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Microwave-Assisted Extraction of Total Bioactive Saponin From Sapindus Mukorossi: Characterization and Evaluation Of Solubilization Properties

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ABSTRACT

Various industrial processes produce oily wastewater that must be removed before discharge to sewers or surface waters. As a result, researchers have been investigating the use of natural surfactants to solve this problem. Among these surfactants, biosurfactants have received considerable attention due to their eco-friendly and non-toxic properties, making them a desirable substitute for synthetic surfactants. This study specifically aimed to extract and characterize a natural surfactant called saponin from Sapindus mukorossi and study its ability to solubilize naphthalene. New extraction technique, specifically using environmentally friendly microwave-assisted extraction (MAE), have been designed to extract saponins from Sapindus mukorossi. The microwave-assisted green extraction method was found to produce the highest amount of saponins from the source material. The resulting saponin, identified as a bioactive product, underwent purification and characterization by infrared and UV-visible spectroscopy to validate its surfactant properties and verify its qualitative composition. Quantification of saponins was carried out by HPLC and a more detailed examination was carried out by LC-ESI/MS. In this study, we also investigated the micellar solubilization of naphthalene in saponin micelles, focusing on the effects of pH and NaCl. It was observed that the adsorption of naphthalene onto saponin micelle aggregates plays an important role in enhancing solubilization. Saponins are very effective in enhancing the solubilization of naphthalene and have potential applications in the removal of organic pollutants from contaminated soil and wastewater.

Keywords: Extraction; Saponin; Sapindus Mukorossi; biosurfactant; solubilization.

1 Introduction

Contamination of soil and groundwater by toxic and hazardous organic compounds is a serious environmental problem, requiring increased attention to the removal of hydrophobic organic compounds (HOCs) from these sources. Surfactants increase the solubility of HOC in the aqueous phase by incorporating the HOC compounds into the hydrophobic core of surfactant micelles, providing a viable solution [1]. In response to the environmental concerns associated with synthetic surfactants, significant efforts have been made to develop natural biosurfactants from plants, animals, or microorganisms [2]. Plant saponins are one of the biosufactants that has attracted much interest from researchers due to their excellent functional properties and health benefits, as well as environmental sustainability, biodegradability and renewable potential. Sapindus mukorossi, known as Reeta or soapnut fruit, is a major source of saponins and is widely cultivated in India and other subcontinents of Asia [3]. Considering the potential of saponins as important substances, great efforts have been made to obtain saponin-rich extracts. Generally, the techniques used to obtain saponins can be divided into two categories: conventional techniques and environmentally friendly techniques. Traditional extraction techniques such as maceration extraction (ME) have been found to be inefficient extraction methods due to low diffusivity, high solvent requirements, and long extraction times [4]. Nevertheless, microwave-assisted extraction (MAE), which is a kind of eco-friendly technology according to the requirements of environmental protection, is widely used in laboratory settings, with short time, high applicability, and solvent It has many advantages over traditional extraction methods, such as high extraction rate of active components [5]. The aim of this study is to investigate the influence of extraction parameters on the yield of saponins obtained from the pericarp of Sapindus

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mukorossi. In particular, this study includes a comparison of extraction methods under different conditions, including traditional solid-liquid methods and environmentally friendly approaches. The study also includes characterization of the extracted saponins. Additionally, this study also features the investigation of saponin's properties as a surfactant and its ability to dissolve naphthalene.

2 Experimental

Dry fruits of Sapindus were obtained from the city of Sidi Bel Abbes, Algeria. The main factors influencing the extraction of saponins, such as extraction solvents, temperature, time, and material ratios (fruit pulp weight: extraction solvent volume), were individually studied. A comparison was made between conventional solid-liquid extraction and green extraction methods under various conditions.The saponin product obtained is subjected to characterization through infrared and UV-visible spectroscopy to confirm its surfactant properties and determine its qualitative composition. Saponins was quantified by HPLC and qualitated further by LC-ESI/MS to evaluate the extraction yields of total saponins. The effect of solution pH on the solubilization of dyes was investigated within the pH range of 3 to 12. The pH of aqueous reetha solution was maintained by adding the appropriate amount of 0.1M HCl and 0.1M NaOH to the solution. Also, the effect of NaCl salt concentration in surfactant solution (10 - 50 gL^{-1}) on solubilization of naphthalene were examined.

3 Results and Discussion

Microwave assisted extraction reaches its maximum yield in a significantly shorter time than maceration. The highest saponin yield is achieved in 6 minutes with microwave assisted extraction, while maceration takes 180 minutes to reach its maximum yield. The FTIR transmission spectrum of pure saponin was analyzed, revealing features such as hydroxyl group (-OH) stretching to 3455 cm^{-1}, carbon-hydrogen (-CH_2) stretching to 2068 cm^{-1}, and C=O stretching to 1639 cm^{-1}. In addition, the transmission spectra of the C-O-C and carboxylic ester groups were observed at 1062 cm^{-1}, with C=C observed at 677 cm^{-1}. The non-ionic saponin showed UV absorption in the range 290 to 240 nm, with a maximum absorbance at 267 nm. For the determination of the composition of the saponin extract of S. mukorossi, HPLC and ESI-MS was performed in positive and negative ion modes, briefly peak times for glycosides ranging from 4 to 10 minutes, while peaks appearing between 10 and 20 minutes mainly represented triterpenoid saponins. The aggregation and solubilization capacities of saponin micelles for naphthalene can be influenced by variations in ionic strength and pH.

4 Conclusions

A highly efficient microwave assisted extraction process has been designed to extract the total saponins of Sapindus mukorossi. This method demonstrated a shorter extraction time and gave a higher extraction efficiency compared to other techniques. The characterization of the extract through physicochemical analysis methods confirmed the properties of saponins, indicating their potential as an ecological alternative to conventional synthetic surfactants. Moreover, the results highlight the potential applications of saponin in environmental processes.

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