

Solar energy-based extraction of essential oils from cloves, cinnamon, orange, lemon, eucalyptus, and cardamom: A clean energy technology for green extraction

Asaad Rehman Al-Hilphy¹ | Abdul-Hadi K. Ahmed¹ | Mohsen Gavahian²  |
Ho-Hsien Chen² | Farid Chemat³  | Thamer-K.M. Al-Behadli¹ |
Mohd Zuhair Mohd Nor⁴  | So'bah Ahmad⁵

¹Department of Food Sciences, College of Agriculture, University of Basrah, Basrah, Iraq

²Department of Food Science, National Pingtung University of Science and Technology, Pingtung, Taiwan

³GREEN Team Extraction, UMR408, INRA, Université D'Avignon et des Pays de Vaucluse, Avignon Cedex, France

⁴Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, Malaysia

⁵School of Industrial Technology, Faculty of Applied Science, Universiti Teknologi MARA, Shah Alam, Malaysia

Correspondence

Dr. Mohsen Gavahian, National Pingtung University of Science and Technology, Pingtung 91201, Taiwan.
Email: mohsengavahian@yahoo.com

Abstract

Conventional essential oil extraction systems cannot meet the green extraction concepts and sustainable development goals (SDGs). Therefore, there is a need to develop alternative systems based on clean energy. The present study aims to investigate the possibility of essential oil extraction using solar energy without utilizing synthetic solvents. Hence, an eco-friendly solar energy-based extraction system (SEE) was developed to extract essential oils from cloves and cinnamon barks, orange and lemon peels, eucalyptus leaves, and cardamom seeds. Essential oils were assessed in terms of yield, physical properties, and chemical composition using gas chromatography–mass spectrometry assay. Also, the process sustainability was analyzed by the green extraction evaluation approach, and results were compared with those of traditional hydro-distillation (THD). Replacing THD with SEE increased the extraction time by 0.65, 0.80, 0.41, 0.61, 0.39, and 0.45 h for processing clove, cinnamon, orange, lemon, eucalyptus, and cardamom, respectively. The optimum solar radiation for extraction was about 1000 W/m². Also, oxygen compounds (96.45, 79.640, 42.98, and 83.76%) comprised the main proportion in the clove, cinnamon, eucalyptus, and cardamom essential oils, while orange and lemon essential oils had a high presence of terpenes. Furthermore, essential oils obtained by SEE had a similar yield and alcohol solubility to THD. According to green extraction process analysis, solar energy-based extraction was 23–34% greener than THD, depending on the type of plant material.

Practical Applications

The innovative solar-based extraction system designed and developed in this research can be used at farms and small factories to obtain essential oils using the zero-energy concept. From the energy consumption viewpoint, this technology can be regarded as “free process” which can reduce production costs. Also, the unique design of the heating section of this new system prevents overheating of the sample, making this new solar-based system suitable for the extraction of thermolabile compounds from plant materials. In this sense, obtaining a high-quality essential oil