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Kinetic Study and Optimization of Extraction Process Conditions

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Abstract

Optimization and advanced control of extraction processes are very important in the chemical engineering field for development of processes resulting in high yield with minimal costs of time and energy. In the present work, two extraction methods (hydrodistillation and volatile solvent extraction using a Soxhlet extractor) were performed on a medicinal plant (*Marrubium vulgare* L.). The influence of various operating parameters such as: (extraction temperatures, drying and grinding the plant, the solvent to solid mass ratio, the contact-time, and the nature of the solvent) on the extraction yield was studied in order to determine the operating conditions favorable to the realization of the extraction process, resulting in high yield. The optimum conditions were: the mass ratio, 3%; extraction time, 180 min; diameter of powder particles ($0.1<d_p<0.63$(mm)); The extraction temperature, 120°C; and the proportion of water pretreatment affected also on the yield extraction. Furthermore, a sigmoid model was proposed to describe the impact of increasing temperature on extraction yields.

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Keywords: Operating factors; Essential Oil; *Marrubium vulgare* L.

1. Introduction

Most things can be improved, so engineers and scientists optimize. While designing systems and products requires a deep understanding of influences that achieve desirable performance, the need for an efficient and systematic approach drives the need for optimization strategies [1].

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Plants have been the main source of medicines since ancient times [2]. They are applied in medicine, pharmaceutical botany and pharmacology as well as for food conservation thanks to their biological activities. *Marrubium vulgare*, commonly known as white horehound is herbaceous plant belonging Lamiaceae family; it is a well-known herbal medicine that is widespread in North Africa and cover vast territories valued at more than ten million hectares. *M. vulgare* is cultivated worldwide as a source for food flavoring and for medicinal purposes [3-5]. Traditionally, it has been used for acute or chronic bronchitis, whooping cough, and specifically for bronchitis with non-productive cough [6]. Thanks to the great importance of this medicinal plant, it has been the purpose of several previous researches that has especially marked its antibacterial, antifungal, and antioxidant proprieties. Among the newest reviews: the paper of [7] deals the composition and antibacterial activity of *M. vulgare* E.O from Eastern Algeria, authors in [3] have reported in their paper the larvicidal effect of *M. vulgare* extract.

Essential oils are isolated using a number of methods, it has been found that their properties vary and depend on the method used [8]. Since concentrations of bioactive compounds in extracts are usually low, efforts are made to increase the extract yield while keeping the process cost as low as possible [9]. From the technological point of view, the important operating variables such as extracting solvent, solvent to solid ratio, temperature, and extraction time should be optimized for increasing the extraction yield. Therefore, Artificial Intelligence has been used to solve different optimization problems [1, 9, 10-15].

This work aims to perform the optimization of some factors influencing the extraction yield by HD and EVS using soxhlet apparatus as well as the kinetic studies in order to improve the operating efficiency and maximize the performance of the extraction process and reduce the costs and energy consumption by analyzing the variation of process yield with time.

Nomenclature

A_1	Lowest asymptotic value
A_2	Highest asymptotic value
d_p	Diameter of plant particles [mm]
P	Mass ratio
R^2	Correlation coefficient
T_1	Steepness of the Boltzmann sigmoid curve

2. Material and Methods

2.1. Plant material

Mature whole *Marrubium vulgare* L. plant was collected in northern Algeria. The plant material was dried to constant weight in the drying oven, which was kept at a temperature of 30°C, for 6 days and then stored in a dry place prior to use. An experimental program has been carried out in our laboratory, involving extraction processes (HD and EVS) as well as the study operating conditions effect on the E.O yield. The overall steps are summarized in the processes description (Fig.1).

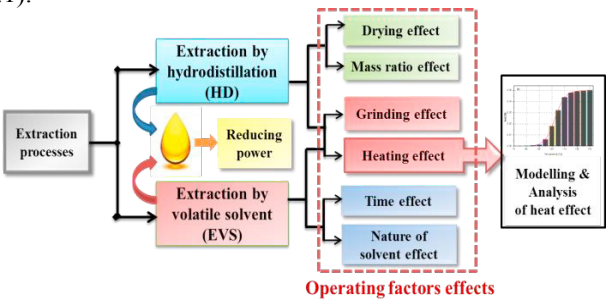

Fig. 1. Schema of experimental procedure.