Influence of electromagnetic field on the extraction efficiency of essential oils from the howthorn (Crataegus monogyna)

I M Naghiu[1], P A Pop[2] and C Tripe Vidican[2]

[1] Doctoral School of Industrial Engineering, University of Oradea

[2] Faculty of Management and Technological Engineering, Department of Robotics and Mechatronics, University of Oradea, 1 Universității Str., Oradea, 410087, Romania

E-mail: iuliananaghiu@gmail.com

Abstract. The paper presents a study on the influence of electromagnetic field power on the hydroalcoholic extraction process from hawthorn (Crataegus monogyna) leaves and flowers. Microwave-assisted extraction was performed at three power levels (50 W, 100 W, and 150 W) using 60° ethyl alcohol as the solvent to evaluate how electromagnetic energy accelerates mass transfer and the solubilization of bioactive compounds. The samples underwent preliminary maceration, followed by exposure to the electromagnetic field, and the extracts were monitored for visible and gravimetric changes to assess the progress of the process. The results indicate that an increase in magnetron power is due to an intensified extraction. The extracts become more concentrated and more intensely colored as the applied energy increases. The study proposes a rapid, efficient, and accessible technique for obtaining hydroalcoholic extracts from hawthorn, with potential applications in phytochemical research and in the natural products industry.

1. Introduction

The medicinal plants represent an important source of bioactive compounds, while the modern extraction methods have been significantly evaluated in the last two decades. Crataegus monogyna (hawthorn) is recognized for its high levels of flavonoids, polyphenols, and volatile compounds, and is used in phytotherapy, cosmetics, and nutritional supplements. [1], [2], [3], [4], [5]. [6], [7],[8], [9].

Hawthorn (Crataegus monogyna) represents one of the European medicinal plants studied due to its high flavonoid content, triterpenoid acids, proanthocyanidins, and volatile compounds with cardioprotective aims. Its essential oils and hydroalcoholic extracts are used in the pharma, food, and cosmetic industry, and have antioxidant, anti-inflammatory, and vasodilator properties. However, the efficiency of volatile compounds depends of extraction method.

The technological progresses had getting into microwave-assisted extraction (MAE), which is an efficient, fast, and green technique. This accelerates the process by volumetric heat, that generating a raising of diffusion and an effusion fracture of cellular walls [1], [4], [7].

The traditional methods, such as hydrodynamic distillation, simple maceration, or Soxhlet extraction, are efficient but require high temperatures and can degrade thermolabile compounds. In the last decade, microwave-assisted extraction of high-frequency has established itself as a modern, fast, and efficient technique, offering a uniform volumetric heat and an accelerated mass transfer.

The use of electromagnetic fields in the extraction of essential oils allows the reduction of solvent consumption, total worktime, and increases efficiency for the achievement of volatile compounds. The interaction between electromagnetic waves and polar molecules facilitates the orientation of dipoles and rapid heat of vegetal material due to the breaking of cellular walls and the release of active substances.

There are many studies into specialty literature dedicated aromatics plants such as lavender, mint, oregano, or coriander. However, the research on assisted extraction of the electromagnetic field applied to species of Crataegus is limited. This data missing justifies the necessity of studying hawthorn for the evaluation of the different powers of magnetron effects on final efficiency.

Comparatively with conventional extractions (Soxhlet maceration), the MAE represents:

- Short time of processing,
- Minimal consumption of solvent,
- Superior efficiency,
- Protection of sensitive compounds at temperature [3], [13].

The hawthorn by MAE is less studied, but recent studies from 2025 confirmed the method's efficiency in polyphenols and aromatic compounds extraction [1].

The goal of this study is the evaluation of electromagnetic field power influence on extraction efficiency from leaves and flowers of hawthorn by using 60° ethyl alcohol as solvent.

2. Materials and method

2.1. Vegetal material

The vegetal material used consists of dried leaves and flowers of hawthorn (*Crataegus monogyna*), which are hand-harvested and naturally dried at room temperature and in well-ventilated conditions. After drying, the material was shredded to increase the contact surface with the solvent. The phytochemistry profile of hawthorn is documented in numerous studies [8], [10].

2.2. Solvent used

The extraction of volatile compounds requires a solvent that solubilizes both hydrophobic fractions and soluble. It was chosen 60° ethyl alcohol for:

- Excellent solubility of essential oils in ethanol, unlike distilled water, which doesn't dissolve lipophilic compounds [11], [12].
- Optimal compound in electromagnetic field, evaporates fast and facilitates the breaking of cellular walls [4], [7].
- Safety and green character, being a natural solvent, biodegradable, used on a large scale in the food industry [11].
- Increased efficiency in the extraction of bioactive compounds from medicinal plants [14].

This combination makes it 60° ethyl alcohol to be the preferred solvent of MAE in modern studies [6], [12]. The samples were covered with 50 ml of solvent and left to soak for 60 min at room temperature to promote complete wetting and preliminary diffusion of the compounds.

2.3. Equipment and experimental conditions

The extraction was realized with a system based on a magnetron, which had the following characteristics:

- Frequency: 2.45 GHz
- Power used: 50 W, 100 W, and 150 W
- Recipient, borosilicate glass
- Cooling system for condensing ethanol vapours.

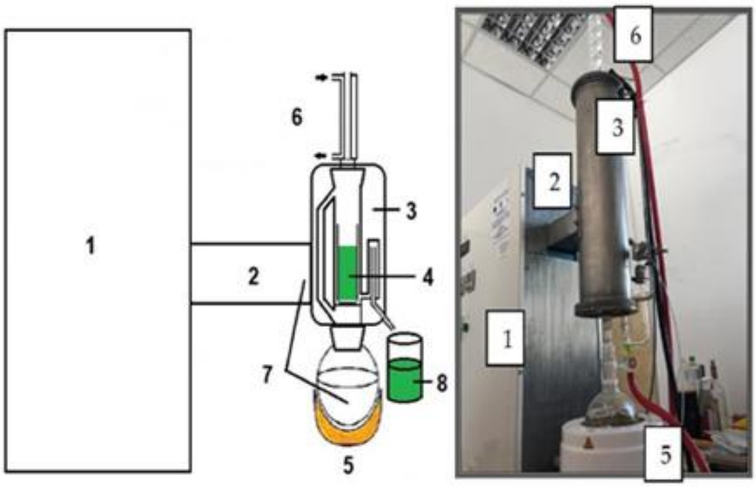

Figure 1. System designed for the extraction of volatile oils: 1- microwave generator. 2- microwave guide, 3- applicator, 4- hawthorn sample, 5- extraction solvent heating nest, 6- steam condensers, 7- extraction solvent, and 8—extract. [15]

MAE is preferred for its thermal stability and short time for processing, which has been confirmed in many studies [1], [3], [5].

The heating by microwaves allows a direct energy transfer to polar molecules of solvent, generating a uniform volumetric heat, essential for acceleration of the extraction process.

2.4. Proceeding of extraction

For each sample, the following steps are taken:

- 20 g of leaves or flowers were weighed.
- 200 ml of 60° ethanol was added (report of 1:10).
- The sample was subjected to magnetic fields at different powers (50 / 100 / 150 W), after left to soak for 60 min.
- Extraction time: 10-12 min.
- The filtrated extract was weighed to calculate the efficiency.

The macerated samples were introduced into the magnetron chamber and subjected to extraction at three power levels.

- 50 W – slow extraction, corresponding to a moderate heat.
- 100 W - average extraction, characterized by an equilibrium between intensity and stability.
- 150 W – intense extraction with rapid release of active compounds.

The exposure time was maintained constant for all samples. During the process, the solvent and vegetal material were subjected to a uniform heat process that promotes the penetration of ethanol into plant tissues and breaks cell walls, facilitating the release of active compounds. Similar methods are used in international studies [1], [2], [13].

2.5. Determination of efficiency

The extraction efficiency was expressed in percentage for :

$$R(\%) = \frac{m_{\text{extract}}}{m_{\text{vegetal material}}} \times 100 \quad (1)$$

This indicator allowed the comparison of extraction efficiency in function of:

- Type of vegetal material (leaves vs. flowers).
- Magnetron power
- Type of solvent (60° ethyl alcohol)

3. Results and discussions

3.1. Efficiency obtained

The results of efficiency obtained after extraction are shown in Tab. 1.

Table 1. Efficiency obtained after extraction

Power	Leaves (%)	Flowers (%)
50 W	4.2	5.8
100 W	6.7	8.9
150 W	9.8	12.5

The ascending tendency confirms the data on literature about the increasing efficiency of the MAE increases with electromagnetic field power [1], [4], [13].

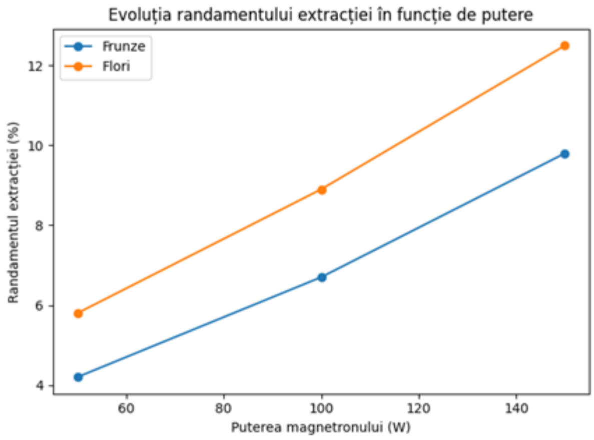

Figure 2. The evolution of extraction efficiency as a function of power magnetron for leaves and flowers of dried hawthorn,

This behaviour can be explained by specific mechanisms of microwave-assisted extraction, such as:

- Increase in internal temperature determines the extension of the solvent and increases the pressure within vegetal cells.
- Fast orientation of dipoles accelerates the energy transfer in a hydroalcoholic solvent.
- Breakdown of cell walls promotes the release of volatile compounds and polyphenolics.
- Uniform volumetric heat reduces the thermal losses and accelerates the process.

At low power (50 W), these effects are limited, which explains the modest efficiency.

At an average power (100 W), the process becomes efficient, and at 150 W, the applied energy produces fast and profound extraction.

3.2. Differences between leaves and flowers
The experiment results showed that the flowers had superior efficiency with 20-30%, because of:

- More great content of aromatic compounds.
- Increased structural permeability
- Density of secretory glands.[8], [10].

3.3. Influence of electromagnetic field
The experiment results indicated that increasing the power from 50 W to 150 W has led to:

- Doubling the efficiency at leaves,
- Increasing by up to 100% at leaves.

A similar behaviour was found in the studies of MAE applied to aromatic plants [2], [5].

4. Conclusions

The study confirms that microwave-assisted extraction using 60° ethyl alcohol is an efficient method for the extraction of bioactive compounds from hawthorn. The magnetron power significantly influences the efficiency, and the flowers represent a rich source, like leaves. So, the important aim of electromagnetic field power stands out in the hydroalcoholic extraction process from leaves and flowers of hawthorn (*Crataegus monogyna*). The results obtained show a clear increasing of extraction efficiency that confirms the efficiency of the waves-assisted extraction technique in the mobilization of bioactive compounds from vegetal material.

At low power (50 W), the extraction process had a slow evolution, in a similar mode of accelerated maceration, the volume of transferred compounds being moderate. At an average power (100 W), it is observed that a visible increasing of efficiency, and at maximum power used in the study (150 W), the extraction becomes intense, generating the extracts more concentrated, with a greater load of polyphenolic and volatile compounds.

The constant differences between the extracts obtained from leaves and flowers are due to the histological characteristics of vegetative tissues. This is in concordance with the specialty literature that signals a rapid extraction into the structural flower due to more fragile tissues and higher content of volatile compounds.

Although the used method is one simplified without supplementary steps of filtering or separation of volatile fractions, the results obtained are relevant for preliminary characterization of hawthorn within an electromagnetic field. So, this paper offers a valuable starting point for the next research, which can be inserted with advanced analysis methods (GC–MS, HPLC), proceedings of separation and optimization of technological parameters.

In conclusion, the hydroalcoholic-assisted extraction by the electromagnetic field represents a modern, fast, and efficient method with high potential of application in the natural products industry and in phytochemical research. The results of this study support the development of innovation processes that can be the basis of next applications in the phytotherapy field and in the processing of vegetable raw materials.

References

[1] A.I. Gavrila et al., “Optimization of microwave-assisted extraction of polyphenols from Crataegus monogyna L.,” Antioxidants, vol. 14, no. 3, p. 357, 2025.

[2] N.A.T. Le et al., “Evaluating microwave-assisted extraction of Elsholtzia Cristata essential oils: Efficiency, chemical profile and antibacterial activity” Current Microwave Chemistry, 2023.

[3] D. Iordache, D. Niculae, F.I. Hathazi, Utilization of microwave energy for decontamination of oil-polluted soils, Journal of Microwave Power and Electromagnetic Energy, Volume: 44, Issue: 4, Pages: 213-221, 2010, ISSN: 0832-7823.

[4] H. Alkadi, M. Albasha, and M. Alkadi, “Recent advances in microwave-assisted extraction of bioactive compounds from complex herbal: A review” Journal of Herbal Medicine, vol.41, October 2023, doi 10.1016/j.hermed.2023.100693.

[5] C. Proestos, “Ultrasound and microwave-assisted extraction of phenolic compounds from Mediterranean herbs” Chemistry Proceedings, 2021.
[6] A. Azmir et al., “Techniques for extraction of bioactive compounds,” CEP, vol. 124, 2020.
[7] A. Lucchesi et al., “Solvent-free microwave extraction,” J. Chromatogr. A, 2021.
[8] D. Munteanu and N. Stan, “Phytochemical composition of Crataegus monogyna,” Plants, 2021.
[9] M. S. Ivănescu et al., “Comparative study of hawthorn extracts,” Farmacia, 2022.
[10] T. Ștefănuț, “Flavonoids and phenolic acids in Crataegus,” 2021.
[11] S. C. Moldoveanu, “Solvent extraction of natural products,” J. Chromatogr. Sci., 2020.
[12] G. Brunner, “Hydroalcoholic extraction of herbal materials” Sep. Sci. Technol., 2022.
[13] S. Bousbia et al., “Comparison of extraction methods,” J. Food Eng., 2020.
[14] C. S. López et al., “Ethanol-Based extraction of bioactives” JARMAP, 2023
[15] L. Bandici, A.C. Teusdea, V.D. Soproni, F.I. Hathazi, et al., The influence of microwave treatments on bioactivecompounds and antioxidant capacity of mentha piperita L., Materials 2022, 15, 7789.