)

Interactions	T_M (°C)	T_S (°C)	t_M (min)	MNT (%)	Acidity (%)
Malaxation temperature × Malaxation time	30	-	30	-	0.55
Malaxation temperature × Sonication	30	40	-	-	0.50
Malaxation temperature × MNT (%)	30	-	-	1	0.73

T_M: Malaxation temperature, T_S: Sonication temperature and t_M: Malaxation time

These optimal values obtained for the Azeradj variety could be recommended to extract oil at low temperature and low acidity to preserve its quality nutrition. These observations agree with those of Veneziani *et al.*[21], who have reported that olive oil organoleptic and nutritional qualities are preserved at low extraction temperature.

CONCLUSION

This study has shown that response surface methodology is an effective way to determine the optimal conditions for oil extraction from olive fruits by oleo-doser. Analysis of variance has shown that the effects of all the process variables including malaxation temperature, sonication temperature, malaxation time and MNT (%) were statistically significant. A polynomial model was obtained for predicting oil yield. The conditions during oil olive extraction for maximum oil yield (23.28%) were found to be 90°C for malaxation temperature, 60°C for sonication temperature, 30 min for malaxation time and 3% for micronized natural talc.

SIGNIFICANCE STATEMENT

This study has revealed that by controlling the effect of malaxation temperature and time, sonication temperature and MNT%, using response surface methodology, it is possible to improve the extraction rate of olive oil at low acidity. The contours plot allowed us to predict the optimal conditions to extract oil olive of high quality, for instance, it would be interesting to apply for Azeradj variety the following conditions to obtain an olive oil of quality at low temperature: Malaxation temperature = 30°C, malaxation time = 60 min, sonication temperature = 60°C and MNT (%) = 3%.

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