JOURNAL OF AGRICULTURE AND APPLIED BIOLOGY
2025, Vol. 6, No. 2, 210 - 221
http://dx.doi.org/10.11594/jaab.06.02.06
E-ISSN: 2723-5106

Research Article

Effect of pulsed electric field on yield and absorption of *Basil* essential oil

Abdelkader Baghdad[1], Abdelkader Elkebir[2], Kaddour Miloudi[1, 3*], Fouad Kherbouche[1], Youcef Benmimoun[1], Abderrahmane Hamimed[3]

[1]Laboratory of Science and Technology of Water, University of Mascara, Algeria
[2]Department of Electrical Engineering, Faculty of Science and Technology, University of Mascara, Algeria
[3]Laboratory of Biological Systems and Geomatics Research, University of Mascara, Algeria

Article history:

Received 30 December 2024
Revised 10 February 2025
Accepted 11 February 2025
Published 07 May 2025

Keywords:

Absorbance
Essential oil
Extraction
Leaves
Pulsed electric field

***Corresponding author:**

E-mail:
miloudi.kaddour@univ-mascara.dz

Abstract

This experimental study was conducted to investigate the qualitative and quantitative variations of pulsed electric field (PEF) application on the extraction of basil essential oil. This method is presented as non-thermal technique for permeabilizing plant tissue membranes, thereby improving extraction yield and efficiency. Optimal PEF energy levels can significantly improve oil yield without compromising quality, making it a valuable technique for industrial applications. The tests were carried out with a laboratory-scale installation that includes a high-voltage pulse generator generating exponential decay wave pulses at a frequency of 1 Hz. After treatment with a pulsed electric field (PEF) with an intensity of 2 $kV.cm^{-1}$, a specific energy of 5 $kJ.kg^{-1}$ and a 60-minute distillation, the yield of basil EO increased from 0.63% (control) to 0.82%, an increase of 30.16%. However, when the basil leaves were treated with a very high specific energy PEF (50 $kJ.kg^{-1}$), a non-significant increase in EO yield compared to the control was observed. The relatively low energy consumption and the processing speed enabled by the PEF technique represent a major asset for the processing of plant raw materials. The study of the effect of pulsed electric field (PEF) on the absorbance of basil EO revealed an increase in the absorption of essential oils when applying PEF at moderate specific energies. High absorbance, as in the case of basil essential oil treated with a PEF of 2 $kV.cm^{-1}$ and a specific energy of 10 $kJ.kg^{-1}$, indicates that the sample has a high reducing power. This is important for quality control of essential oils in industry.

How to cite:
Baghdad, A., Elkebir, A., Miloudi, K., Kherbouche, F., Benmimoun, Y., & Hamimed, A. (2025). Effect of pulsed electric field on yield and absorption of *Basil* essential oil. *Journal of Agriculture and Applied Biology, 6*(2): 210 - 221. doi: 10.11594/jaab.06.02.06

1. Introduction

Essential oils (EOs) have diverse applications in industries such as pharmaceuticals, food, cosmetics, and agriculture due to their antimicrobial, antioxidant, anti-inflammatory, antiviral, and aromatic properties (Al-Refaie et al., 2023; Salanță & Cropotova, 2022; Sharma et al., 2023). Their bioactive compounds contribute to therapeutic benefits, including pathogen inhibition, oxidative stress reduction, and immune support (Hassid et al., 2024; Hou et al., 2022; Prakash et al., 2024). Additionally, their aromatic qualities enhance personal care products and aromatherapy, promoting mental well-being.

EOs are used in the agricultural sector as natural substitutes for synthetic pesticides and herbicides (Bolouri et al., 2022) and as green insecticides Owing to their minimal impact on the environment. (Popescu et al., 2024) . Additionally, EOs play a role in preventing preharvest sprouting in crops like wheat and barley, contributing to improved yield and quality in agriculture (Bolouri et al., 2022). The application includes pest control management due to their bioactivities (Kiruthika & Vishali, 2023; Prakash et al., 2024).

Research indicates that EOs have the ability to biodegrade into non-toxic compounds, making them a promising option for developing safer pesticide formulations in agriculture (Assadpour et al., 2024). Additionally, they can help prevent preharvest sprouting in crops like wheat and barley, contributing to improved yield and quality in agriculture (Bolouri et al., 2022), and their components can serve as beneficial food supplements, potentially enhancing growth in livestock (Wike et al., 2024).

Basil essential oil (BEO), derived from *Ocimum basilicum*, is a versatile product with a wide range of industrial applications. BEO is used in food packaging to extend shelf life due to its antimicrobial properties (Amor et al., 2021) . Additionally, BEO treatments on tomatoes have shown to reduce microbial growth and maintain quality during storage, demonstrating its potential as a natural preservative (Ionica et al., 2022). Its application in fruit production chains helps in maintaining fruit quality and reducing spoilage (Tangpao et al., 2022).

The aromatic properties of *basil* essential oil make it a popular choice for flavoring in culinary applications. Its use in enhancing the taste and aroma of food products is well documented, contributing to its demand in the food industry (Alexandre et al., 2021). In agriculture, *basil* essential oil serves as a natural pesticide and fungicide. It has shown effectiveness against storage fungi and pests, offering an eco-friendly alternative to synthetic chemicals (Torre et al., 2021). Its repellent activity against insects like cockroaches further underscores its utility in pest management (Nour et al., 2022).

Essential oil refers to a product derived from vegetable material, acquired either by water or steam distillation, mechanical extraction From the peel of citrus fruits., or dry distillation, using just physical methods (ISO 9235, 1997), (Turek & Stintzing, 2013). Distillation is the most commonly used extraction method (Richard & Multon, 1992) . Traditional essential oil extraction techniques require significant adaptations in order to reduce investment costs, increase extraction yield, minimize production costs and protect the environment (Miloudi et al., 2018).

Advanced extraction techniques are more environmentally friendly, more efficient, and offer higher yields than conventional methods that often result in loss of volatile compounds due to prolonged exposure to heat (Azmir et al., 2013; Crescente et al., 2023). The use of alternative techniques such as pulsed electric field (PEF) treatment is a solution proposed to enable the maintenance and economic development of this field (Barros et al., 2022; Hadri et al., 2023; Miloudi et al., 2022; Yajun et al., 2017).

PEF has been studied as an unconventional method to improve the overall yield and selectivity of bioactive components from plant materials (Azmir et al., 2013; Theagarajan et al., 2024; Toepfl et al., 2006). PEF is considered a green technology and non-thermal technology due to its reduced energy and solvent requirements (Feng et al., 2022; Hernández-Corroto et al., 2023; Tintchev et al., 2012). The technology involves applying brief pulses of high-voltage electric fields to material placed between two electrodes (Dobreva et al., 2013; Feng et al., 2022), which permeabilize cell membranes, without significant heat production, thus maintaining the quality of heat-sensitive products (Oey et al., 2022). This process known as electroporation, leading to various applications across different fields such as medicine, food processing, and agriculture (Jeong et al., 2024; Qu et al., 2023; Shorstkii et al., 2023).

Economically, PEF can reduce processing costs by minimizing energy consumption and preserving product quality (Miloudi et al., 2022), which can lead to longer shelf life and reduced waste (Jeong et al., 2024), is recognized also for its efficiency, sustainability, low heat generation and ability to preserve the quality of the extracted oils (Oey et al., 2022). PEF is applied of essential oils of *eucalyptus* and *rosemary* (Barros et al., 2022), *Mentha spicata* (Miloudi et al., 2022), *Marrubium vulgare* (Miloudi et al., 2018), *Rose* (Yajun et al., 2017) , *Lavender* (Hadri et al., 2023), *Rose Blossom* (Tintchev et al., 2012) and *Nepeta* (Dobreva et al., 2013). The quality and the composition of the treated essential oils is not affected (Sharma et al., 2023).

The assessment of essential oil quality using absorption techniques employs advanced methodologies that improve accuracy and efficiency. These techniques analyze light interactions with the oils to determine their absorption properties, providing critical insights for quality evaluation (Semenova et al., 2017) .

This study aimed to examine the impact of PEF treatment on the yield and absorption of basil essential oil. Unlike conventional hydrodistillation, the proposed method incorporated factors such as electric field intensity and specific energy to enhance extraction efficiency while maintaining oil quality.

2. Materials and methods

2.1 Plant material

Basil (*Ocimum L.*) (Family Lamiaceae) is known for its aroma and pleasant taste, including 50–60 species, which are widely distributed across the globe (Mulugeta et al., 2024). Dried basil leaves used in the study were purchased from a herbalist in Mascara (North-western Algeria) in July 2024. We did not try to comminute them to avoid the loss of volatiles as was observed and indicate by Adaşoğlu et al. (1994) and Reverchon et al. (1995). In addition, the distillation has performed on the same lot of material.

2.2 Essential oil (EO) extraction

The experimental bench and methodology of essential oil extraction used in this work were previously detailed by Miloudi et al. (2018) and Miloudi et al. (2022). Dried *Basil* leaf samples were subjected to hydrodistillation using a Clevenger-type apparatus, standardized according to the European Pharmacopoeia.

Multiple distillations were performed by boiling 30 g of dried plant material in water for 60 min in a 2-litre flask. The extracted EOs were collected, stored in amber glass containers and kept refrigerated at 4 ◦ C until use. The essential oil extraction yield is determined as the ratio of the extracted essential oil mass (m) to the total processed plant material mass (M), expressed as:

$$Y (\%) = (m / M) \times 100 \quad (1)$$

2.3 Pulsed electric fields (PEF) treatments

PEF treatments were carried out using a system designed and manufactured by the laboratory. The system of PEF (Figure 1) is the same as set out by Miloudi et al. (2022). It consists of pulse generator and a treatment chamber. The pulse generator is designed to operate at a peak voltage of 6 kV, generating exponential decay wave pulses from energy storage capacitors (4µF±5%, 3000Vdc, 115A rms) at a frequency of 1 Hz.

The treatment chamber consists of a rectangular container with two stainless steel flat and parallel plate electrodes with a gap of 1.5 cm, a length of 20 cm and a height of 7 cm, is exposed to an electric field of intensity calculated by the equation:

E=U/d (U: voltage, d: distance between electrodes). (2)

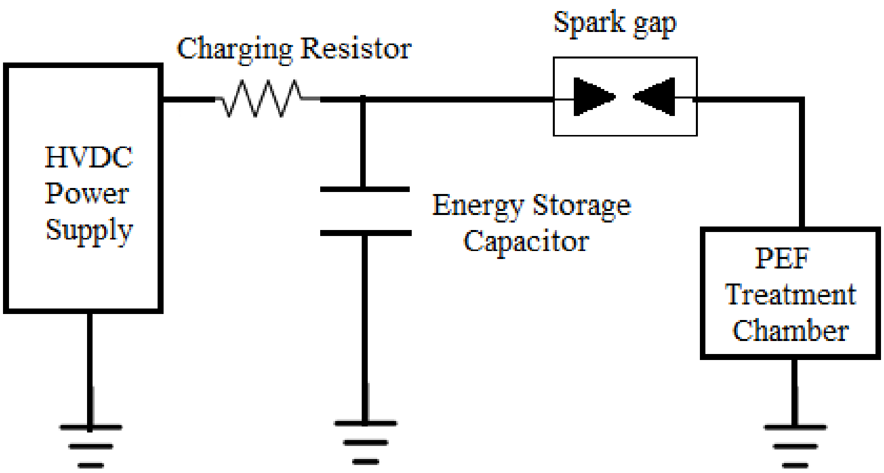

Figure 1. Pulsed electric field system (Miloudi et al., 2022)

Additionally, the walls of the electrodes were covered with thermal insulation material to prevent heat loss, although the top of the chamber was open. Immediately before distillation, the samples were exposed to PEF. A 30 g sample with water was placed into the treatment chamber. The treatment was performed at a field strength of 2 $kV.cm^{-1}$ based on previous results (Abenoza et al., 2013; Hadri et al., 2023; Miloudi et al., 2022; Tale Masouleh et al., 2015), and a specific energy input of 5 $kJ.kg^{-1}$, 10 $kJ.kg^{-1}$ and 50 $kJ.kg^{-1}$ in which PEF-treated aromatic plants enhanced their yield of essential oil.

The ratio of water to material was 3:1 (mL:g) and the variation of temperature of sample after PEF application did not exceed 1°C untreated sample was considered as a control sample. All experiments were repeated 3 times and the effects of PEF on the yield of essential oil were examined.

2.4 Absorption spectrophotometry method

Spectrophotometric analysis was performed using Spectrophotometer JENWAY IC 6400. Absorption spectrophotometer has working range of 320–950 nm and the spectrophotometric method in the analysis of essential oils uses the absorption of monochromatic light, which greatly increases the accuracy of the analysis. According to the method described by Huet (1976), 0.25g *Basil* essential oil is taken and diluted in 100 ml with ethanol 95%. This creates a true solution that respects Beer's law, allowing reliable absorbance measurements. The method is applicable to mixtures and colorless solutions. The analysis requires a small amount of solution. It demonstrates high sensitivity, with negligible instrument error and capable of detecting essential oil concentrations as low as 0.008 mg (Semenova et al., 2017). The primary advantage of UV spectrophotometric method is the ability to being use as easy, safe, rapid, and cost-effectiveness. Making it well-suited as an initial analytical approach (Piao et al., 2020; Teeka et al., 2014).

3. Result and discussion

3.1 Yield of essential oil by conventional method

In the present study, the extraction yield of *Basil* essential oil obtained by conventional hydrodistillation was 0.63% after 60 min of distillation. The yields obtained in other works were 0.57% (Zeković et al., 2015), 0.4% of Bosnian *Basil* (Stanojevic et al., 2017) and 0.76% (Torre et al., 2021) after 120 min of distillation.

Our results are in agreement with those of Yaldiz and Camlica (2022) who reported that the EO content of basil from diverse origins ranged from 0.04 to 1.07%. Others have reported that the EO yield of *Basil* ranged from 0.25 to 1.06% (Karaca et al., 2017), 0.75 to 0.84% (Arabaci & Bayram, 2004), and 0.41% to 0.65% (Antić et al., 2019).

For the *Basil* varieties that are known to have the highest essential oil yields, the yields were 1.00% for the “Italiano” variety, 0.90% for the “Fraganza” variety, and the “Manolo” variety has a yield of less than 0.57% (Silvestre & Pauletti, 2022). The quantity of essential oil from *Basil* leaves obtained in the present study was within the range reported for basil in all previously cited studies.

The yield of *Basil* essential oil is influenced by serval keys factors, including abiotic stress conditions, fertilization methods, genetic variations and environmental conditions. Acknowledge these factors can help optimize the cultivation of *Basil* for essential oil production (El Gohary et al., 2023; Kumar et al., 2024).

3.2 Effect of PEF on EO yield extraction

Based on the experimental results, the pulsed electric field intensity of 2 kV.cm^{-1} with specific energy inputs of 5 kJ.kg^{-1}, 10 kJ.kg^{-1} and 50 kJ.kg^{-1} and distillation time of 60 min were used. The effect of different methods (conventional hydrodistillation and combined hydrodistillation with PEF) on essential oil yield of *Basil* were illustrated in Figure 2.

In general, the EO yield of *Basil* leaves was influenced and increased after pulsed electric field treatment. As shown in Figure 2, the EO yield of *Basil* obtained by the conventional method (Control) increased from 0.63% to 0.82% after PEF treatment at 2.0 kV/cm^{-1} and 5 kJ.kg^{-1} of total specific energy, with a 30.16% increase for the same distillation time (60 min).

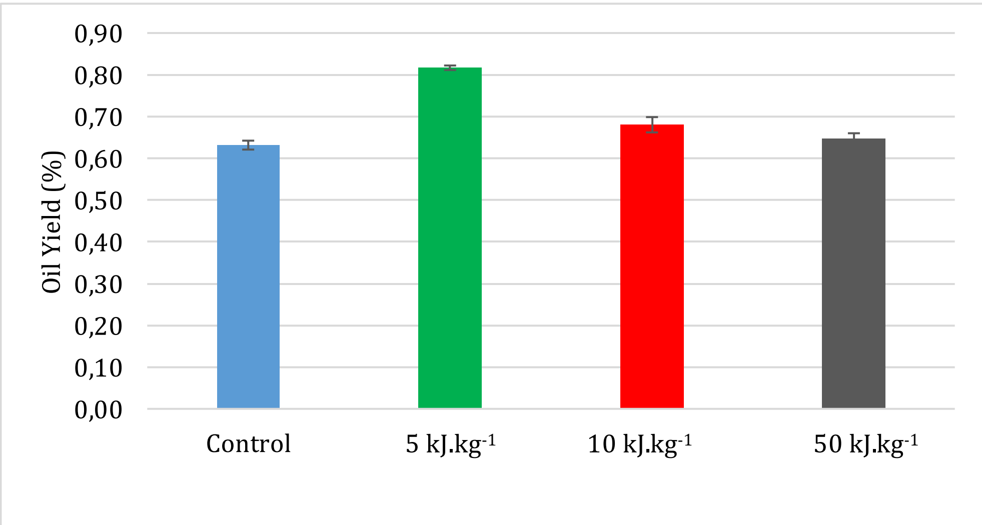

Figure 2. Effect of pulsed electric field on Basilic essential oil yield

After PEF application, the permeability of the intracellular material increases which improves mass transfer and enhances essential oil extraction according to the literature (Angersbach et al., 2000; Vorobiev & Lebovka, 2011; Zimmermann et al., 1974).

Increasing the PEF intensity from 5 $kJ.kg^{-1}$ to 10 $kJ.kg^{-1}$ and then to 50 $kJ.kg^{-1}$ of total specific energy did not have a significant impact on increasing the extraction yield of *Basil* essential oil. However, decreases of 17.07% and 20.73% were observed when the PEF intensity of 2 $kV.cm^{-1}$ increased from 5 $kJ.kg^{-1}$ to 10 $kJ.kg^{-1}$ and then to 50 $kJ.kg^{-1}$ of total specific energy respectively.

These results proved that the treatment of plant material at very high PEF intensities leads to losses in the quantity of oil due to damage to cell membranes during treatment that increases the vaporization of volatile oil as indicated by other researchers (Miloudi et al., 2018; Tintchev et al., 2012; Yajun et al., 2017). We also observed a non-significant decrease in EO yield from 0.68% to 0.65% when PEF intensity increased from 10 $kJ.kg^{-1}$ to 50 $kJ.kg^{1}$ of total specific energy.

3.3 Effect of PEF on absorption of Basil EO

The absorbance of different PEF-treated and untreated (Control) *Basil* essential oil samples were measured by spectrophotometer according to the literature (Brlek et al., 2021; Lafhal et al., 2016; Predoi et al., 2018; Teeka et al., 2014). Figure 3 shows that the absorbance of EO from *Basil* treated by PEF of 2$kV.cm^{-1}$, 5 $kJ.kg^{-1}$ and 10 $kJ.kg^{-1}$ specific energy was higher than the absorbance of EO from a reference sample (Control).

The high essential oil absorption capacity means that the material can effectively absorb and retain a significant amount of essential oil within its structure, thereby enhancing its antibacterial and therapeutic properties, and extending the oil release time for prolonged efficacy according to the literature (Numan et al., 2019; Radomski et al., 2021; Samfira et al., 2015).

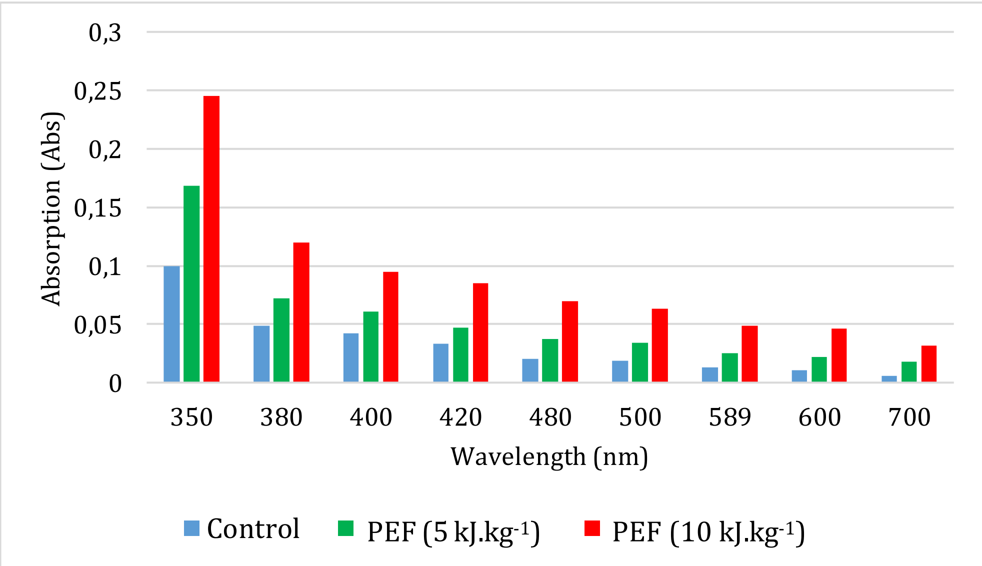

Figure 3. Effect of PEF on absorption of Basil EO, range 350–700 nm

In Figure 4, it was observed that the absorbance of the sample treated with PEF of 2$kV.cm^{-1}$ and 50 $kJ.kg^{-1}$ of specific energy has a low value compared to the reference sample and the other two samples treated with PEF of 2$kV.cm^{-1}$, 5 $kJ.kg^{-1}$ and 10 $kJ.kg^{-1}$ of specific energies respectively. This means that the treatment of *Basil* EO with very high specific energy PEFs caused EO degradation due to oxidation and polymerization.

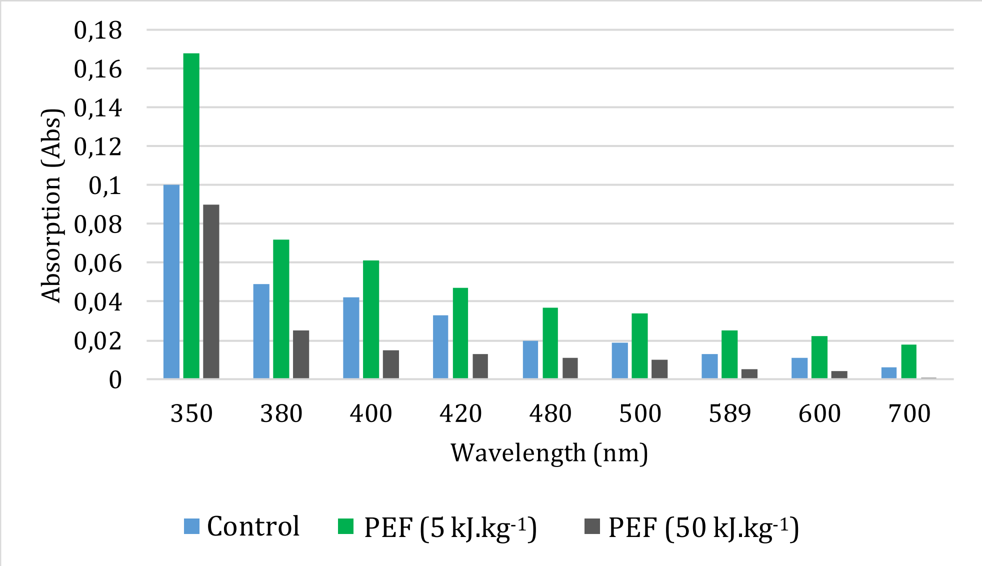

Figure 4. Effect of PEF intensity on absorption of Basil EO

This change in absorbance can lead to reduced stability which can significantly decrease shelf life, making essential oils less effective and potentially dangerous for consumers as reported by several authors (Al-Harrasi et al., 2022; Numan et al., 2019; Samfira et al., 2015; Turek & Stintzing, 2013).

The results for the absorbance values of essential oils at the standard wavelength λ = 589.3 nm (which is the standard wavelength used) are shown in Figure 5. High absorbance as in the case of *Basil* EO treated with PEF of 2kV.cm^{-1} and 10 kJ.kg^{-1} specific energy indicates that the sample has a high reducing power (Gholivand et al., 2010) , that as the reducing power of a substance increases, it enhances the absorption of light by the sample.

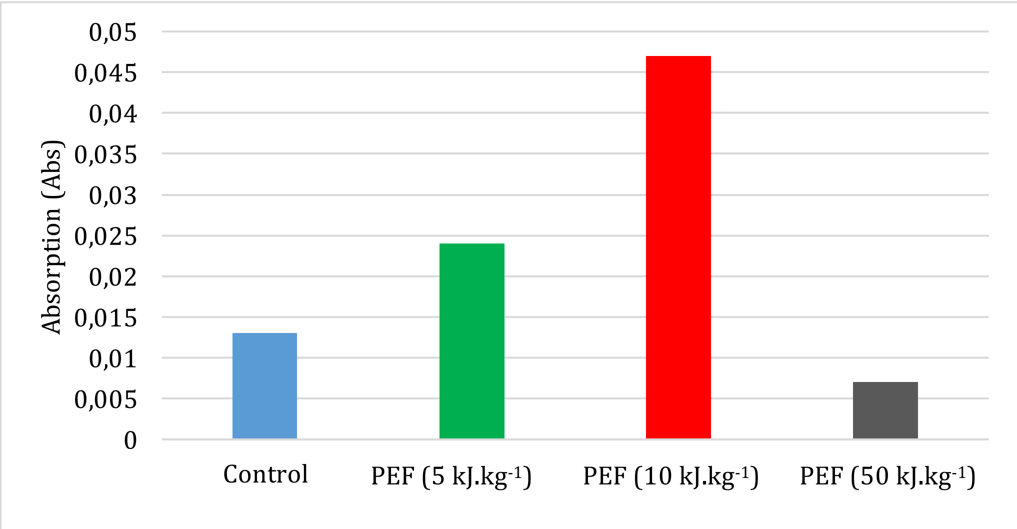

Figure 5. Effect of PEF on absorption of Basilic EO for wavelength (λ = 589.3 nm)

However, the decrease in absorbance reflecting the inhibition of oxidation which can be observed under the action of antioxidants as for the case of EO treated with PEF of 2kV.cm^{-1} and 50 kJ.kg^{-1} of specific energy according to the literature (Chitprasert & Ngamekaue, 2017; Efrati et al., 2014; Zahra & Susanti, 2023).

4. Conclusion

The present work demonstrated that pulsed electric field treatment effectively increases the extraction yield of *Basil* essential oil. An enhancement in oil extraction was observed across all PEF treatments applied with energy input up to certain values. The extraction of EO by the conventional method gave a yield of 0.63%, while the best yield was 0.82% after PEF treatment of 2 $kV.cm^{-1}$ and specific energy of 5 $kJ.kg^{-1}$ in 60 min of distillation. PEF treatment of 2 $kV.cm^{-1}$ and 5 $kJ.kg^{-1}$ total specific energy was sufficient to enhance EO extraction from *Basil*. The results of the spectrometric analysis obtained in this study show that PEF has variable effects on the absorption of *Basil* essential oils. According to our results, PEF was able to enable an increase in absorption, which plays an important role in the evaluation of the quality of essential oils. Pulsed electric field (PEF) treatment under optimized conditions in essential oil extraction can minimize energy consumption, increase productivity and improve quality. Future research should focus on scaling PEF for industrial use, optimizing parameters like pulse length, frequency, and electric field intensity. Understanding its impact on chemical composition, bioactivity, and stability is crucial for pharmaceutical, cosmetic, and food applications. Comparative studies with ultrasound- and microwave-assisted extraction could identify the most efficient and sustainable extraction method.

Author's declaration

The authors declare that they have no competing financial interests. All authors read and approved the final version of the manuscript.

References

Abenoza, M., Benito, M., Saldaña, G., Álvarez, I., Raso, J., & Sánchez-Gimeno, A. (2013). Effects of pulsed electric field on yield extraction and quality of olive oil. *Food and Bioprocess Technology*, *6*, 1367-1373. CrossRef

Adaşoğlu, N., Dinçer, S., & Bolat, E. (1994). Supercritical-fluid extraction of essential oil from Turkish lavender flowers. *The Journal of Supercritical Fluids*, *7*(2), 93-99. CrossRef

Al-Harrasi, A., Bhatia, S., Kaushik, D., Ahmed, M. M., Anwer, K., & Sharma, P. (2022). Quality Control of Essential Oils. In *Role of Essential Oils in the Management of COVID-19* (pp. 169-177). CRC Press.CrossRef

Al-Refaie, D., Mehyar, G. F., & Shahein, M. (2023). Functional Role of Essential Oils as Antimicrobial and Antioxidat Agents in Food Industry: A Review. *Jordan Journal of Agricultural Sciences*, *19*(1), 70-88. CrossRef

Alexandre, S., Vital, A. C. P., Mottin, C., do Prado, R. M., Ornaghi, M. G., Ramos, T. R.,…do Prado, I. N. (2021). Use of alginate edible coating and basil (Ocimum spp) extracts on beef characteristics during storage. *Journal of Food Science and Technology*, *58*, 3835-3843. CrossRef

Amor, G., Sabbah, M., Caputo, L., Idbella, M., De Feo, V., Porta, R.,…Mauriello, G. (2021). Basil essential oil: Composition, antimicrobial properties, and microencapsulation to produce active chitosan films for food packaging. *Foods*, *10*(1), 121. CrossRef

Angersbach, A., Heinz, V., & Knorr, D. (2000). Effects of pulsed electric fields on cell membranes in real food systems. *Innovative Food Science & Emerging Technologies*, *1*(2), 135-149. CrossRef

Antić, M. P., Jelačić, S. C., & Knudsen, T. M. Š. (2019). Chemical composition of the essential oils of three Ocimum basilicum L. cultivars from Serbia. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *47*(2), 347-351. CrossRef

Arabaci, O., & Bayram, E. (2004). The effect of nitrogen fertilization and different plant densities on some agronomic and technologic characteristic of Ocimum basilicum L.(Basil). *Journal of Agronomy*, *3*(4), 255-262. CrossRef

Assadpour, E., Can Karaça, A., Fasamanesh, M., Mahdavi, S. A., Shariat-Alavi, M., Feng, J.,…Jafari, S. M. (2024). Application of essential oils as natural biopesticides; recent advances. *Critical Reviews in Food Science and Nutrition*, *64*(19), 6477-6497. CrossRef

Azmir, J., Zaidul, I. S. M., Rahman, M. M., Sharif, K., Mohamed, A., Sahena, F.,…Omar, A. (2013). Techniques for extraction of bioactive compounds from plant materials: A review. *Journal of food engineering*, *117*(4), 426-436. CrossRef

Barros, M., Redondo, L., Rego, D., Serra, C., & Miloudi, K. (2022). Extraction of essential oils from plants by hydrodistillation with pulsed electric fields (PEF) pre-treatment. *Applied sciences*, *12*(16), 8107. CrossRef

Bolouri, P., Salami, R., Kouhi, S., Kordi, M., Asgari Lajayer, B., Hadian, J., & Astatkie, T. (2022). Applications of essential oils and plant extracts in different industries. *Molecules*, *27*(24), 8999. CrossRef

Brlek, I., Ludaš, A., & Sutlović, A. (2021). Synthesis and spectrophotometric analysis of microcapsules containing immortelle essential oil. *Molecules*, *26*(8), 2390. CrossRef

Chitprasert, P., & Ngamekaue, N. (2017). Stability enhancement of Ocimum Sanctum Linn. essential oils using stearic acid in aluminum carboxymethyl cellulose film-coated gelatin microcapsules. *Journal of food science*, *82*(6), 1310-1318. CrossRef

Crescente, G., Bouymajane, A., Cascone, G., Squillaci, G., Morana, A., & Moccia, S. (2023). Essential Oils: An Overview of Extraction Methods and Food Applications. *Current Nutraceuticals*, *4*(1). CrossRef

Dobreva, A., Tintchev, F., Dzhurmanski, A., & Toepfl, S. (2013). Effect of pulsed electric fields on distillation of essential oil crops. *Comptes rendus de l'Académie Bulgare des Sciences*, *66*(9), 1255-1260. CrossRef

Efrati, R., Natan, M., Pelah, A., Haberer, A., Banin, E., Dotan, A., & Ophir, A. (2014). The effect of polyethylene crystallinity and polarity on thermal stability and controlled release of essential oils in antimicrobial films. *Journal of Applied Polymer Science*, *131*(11). CrossRef

El Gohary, A. E., Hendawy, S. F., Hussein, M. S., Elsayed, S. I., Omer, E. A., & El-Gendy, A. E.-N. G. (2023). Application of Humic Acid and Algal Extract: An Eco-friendly Strategy for Improving Growth and Essential Oil Composition of Two Basil Varieties under Salty Soil Stress Conditions. *Journal of Essential Oil Bearing Plants*, *26*(1), 32-44. CrossRef

Feng, Y., Yang, T., Zhang, Y., Zhang, A., Gai, L., & Niu, D. (2022). Potential applications of pulsed electric field in the fermented wine industry. *Frontiers in Nutrition*, *9*, 1048632. CrossRef

Gholivand, M. B., Rahimi-Nasrabadi, M., Batooli, H., & Ebrahimabadi, A. H. (2010). Chemical composition and antioxidant activities of the essential oil and methanol extracts of Psammogeton canescens. *Food and Chemical Toxicology*, *48*(1), 24-28. CrossRef

Hadri, A. M., Benmimoun, Y., Miloudi, K., Bouhadda, Y., Elsayed, S. T., & Hamimed, A. (2023). Effect of pulsed electric field treatment on the extraction of essential oil from lavender (Lavandula angustifolia Mill.). International Journal of Biology and Biotechnology, *20*, 37-46. CrossRef

Hassid, A., Salla, M., Krayem, M., Khaled, S., Hassan, H., & El Khatib, S. (2024). A Review on the Versatile Applications of Plant-Based Essential Oils in Food Flavoring, Culinary Uses and Health Benefits. *Preprints*. CrossRef

Hernández-Corroto, E., Marina, M. L., & García, M. C. (2023). Application of high-voltage electrical discharges to the recovery of phenolic compounds from winery wastes. In *Processing of Food Products and Wastes with High Voltage Electrical Discharges* (pp. 95-119). Elsevier. CrossRef

Hou, T., Sana, S. S., Li, H., Xing, Y., Nanda, A., Netala, V. R., & Zhang, Z. (2022). Essential oils and its antibacterial, antifungal and anti-oxidant activity applications: A review. *Food Bioscience*, *47*, 101716. CrossRef

Huet, R. (1976). L'ISO adopte l'indice CD. *Revue Fruits ISHS*, 31(1),67-68. CrossRef

Ionica, M. E., Tutulescu, F., & Bita, A. (2022). Development of basil essential oil (BEO) as a novel alternative to prolong the storage of tomato (Lycopersicum esculentum L.). *Agriculture*, *12*(12), 2135. CrossRef

Jeong, S.-H., Lee, H.-B., & Lee, D.-U. (2024). Effects of Pulsed Electric Field on Meat Tenderization and Microbial Decontamination: A Review. *Food Science of Animal Resources*, *44*(2), 239. CrossRef

Karaca, M., Kara, Ş. M., & Özcan, M. M. (2017). Bazı fesleğen (Ocimum basilicum L.) popülasyonlarının herba verimi ve uçucu yağ oranının belirlenmesi. *Ordu Üniversitesi Bilim ve Teknoloji Dergisi*, *7*(2), 160-169. CrossRef

Kiruthika, S., & Vishali, S. (2023). Industrial Application of Essential Oils. *Essential Oils: Extraction Methods and Applications*, 49-67. CrossRef

Kumar, A., Sharma, N., Kumar, A., Kumar, D., Jnanesha, A., Gupta, A. K.,…Lal, R. (2024). Differential responses of genotype× environment interaction on Agronomic interventions affect the yield and quality of essential oil of interspecific basil hybrid of Ocimum basilicum L.× Ocimum kilimandscharicum. *Ecological Genetics and Genomics*, *30*, 100217. CrossRef

Lafhal, S., Vanloot, P., Bombarda, I., Kister, J., & Dupuy, N. (2016). Identification of metabolomic markers of lavender and lavandin essential oils using mid-infrared spectroscopy. *Vibrational Spectroscopy*, *85*, 79-90. CrossRef

Miloudi, K., Hamimed, A., Benmimoun, Y., Bellebna, Y., Taibi, A., & Tilmatine, A. (2018). Intensification of essential oil extraction of the Marrubium vulgare using pulsed electric field. *Journal of Essential Oil Bearing Plants*, *21*(3), 811-824. CrossRef

Miloudi, K., Hamimed, A., Bouhadda, Y., Benmimoun, Y., Belhouala, K., & Benarba, B. (2022). Impact of pulsed electric field treatment for extracting essential oil from Mentha Spicata L. *International Journal of Electrochemical Science*, *17*(8), 220829. CrossRef

Mulugeta, S. M., Gosztola, B., & Radácsi, P. (2024). Diversity in morphology and bioactive compounds among selected Ocimum species. *Biochemical Systematics and Ecology*, *114*, 104826. CrossRef

Nour, A. H., İdris, A. A., Ishag, O., & Nour, A. (2022). Chemical Composition and Repellent Activity of Methyl Cinnamate-Rich Basil (Ocimum basilicum) Essential Oil. *Journal of the Turkish Chemical Society Section A: Chemistry*, *9*(4), 1277-1284. CrossRef

Numan, N. H., Hussein, K., Sadkhan, A. K., & AL-Nuwab, M. A. (2019). Characterization of Some Natural Oils Used for Medical Purposes by Ultraviolet–Visible spectroscopy. *journal of the college of basic education*, *25*(105), 36-44. CrossRef

Oey, I., Giteru, S., & Leong, S. Y. (2022). Methods and protocols for pulsed electric fields treatment of foods. In *Emerging Food Processing Technologies* (pp. 1-29). Springer. CrossRef

Piao, X., Zhang, L., Zhang, S., & Yi, F. (2020). Nematicidal action of microencapsulated essential oil of flesh fingered citron. *Journal of Chemistry*, *2020*(1), 7934605. CrossRef

Popescu, I. E., Gostin, I. N., & Blidar, C. F. (2024). An Overview of the Mechanisms of Action and Administration Technologies of the Essential Oils Used as Green Insecticides. *AgriEngineering*, *6*(2), 1195-1217. CrossRef

Prakash, B., Singh, P. P., Gupta, V., & Raghuvanshi, T. S. (2024). Essential oils as green promising alternatives to chemical preservatives for agri-food products: New insight into molecular mechanism, toxicity assessment, and safety profile. *Food and Chemical Toxicology*, *183*, 114241. CrossRef

Predoi, D., Groza, A., Iconaru, S. L., Predoi, G., Barbuceanu, F., Guegan, R.,…Cimpeanu, C. (2018). Properties of basil and lavender essential oils adsorbed on the surface of hydroxyapatite. *Materials*, *11*(5), 652. CrossRef

Qu, H., Wang, Y., Wang, B., & Li, C. (2023). Pulsed electric field treatment of seeds altered the endophytic bacterial community and promotes early growth of roots in buckwheat. *BMC microbiology*, *23*(1), 290.CrossRef

Radomski, F. A. D., de Araujo Duarte, C., Ribeiro, E., & de Sá, E. L. (2021). Optical Investigation of Essential Oils Using Absorbance and Photoluminescence. *Applied Spectroscopy*, *75*(9), 1136-1145. CrossRef

Reverchon, E., Porta, G. D., & Senatore, F. (1995). Supercritical CO2 extraction and fractionation of lavender essential oil and waxes. *Journal of Agricultural and Food Chemistry*, *43*(6), 1654-1658. CrossRef

Richard, H., & Multon, J.-L. (1992). *Les arômes alimentaires [Food aromas]*. Technique & Documentation-Lavoisier Paris, France.

Salanță, L. C., & Cropotova, J. (2022). An Update on Effectiveness and Practicability of Plant Essential Oils in the Food Industry. *Plants*, *11*(19), NA-NA. CrossRef

Samfira, I., Rodino, S., Petrache, P., Cristina, R., Butu, M., & Butnariu, M. (2015). Characterization and identity confirmation of essential oils by mid infrared absorption spectrophotometry. *Dig. J. Nanomater. Biostruct*, *10*(2), 557-566. Direct Link.

Semenova, E., Presnyakova, V., Goncharov, D., Goncharov, M., Presnyakova, E., Presnyakov, S.,…Kolesnikova, S. (2017). *Spectrophotometric method for quantitative measuring essential oil in aromatic water and distillate with rose smell* Journal of Physics: Conference Series, 784 012053. CrossRef

Sharma, A., Kumar, V., Mittal, C., Rana, V., Dabral, K., & Parveen, G. (2023). Role of Essential Oil Used Pharmaceutical Cosmetic Product. *Journal for Research in Applied Sciences and Biotechnology*, *2*(3), 147-157. CrossRef

Shorstkii, I., Stuehmeier-Niehe, C., Sosnin, M., Mounassar, E. H. A., Comiotto-Alles, M., Siemer, C., & Toepfl, S. (2023). Pulsed Electric Field Treatment Application to Improve Product Yield and Efficiency of Bioactive Compounds through Extraction from Peels in Kiwifruit Processing. *Journal of Food Processing and Preservation*, *2023*(1), 8172255. CrossRef

Silvestre, W. P., & Pauletti, G. F. (2022). Evaluation of extraction yield and chemical composition of the essential oil of five commercial varieties of basil (Ocimum basilicum L.). *Interdisciplinary Journal of Applied Science*, *6*(10), 44-50. CrossRef

Stanojevic, L. P., Marjanovic-Balaban, Z. R., Kalaba, V. D., Stanojevic, J. S., Cvetkovic, D. J., & Cakic, M. D. (2017). Chemical composition, antioxidant and antimicrobial activity of basil (Ocimum basilicum L.) essential oil. *Journal of Essential Oil Bearing Plants*, *20*(6), 1557-1569. CrossRef

Tale Masouleh, Z., Asadollahi, S., & Eshaghi, M. (2015). Effects of pulsed electric fields as a pre-treatment on yield extraction and some quality properties of sesame oil. *International Journal of Review in Life Sciences*, *5*(10), 1100-1104.

Tangpao, T., Charoimek, N., Teerakitchotikan, P., Leksawasdi, N., Jantanasakulwong, K., Rachtanapun, P.,…Ruksiriwanich, W. (2022). Volatile organic compounds from basil essential oils: plant taxonomy, biological activities, and their applications in tropical fruit productions. *Horticulturae*, *8*(2), 144.CrossRef

Teeka, P., Chaiyasat, A., & Chaiyasat, P. (2014). Preparation of poly (methyl methacrylate) microcapsule with encapsulated jasmine oil. *Energy Procedia*, *56*, 181-186. CrossRef

Theagarajan, R., Balendran, S. D., & Sethupathy, P. (2024). Pulsed Electric Fields as a Green Technology for the Extraction of Bioactive Compounds. In *Bioactive Extraction and Application in Food and Nutraceutical Industries* (pp. 201-222). Springer. CrossRef

Tintchev, F., Dobreva, A., Schulz, H., & Toepfl, S. (2012). Effect of pulsed electric fields on yield and chemical composition of rose oil (Rosa damascena Mill.). *Journal of Essential Oil Bearing Plants*, *15*(6), 876-884. CrossRef

Toepfl, S., Mathys, A., Heinz, V., & Knorr, D. (2006). Potential of high hydrostatic pressure and pulsed electric fields for energy efficient and environmentally friendly food processing. *Food Reviews International*, *22*(4), 405-423. CrossRef

Torre, R., Pereira, E. A. D., Nascimento, R. V., Guedes, T. F., de Souza Faria, P. R., de Souza Alves, M., & de Souza, M. A. A. (2021). Agroecological approach to seed protection using basil essential oil. *Industrial Crops and Products*, *171*, 113932. CrossRef

Turek, C., & Stintzing, F. C. (2013). Stability of essential oils: a review. *Comprehensive reviews in food science and food safety*, *12*(1), 40-53. CrossRef

Vorobiev, E., & Lebovka, N. (2011). Pulse electric field-assisted extraction. *Enhancing extraction processes in the food industry*, 25-84. CrossRef

Wike, N. Y., Olaniyan, O. T., Adetunji, C. O., Adetunji, J. B., Akinbo, O., Adetuyi, B. O.,…Nathaniel, M. O. (2024). Application of essential oil in livestock production. In *Applications of Essential Oils in the Food Industry* (pp. 285-292). Elsevier. CrossRef

Yajun, Z., Changmei, X., Susu, Z., Guangming, Y., Ling, Z., & Shujie, W. (2017). Effects of high intensity pulsed electric fields on yield and chemical composition of rose essential oil. *International Journal of Agricultural and Biological Engineering*, *10*(3), 295-301. CrossRef

Yaldiz, G., & Camlica, M. (2022). Essential oils content, composition and antioxidant activity of selected basil (Ocimum basilicum L.) genotypes. *South African Journal of Botany*, *151*, 675-694. CrossRef

Zahra, A., & Susanti, I. (2023). Review Development of Essential Oil Nano Preparation Formulations to Pharmacological Activity. *J. Pharm. Sci.*, *6*(2), 381-387. CrossRef

Zeković, Z. P., Filip, S. Đ., Vidović, S. S., Adamović, D. S., & Elgndi, A. M. (2015). Basil (Ocimum basilicum L.) essential oil and extracts obtained by supercritical fluid extraction. *Acta periodica technologica*(46), 259-269. CrossRef

Zimmermann, U., Pilwat, G., & Riemann, F. (1974). Dielectric breakdown of cell membranes. *Biophysical journal*, *14*(11), 881-899. CrossRef