



Microwave-assisted hydrodistillation of essential oil from fennel seeds: Optimization using Plackett–Burman design and response surface methodology

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ABSTRACT

The study aims to optimize the microwave-assisted hydrodistillation (MAHD) of *Foeniculum vulgare* seed essential oil (FSEO), for the purposes of maximizing efficiency and reducing costs in terms of time and energy. Plackett–Burman design (PBD) was investigated to screen the six different variables affecting FSEO extraction and select the most significant ones. Response Surface Methodology (RSM) was used to evaluate the interactions of the significant parameters and to determine optimal conditions. MAHD and the traditional hydrodistillation (HD) techniques were compared in terms of extraction efficiency, economic and environmental impacts, and chemical composition of the FSEO. The optimum conditions of the studied responses were particle size less than 333.4673 µm, at the irradiation time of 20 min and a microwave power of 305.9282 W with a solid-liquid ratio of 0.1477 g/mL. Gas Chromatography (GC) analysis showed that the FSEO composition in MAHD and HD is similar with slight differences. Therefore, the results show that the microwave-assisted hydrodistillation method is an innovative, economical and environmentally friendly approach to efficiently and safely extract essential oil an economic and green innovative approach to extract efficiently and safely the essential oil (EO).

1. Introduction

Foeniculum vulgare, commonly known as fennel, is an aromatic plant from Mediterranean regions. It is renowned for its wide use in several fields (Malo et al., 2012) and it is generally used in traditional medicine and recommended for abdominal and neurological disorders, vomiting and diarrhea as well as kidney stones. Moreover, it is considered an excellent carminative and antispasmodic plant; it also has antiulcer and antiseptic properties (Shahat et al., 2012). Fennel seeds are commonly used in culinary preparations for its various health-promoting compounds such as minerals and vitamins (Salama et al., 2015). It is also used in the perfumery, cosmetic, pharmaceutical and food industries, mainly in beverages and confectionery (Sayed Ahmad et al., 2018). FSEO have been used as an antioxidant, anti-inflammatory and antimicrobial agent (Benmoussa et al., 2019).

Moser et al. (2014) determined that the maximum yield of fennel seeds is 1.37 %. Recently, González-Rivera et al. (2016) noted that fennel seeds contain 0.75 % EO. Fennel has a characteristic flavor due to its high EO content; the main components of FSEO are Trans-anethole, Fenchone, Estragole and α -Phellandrene (Rather et al., 2016). Several studies have shown that FSEO has considerable chemo-diversity depending on the geographical origin and extraction method (Kapoor et al., 2004 and Gross et al., 2009). Extraction is a necessary step to obtain EO and the choice of the extraction method plays a significant role in the yield and EO constitution. Therefore, it is important to choose a method that gives maximum yield with minimum change in the functional properties of the extracted EO (Ullah et al., 2019).

Several methods are traditionally and widely used to obtain EO from the plant and the main methods are hydrodistillation, steam distillation, maceration and expression (Golmakani and Rezaei, 2008). However,

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