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Parametric modeling hydrodistillation of *Eucalyptus camaldulensis* Dehnh. essential oil Algerian by the response surface methodology

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ABSTRACT

The objective of this study is to optimize the parameters of hydrodistillation of *Eucalyptus camaldulensis* Dehnh. essential oil Algerian through the Response Surface Methodology (RSM), the parameters examined are the granulometry (particles diameter), condensation flow and extraction time. A 3-factor Box-Behnken design was used to produce combinations of factors, from the response surface analysis a second order polynomial expression was deduced and used to determine the best oil yield extracted as function of the optimum conditions.

INTRODUCTION

Response surface methodology (RSM) is one of the popular methods in the development and optimization of different systems. RSM is a collection of mathematical and statistical techniques for empirical model building, in which a response of interest is influenced by several variables and the objective is to optimize this response [1]. RSM is widely used in optimization studies in recent years in various fields, such as industries, medicine, electronics, automation, chemistry, agriculture, analysis, etc. whose main objective is to optimize, develop and improve the system's response to important applications in the design and formulation of new products [1,2]. The application of this methodology not only saves time and reagents, but also provides information on parameter interactions [3].

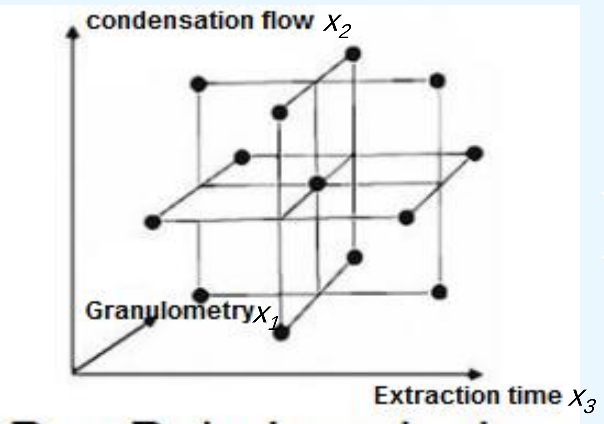
the present document provides the parametric optimization of essential oil hydrodistillation from the leaves of the medicinal plant *Eucalyptus camaldulensis* of Algerian origin using the response surface methodology in the aim of studying the effects of extraction parameters (granulometry, condensation flow and extraction time) and their interactions on the extracted oil yield.

PROBLEM

The majority of medicinal plants contain only 1% (m/m) of essential oil [4]. Even with this very low yield, essential oils are a significant industrial importance and market value. In order to improve the essential oil yield, the present document provides the parametric optimization of essential oil hydrodistillation from the leaves of the medicinal plant *Eucalyptus camaldulensis* of Algerian origin using the response surface methodology, and develop a new automatic process that allows to control and keep the extraction processes under these optimum operating conditions.

METHODOLGY

The plant used in this study is harvested in the Wilaya of Oum el Bouaghi region in northeastern Algeria.



Box-Behnken design

Particles sizes diameter of *Eucalyptus camaldulensis*

With these experimental data a total of 15 trials were generated

Hydrodistillation extraction

$$\text{Oil yield (\%)} = \frac{\text{Extracted oil weight (g)}}{\text{Weight of plant material used (g)}}$$

Maximisation of the essential oil yield

RESULTS AND DISCUSSION

A. Experimental yield

The estimation of the essential oil yield obtained by hydrodistillation reveals a value between 0.34-0.51%.

B. Model equation

The experimental yield is used to determine the values of the regression coefficients of the polynomial. With all possible combinations of the three parameters, the model developed in terms of experimental values is given by this equation :

$$Y\,(\%) = 0.031667x_1^2 - 0.012083x_2^2 - 1.34259.10^{-5}x_3^2 - 0.01500x_1x_2 - 1.66667.10^{-4}x_1x_3 + 2.500.10^{-4}x_2x_3 - 0.11400x_1 + 0.055500x_2 + 5.48333.10^{-3}x_3 - 0.098183$$

C. Validation of model

The results were statistically tested by analysis of variance (ANOVA) "*Tab. I*". The analysis showed that the experimental data were very adapted to the second-order polynomial model with p-value=0.0193

Tab I. Analysis of variance (ANOVA) for the quadratic model

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F
Model	0.027	9	$2.964.10^{-3}$	7.53	0.0193*
Residual	$1.967.10^{-3}$	5	$3.933.10^{-4}$		
Pure Error	$6.667.10^{-3}$	2	$3.333.10^{-5}$		
Cor Total	0.029	14			
R-Squared (R^2)	0.9313				

The significance of the model was verified by the coefficient of determination (R^2). The curve representative of the values of the predicted yield as a function of the experimental yield is shown in "Fig. 1", where we see from the graph that the cloud of points is not far from the line of equation (y=x) with a coefficient of determination R^2=0.9313, indicating that the model has good descriptive quality.

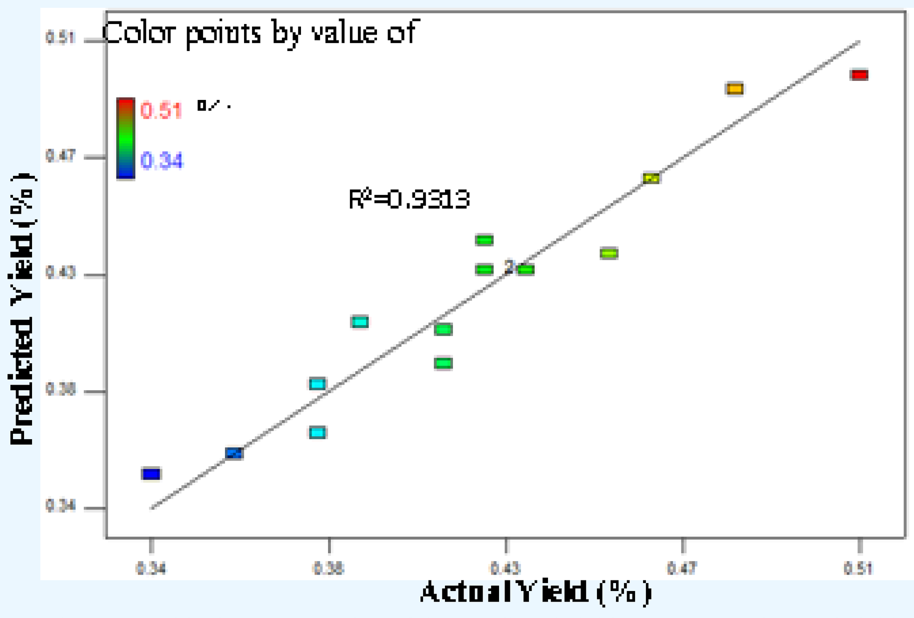


Fig. 1. Graphical representation of the predicted yield versus experimental yield

D. Parameters optimization

The application of the response surface methodology leads us to optimize the operating conditions of hydrodistillation of *Eucalyptus camaldulensis* essential oil for a better yield. The interpretation of the surface "*Fig. 2*" shows that the oil yield is proportional to the time extraction and condensation flow, and inversely proportional to the granulometry, and it is found that the optimal value of the yield (highest value) 0.52% is obtained by combining the following operating conditions : the smallest particle diameter (1mm), the longest extraction time (210min), and the high condensing flow (3,4ml/min). This maximum yield was not found experimentally but calculated theoretically by the Design-Expert7 software using the polynomial equation.

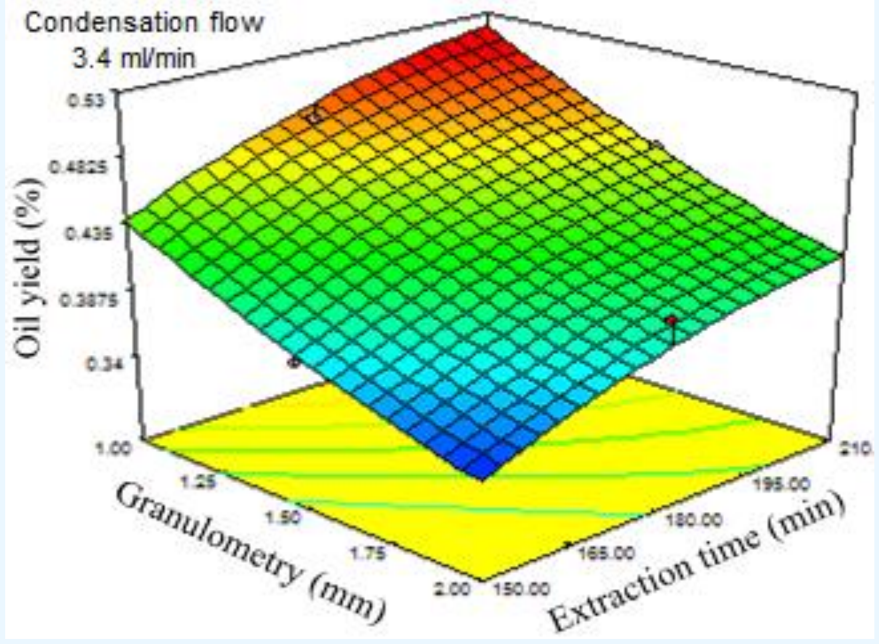


Fig. 2. 3D response surfaces to show the effect of the hydrodistillation parameters on the % oil yield : extraction time ; granulometry ; with condensation flow 3,4 ml/min.

CONCLUSION

The results of the study revealed that the essential oil of the plant species Eucalyptus camaldulensis can be easily extracted using the hydrodistillation technique, where the response surface methodology with a 3-factor Box-Behnken design has been applied to study and optimize the process. The high regression coefficients of the response R2=0.9313 with the model value *p*-value=0.0193 showed that the model developed was well adapted to the experimental data and the optimum value of the essential oil yield Y=0.52 % is obtained by combining the following operating conditions: granulometry (1mm), condensation flow (1.4ml/min) and extraction time of (210min).

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