The Journal of Supercritical Fluids 133 (2018) 177–183

Contents lists available at ScienceDirect

The Journal of Supercritical Fluids

journal homepage: www.elsevier.com/locate/supflu

Subcritical water extraction of bioactive components from red ginseng (*Panax ginseng* C.A. *Meyer*)

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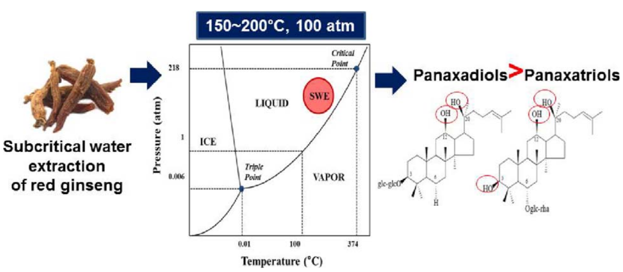
GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Subcritical water extraction
Red ginseng
Ginsenoside
Antioxidant activity

ABSTRACT

Subcritical water extraction (SWE) could be an eco-friendly excellent alternative to the traditional extraction method for extracting red ginseng (*Panax ginseng* C.A. meyer). In this study, the bioactive components of red ginseng were analyzed by varying the temperature (150–200 °C) and extraction time (5–30 min) in SWE. The maximum yields of ginsenoside Rg3 and Rh2, which have 2 hydroxyl groups (200 °C), appeared at a higher temperature compared to ginsenoside Rg2 and Rh1, which have 3 hydroxyl groups (150 °C), in SWE. The antioxidative properties were maximized at 200 °C for 20 min (total phenolic content = 49.55 ± 1.03 mg gallic acid equivalent/g red ginseng, maltol content = 1.19 ± 0.01 mg/g red ginseng, the Maillard reaction product level = 1.14 ± 0.08, and the DPPH-free-radical scavenging activity = 39.97 ± 0.16%). Extracts of red ginseng from SWE all had higher ginsenoside concentrations and antioxidative properties compared to extracts prepared using traditional extraction methods, including ethanol, hot water, and methanol.

1. Introduction

Ginseng (*Panax ginseng* C.A. meyer) is generally divided into fresh ginseng, white ginseng, and red ginseng according to the processing method. Fresh ginseng refers to ginseng in its harvested state, which usually has a moisture content of 70–80%. White ginseng is fresh ginseng that has only been subjected to a drying process using sunlight, hot air, or another method. Red ginseng is manufactured by steaming fresh ginseng before the drying process. Red ginseng exhibits high biological activity due to the steaming process used in its preparation [1]. Red ginseng extract has a high ginsenoside content and can be used as a food or beverage on its own [2,3].

Subcritical water (SW) is present in the liquid state under pressure over a temperature range of 100–374 °C. Increasing its temperature above the boiling point results in the value of the dielectric constant of SW decreasing significantly to become similar to that of organic solvents. For example, 27 for water at approximately 220 °C and 24 for ethanol at room temperature [4,5]. This outcome means that subcritical water extraction (SWE) could be an excellent alternative to traditional extraction methods that use ethanol as a solvent under atmospheric

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http://dx.doi.org/10.1016/j.supflu.2017.09.029
Received 31 May 2017; Received in revised form 27 September 2017; Accepted 27 September 2017
Available online 12 October 2017
0896-8446/

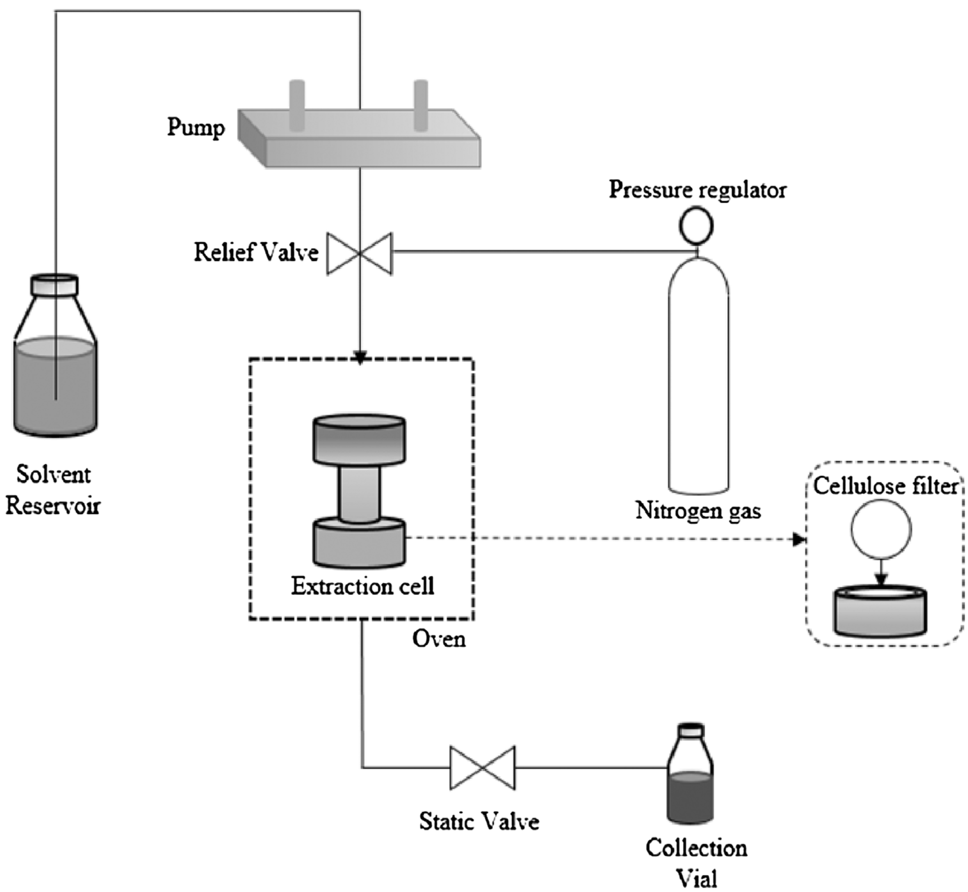

Fig. 1. Schematic of the SWE.

conditions to extract red ginseng. Since SWE only uses purified water as a solvent, it is non-toxic and safe. Furthermore, SWE is an effective recovery method for extracting bioactive components from red ginseng with an extraction time less than 30 min.

Ibanez et al. [6] studied the effects of the temperature of SW on the extraction of rosemary antioxidant compounds. Furthermore, SWE of antioxidant compounds from sea buckthorn (*Hippophae rhamnoides*) leaves was found to be a more efficient method compared to the soxhlet and maceration extraction method [7].

Ginsenosides have been reported to be the main active substance of ginseng, and there has been considerable research into the beneficial effects of ginsenosides, including anticancer, anti-inflammatory, anti-obesity, and anti-stress effects [8–11]. However, since ginsenoside cannot explain all of the bioactivity of ginseng, many studies have investigated the effects of non-saponin substances in ginseng, such as acidic polysaccharides, amino acid derivatives, polyacetylene, and polyphenolic compounds [12–15].

Free radicals cause deleterious effects in the body and degrade the quality of foodstuffs by deteriorating fat and other components. Because the intake of natural antioxidants in the diet is effective at removing free radicals, the presence and amount of antioxidants in food is very important. With increasing interest regarding the healthiness and possible of toxicity of synthetic antioxidants, there is a tendency to prefer natural antioxidants obtained from various plants and fruits [16,17]. It has been reported that the total phenolic content of red ginseng extracts increases with the extraction temperature and that their hydroxyl group scavenges free radicals via hydrogen donation [18]. In particular, the content of maltol, which is a phenolic compound generated by the Maillard reaction, was found to be higher in red ginseng compared to white ginseng. A higher content of maltol, rather than ginsenosides, was reported to be responsible for the enhanced radical scavenging activity of red ginseng [19]. Maillard reaction products in ginseng were reported to be increased by heat processing, and Maillard reaction products contribute to enhancing the antioxidant activities of various foods [20,21]. Maillard reaction products also exert a synergistic effect with polyphenolic compounds by scavenging heavy metals and promoting the decomposition of hydroperoxides [22].

The aim of the present study was to investigate the effects of SWE on the concentration of ginsenosides and antioxidative properties of red ginseng as well as to determine the optimum extraction conditions (i.e., extraction temperature and extraction time). In this study, we also investigated changes in three variables, the total phenolic content, maltol content, and Maillard reaction product level, according to the extraction conditions, which strongly correlated with the DPPH free-radical-scavenging activity of extracts obtained by SWE of red ginseng. In addition, this study also analyzed the antioxidative properties of extracts obtained through traditional extraction methods to confirm the suitability of SWE.

2. Materials and methods

2.1. Material

Four-year-old red ginseng was obtained from Daedong Korea Ginseng (Geumsan, Chungcheongnam-do, South Korea). The red ginseng used in this study was composed of body and roots at a ratio of 7:3. The samples were cut into small pieces using a high-speed mixer (Waring, Torrington, CT, USA), ground into a mesh size of 20–30 mm, and stored at 4 °C before extraction.

2.2. Chemicals

Folin-Ciocalteu reagent, gallic acid (3,4,5-trihydroxybenzoic acid, ≥99%), maltol (3-hydroxy-2-methyl-4-pyrone, > 97%), DPPH (2,2-