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Effect of applied voltage and frequency on extraction parameters and extracted essential oils from *Mentha piperita* by ohmic assisted hydrodistillation

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ABSTRACT

Ohmic-assisted hydrodistillation (OAHD) is a new method proposed for extraction of essential oils in which ohmic heating technology is combined with distillation. In this study, different frequencies (25, 50 and 100 Hz) as well as high and low intensity OAHD (220 and 380 V) were applied on aerial parts of *Mentha piperita* L. and the results were compared with those of the conventional hydrodistillation (HD). The results showed that high and low intensity OAHD methods had the extraction times of 13.54 and 19.71 min, respectively, while this value was about 1 h for HD. Scanning electron micrographs of mint showed a sudden eruption of essential oil glands for all OAHD samples. GC–MS analysis did not indicate any noticeable changes in the compounds of all extracted essential oils. The results of this study showed that higher applied voltage can speed up OAHD and confirmed this emerging technology as a green technology (considering fossil fuels as the main source of electrical energy).

Industrial relevance: The quality and quantity of essential oils extracted from herbs and other raw materials are affected by the extraction method. In this research different frequencies (25, 50 and 100 Hz) and also high and low intensity OAHD (220 and 380 V, applicable in industries in many regions) of ohmic-assisted hydrodistillation (OAHD), as an innovative and emerging technology, were used and compared with traditional hydrodistillation in extraction of essential oils from the aerial parts of *Mentha piperita* L. (peppermint). All OAHD treatments were more economical and more environmentally friendly than hydrodistillation method. In addition, high intensity OAHD method not only can enhance the amount of extracted essential oil but also was the quickest method and consequently can be a valuable industrial alternative for extraction of essential oils.

1. Introduction

The genus *Mentha* (family Lamiaceae), comprising more than 25 species, grows widely throughout the temperate regions of the world (Gulluce et al., 2007). *Mentha piperita* (commonly known as peppermint) is frequently cultivated in many countries of East Asia, Europe, America and Australia for the production of essential oils (Gulluce et al., 2007; Pandey, Rai, & Acharya, 2003). The essential oils and extracts from peppermint have been in use since ancient times for the treatment of many digestive tract diseases and in cuisines (Iscan et al., 2002). The essential oil of peppermint is commercially used in foods, beverages, pharmaceuticals, cosmetics, health and tobacco industries (Carmines, 2002). The latter consumes about 40% of the total mint oil followed by pharmaceutical and confectionary industries. Usually the major components of peppermint oil include menthol, menthone and menthofuran. Menthol, the main substance that gives the mints their characteristic aromas and flavors, is used as a raw material in toothpaste, toothpowder, chewing tobacco, confectionary, mouth fresheners, analgesic balms, cough drops, perfumes, chewing gums, candies and tobacco industry (Briggs, 1993). The peppermint oil is reported to have antioxidant properties (Ribeiro, Martins, Esquivel, & Bernardo-Gil, 2002), antibacterial activity (Arakawa and Osawa, 2000) and is one of the most important constituents of some over-the-counter remedies in Europe for irritable bowel syndrome (Pittler & Ernst, 1998).

Essential oils can be isolated by a number of methods. Traditional methods of essential oil extraction from plant materials are hydrodistillation (HD), steam distillation and solvent extraction. Among these methods, HD has been the most common approach to

Abbreviations: OAHD, Ohmic assisted hydrodistillation; HD, Hydrodistillation; SHD, Salted hydrodistillation; NHD, Normal hydrodistillation.

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extract the essential oils from the medicinal plants (Stahl-Biskup & Sáez, 2002). However, these methods have some disadvantages. In order to enhance the quality of the extracts, possibly improve the extraction yield and also to reduce the operation costs and time, new approaches such as microwave-assisted extraction, pressurized solvent extraction, supercritical fluid extraction and microwave-assisted hydrodistillation have also been sought (Kaufmann & Christen, 2002; Wang & Weller, 2006; Golmakani & Rezaei, 2008).

Ohmic heating (also referred to as Joule heating) is defined as a process wherein an electrical current (usually alternating) is passed through the materials (Goullieux & Pain, 2005; Vicente, Castro, & Teixeira, 2006) and can be used to generate heat within the product (Knirsch, Santos, Vicente, & Penna, 2010). The heating occurs in the form of internal energy transformation (from electric to thermal which is due to Joule effect) within the material (Sastry & Barach, 2000). Ohmic processing enables us to heat materials at extremely rapid rates (generally, from a few seconds to a few minutes) (Sastry, 2005). Electrical conductivity is the main parameter determining the heating rate of an ohmic heating treatment. Ohmic heating only works in water continuous systems (due to necessity of ionic mobility) and materials with low electrical conductivity like oil droplets in mixed systems (i.e., aromatic plant leaves) cannot be heated directly by ohmic process but oil droplets will be heated almost rapidly through heat transfer from the direct neighborhood which however is very nearby due to the small dimensions (Goullieux & Pain, 2005). Distilled water is an excellent electrical insulator so in many studies on ohmic technology, salted water is used as the liquid phase for ohmic treatments (Goullieux & Pain, 2005). In 1993, with the Food and Drug Administration's (FDA) approval, process of stable low acid foods at ambient temperature became legal. Since then, ohmic heating has been used commercially in Japan, the USA and Europe. Ohmic heating as an alternative extraction technique of medicinal plants was first reported by Sensoy and Sastry (2004). Since then, numerous studies have sought the applicability of this new approach for the extraction of the materials (Lakkakula, Lima, & Walker, 2004; Sensoy, 2002). This heating system in combination with a clevenger type apparatus was recently utilized for extraction of essential oils from some medicinal plants and was named ohmic assisted hydrodistillation (OAHD) (Gavahian et al., 2011, 2012, 2013).

Gavahian et al. (2011) used a combination of ohmic heating and distillation for separation of essentials oils from *Zataria multiflora* Boiss (Shirazi Thyme) and found significant reductions in extraction time and consumed energy for OAHD compare to conventional HD method. This research team also reported similar results on OAHD for *Thymus vulgaris* and *Myrtus communis* (Gavahian et al., 2012, 2013). Nonetheless, it seems that more research is needed to fully explore advantages and disadvantages of OAHD for extraction of essential oils.

Farahnaky, Azizi and Gavahian (2012) revealed that ohmic heating system with three phase power can accelerate heating rate and consequently reduce process time in cooking operation in comparison with single phase power. Previous studies on this emerging extraction method (OAHD) have not examined the effects of applied voltage on extraction process. In many regions, industries can use either single or three phase power (220 and 380 V, indeed) for operating machineries. Furthermore, with the use of OAHD, especially high power OAHD, there is a general concern that direct use of intensive electricity may adversely affect the quality of the extracted essential oil. Moreover, it was previously reported by other researchers that applied frequency may affect ohmic heating process (Kulshrestha & Sastry, 2003; Lakkakula et al., 2004; Lima & Sastry, 1999). Therefore, the aims of this work were to use low power OAHD technique (220 V with 25, 50 and 100 Hz frequencies) and high power OAHD (380 V, 50 Hz) for the extraction of essential oils from dried peppermint aerial parts and to compare the extraction parameters and composition of the extracted essential oils with those obtained by conventional HD (as the reference method).

2. Materials and methods

2.1. Plant materials

Fresh aerial parts of peppermint when the plant has enough foliage (before flowering stage) were collected from an indigenous crop in Noor-Abad (Mamasani province, Iran) in July 2013. The identity of the genus *Mentha* was certified by plant taxonomy experts from the Biology Department of Shiraz University, Shiraz, Iran. The herbs were then dried in a dark room under ambient conditions (30–40 °C) for four days on a large screened tray, packed in high density poly ethylene (HDPE) bags put in a cardboard box and kept in a dark and below 20 °C for further experiments. The moisture content of the plants was measured in triplicate using a laboratory oven by drying until constant weight and was about 12.4 ± 0.2%.

2.2. OAHD

OAHD was performed using a modified version of ohmic distillator device with platinum electrodes as designed and developed by Farahnaky et al. (2010), in the Department of Food Science and Technology of Shiraz University. This updated version of the device was able to change the applied frequency as well as the applied voltage. Processing parameters (e.g., processing time, temperature and power consumption), were precisely monitored using a software developed and coupled with a Wattmeter to record the input power of ohmic apparatus to double check the data given by the software.

To investigate the effect of voltage on extraction parameters and extracted oil, OAHD was performed at 220 V (low intensity OAHD, OAHD 220 V) and 380 V (high intensity OAHD, OAHD 380 V), 50 Hz and variable current values depending on the process time (Fig. 4). In addition, three different frequencies (25, 50 and 100 Hz) were applied in constant voltage of 220 V to investigate its effect on extraction process and extracted oil.

In all OAHD procedures, 30 g of dried peppermint aerial parts and 0.5 L salted water (1%, w/v, NaCl) were heated in the apparatus flask for up to 2 h from initial temperature of 27 ± 1 °C (similar to initial temperature of material in HD method). The extraction process continued until no more essential oils were obtained. During the first 12 min, the amount of collected essential oils was recorded at 1 min intervals. After the first 12 min of extraction, recording of the amount of essential oils continued at 5 min intervals up to 1 h and afterwards at 15 min intervals. To remove water, the extracted essential oils were then dried over anhydrous sodium sulfate and stored in amber vials at 4 °C for further experiments.

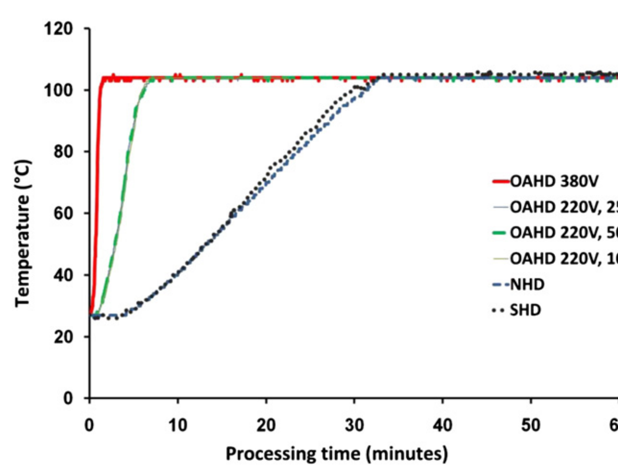

Fig. 1. Temperature–time profile of materials during distillation in OAHD and HD methods.