Extraction of fennel essential oil (*Foeniculum vulgare* M.): method, chemical composition, and kinetic model

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Abstract

Fennel (*Foeniculum vulgare* M.) is one of the most commonly used and extensively studied medicinal herbs worldwide. Many researchers report multitudinous health benefits. This study used hydrodistillation (HD) and microwave-assisted hydrodistillation (MAHD) methods to extract fennel essential oil. Parameters affecting the process such as material-to-water ratio, heater power, and distillation time were investigated. Both techniques achieved the highest yield (1.9%) at a material-to-water ratio of 1:6, heater power of 350 W (HD), and 1080 W (MAHD). Under these conditions, the two-site desorption model showed compatibility, i.e., the extraction process included two stages of breaking essential oil particles and diffusing them from plant cells. Chemical composition analysis showed fennel essential oil contained four main components: anethole (58.76%), estragole (26.55%), terpinolene (8.32%), and D-limonene (4.66%). Among them, anethole is the main scent compound of fennel seed oil and exhibits anticancer activity.

Introduction

Foeniculum vulgare, commonly known as fennel, belongs to the Apiaceae family [1]. It is a prevalent traditional medicinal herb used by humans for a long time. Fennel is used as a seasoning herb. Being aromatic, all parts are used in cooking [2]. It is used to improve the palatability of meat and fish dishes. And it can be used raw in salads and shakes, as a spice, in herbal teas, as a mouth freshener, etc.

Figure 1. *Foeniculum vulgare* plant, flowers and seeds [3].

Multitudinous pharmaceutical applications [4]:

- ✓ Anti-oxidation
- ✓ Anti-inflammation
- ✓ Anti-pyretic
- ✓ Anti-allergic
- ✓ Antibacterial
- ✓ Antifungal
- ✓ Antiviral
- ✓ Anti-colitic
- ✓ Antistress
- ✓ Anxiolytic
- ✓ Diuretic

The kinetic model was used to evaluate variable parameters affecting the hydrodistillation process. From there, we can calculate the required cost of material, energy, labor, and essential oil obtained for a batch.

Methods and Materials

Extraction methods

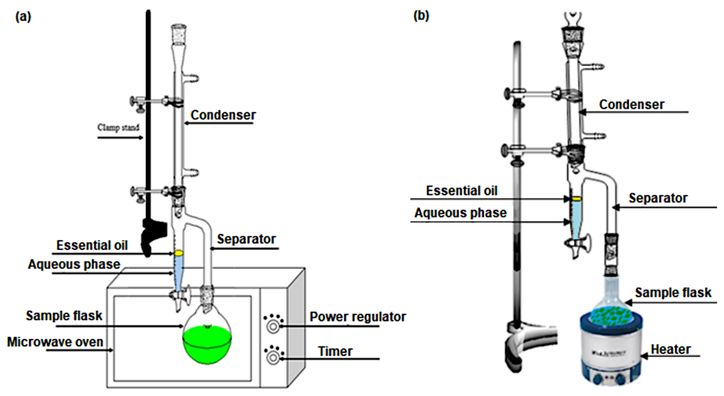

Figure 2. Extraction methods (a) microwave-assisted hydrodistillation and (b) hydrodistillation [5].

Kinetic models

✓ One-site desorption model:

$$\frac{q}{q_o} = 1 - e^{-kt}$$

✓ Two-site desorption model:

$$\frac{q}{q_o} = 1 - Fe^{-k_1 t} - (1 - F)\, e^{-k_2 t}$$

Analytical methods

Moisture content | Density | Chemical composition

Conclusions

In this study, fennel essential oil was obtained by hydrodistillation and microwave-assisted hydrodistillation. Parameters affecting the distillation process such as material-to-water ratio, heater power, and distillation time were investigated. Both methods achieved the highest yield (1.9%) at the material-to-water ratio of 1:6. However, heater power was 350 (HD) and 1080 W (MAHD). Simultaneously, distillation time was 135 (HD) and 95 mins (MAHD).

Fennel essential oil was light yellow and had a characteristic odor. The main components of essential oil were anethole (58.76%), estragole (26.55%), terpinolene (8.32%), and D-limonene (4.66%). Two kinetic models were also proposed to check compatibility with experiments. The results showed two-site desorption model was more suitable, i.e., the extraction process included two stages of breaking essential oil particles and diffusing them from plant cells.

Results

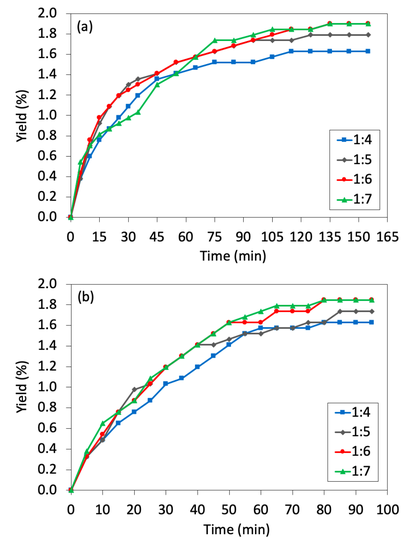

Figure 3. Effect of material-to-water ratio on yield in (a) HD and (b) MAHD.

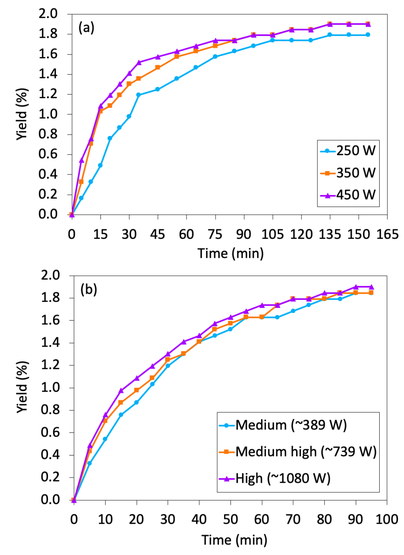

Figure 4. Effect of heater power on yield in (a) HD and (b) MAHD.

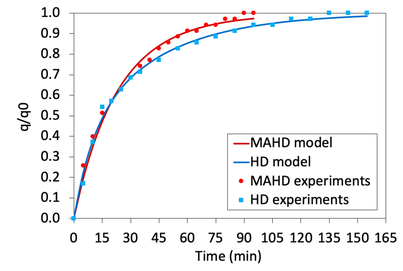

Figure 5. Two-site desorption model fit for HD and MAHD.

Table 1. Kinetic model fit for different extraction methods

Method	one-site desorption model			two-site desorption model				
	k min^{-1}	SSE	R^2	k_1 min^{-1}	k_2 min^{-1}	F	SSE	R^2
HD	0.038	0.033	0.985	0.024	0.099	0.603	0.008	0.995
MAHD	0.041	0.016	0.991	0.032	0.054	0.490	0.014	0.992

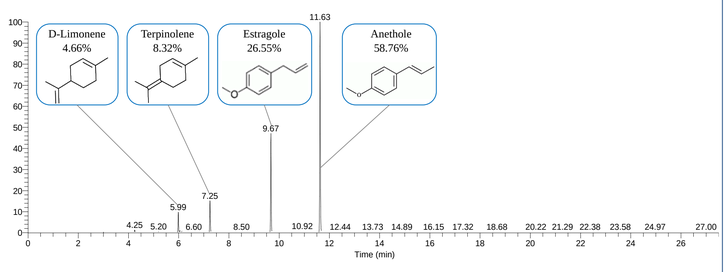

Figure 6. GC-MS spectrum of fennel essential oil

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