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Research article

Drying characteristics and quality of red ginseng using far-infrared rays

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ABSTRACT

Background: The current typical drying methods for red ginseng are sun drying and hot-air drying. The purpose of this study was to investigate drying characteristics of red ginseng by using far-infrared drying.
Methods: The far-infrared drying tests on red ginseng were conducted at two drying stages: (1) high temperature for 24 h drying and (2) low temperature drying until the final moisture content was 13 ± 0.5% (wet basis). The high temperature drying stage included three drying chamber temperature conditions of 60°C, 65°C, and 70°C. The low temperature drying stage was conducted at temperatures of 45°C and 50°C. Drying characteristics were analyzed based on factors such as drying rate, color changes, energy consumption, and saponin content. The results were compared with those of the hot-air and sun drying methods.
Results: The results revealed that increases in drying temperature caused a decrease in drying time and energy consumption for far-infrared drying. The saponin content decreased under all drying conditions after drying, the highest value (11.34 mg/g) was observed at drying conditions of 60∼50°C. The sun drying condition showed the lowest color difference value when compared with far-infrared and hot-air drying.
Conclusion: The far-infrared drying showed a faster drying rate, higher saponin content, lower color difference value, and a decrease in energy consumption than seen in hot-air drying.

1. Introduction

Red ginseng is a type of ginseng that belongs to the Asteraceae family. The main components of red ginseng are saponin, phenolic compounds, and antioxidants. It is widely distributed in Eastern China, Japan, and North and South Korea. It is used both in food and for medicinal purposes [1,2]. The typical drying methods used for red ginseng are sun drying and hot-air drying. Sun drying is the most natural method as it simply uses sunlight and wind. However, this method is weather dependent and there is a high potential for decay of the drying materials. In addition, long drying periods can easily degrade the quality and nutritional properties of red ginseng causing changes in color and the destruction of nutrients. By contrast, hot-air drying has the potential advantage of shorter drying times than those for sun drying. However, hot-air drying needs additional resources, and heat transfer efficiency is low in terms of energy cost [3,4]. When drying materials are exposed to hot-air for extended periods, their surfaces harden and shrink considerably due to rapid water loss, which affects factors such as color, texture, and restoring force of the drying materials [5]. Therefore, an efficient alternative method for drying red ginseng that has a shorter drying time, higher drying quality, and less energy consumption needs to be explored.

The far-infrared ray is an electromagnetic wave with a wavelength of 4–1,000 μm. Radiation energy penetrates objects and stimulates them at their resonance wavelength [6]. Therefore, Far-infrared drying has some advantages over convective hot-air drying, including high heat transfer efficiency, faster drying rate, and

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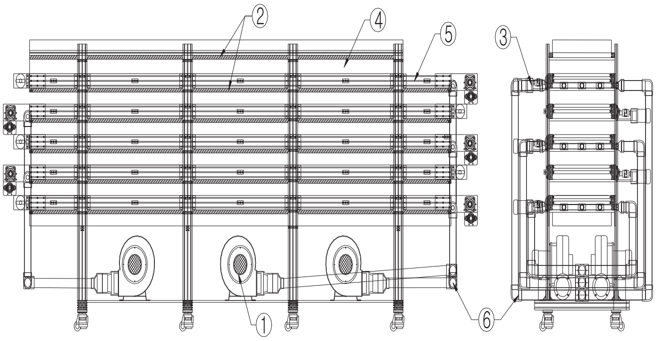

Fig. 1. Schematic diagram of a far-infrared dryer: (1) blast fan, (2) far-infrared heater, (3) motor, (4) drying chamber, (5) belt conveyer, and (6) blast pipe.

low energy cost [7]. Moreover, drying of agricultural products by far-infrared radiation accelerates drying rates and enhances the quality of the dried products. There are many widely reported studies on (1) the photosynthetic characteristics and component analysis of various types of ginseng, (it is known that Korean ginseng contains 34 types of saponins, with ginsenosides Rb1 and Rg1 typically present in the highest amount [8]); and (2) the analysis of vitamins and general components in the leaves of red ginseng [9]. However, little is known on the drying characteristics of red ginseng. Therefore, this study was undertaken to investigate the far-infrared drying characteristics of red ginseng, to determine the effect of two stages of drying temperature on the variability of drying quality, and finally to determine the optimal drying conditions for the far-infrared drying of red ginseng.

2. Materials and methods

2.1. Experimental materials

The red ginseng, used in this study was obtained from the Geumsan ginseng factory. The initial color values of red ginseng were as follows: lightness (38.94–46.33), redness (5.31–7.84) and yellowness (16.92–20.59). The initial moisture content of red ginseng was 35.2 ~ 39.0% [wet basis (wb)].

2.2. Experimental apparatus

A schematic diagram of the experimental apparatus is shown in Fig. 1. The dimensions of the dryer used in this experiment were 5,500 × 1,800 × 900 mm [length (L) × height (H) × width (W)]. The dryer consisted of drying chamber [5,340 × 620 × 90 mm (L × H × W)], a far-infrared heater (MEP-550, Restoration, Korea), blast fan (DTB-402, belt conveyer, Dongkun Industrial Co. Ltd, Incheon, Korea), and a control box to control the belt speed, drying temperature of the far-infrared heater, and air velocity.

2.3. Experimental procedure

Each drying condition used a 180-g sample of red ginseng for the experiment; samples were dried until the final moisture content was 13 ± 0.5% (wb). On the basis of results of the preliminary experiment, far-infrared drying was tested at the high temperature drying stage which included three drying chamber temperature conditions of 60°C, 65°C, and 70°C for 24 h drying, and at the low temperature drying stage which was conducted at temperatures of 45°C and 50°C and air velocities of 0.6 m/s, in order to increase the drying rate and prevent cracks and holes appearing on the surface and inside the ginseng. In this study, drying rate, surface color, energy consumption, and saponin contents were used as quality parameters for the dried red ginseng.

2.4. Analysis

2.4.1. Drying rate

The air-oven method was used to measure the initial moisture content. A sample of about 20 g of red ginseng was taken and dried in an experimental dryer (WFO-600ND, TokyoRi-kakai, Japan) at 105°C for 24 h. The moisture content was determined from the ratio of the weight changes before and after drying. The drying rate was represented by the moisture ratio. The moisture content that was measured at each drying time point was converted into the moisture ratio by using the following equations [10,11]:

$$MR = \frac{M_t - M_e}{M_o - M_e} \tag{1}$$

$$M_e = \frac{M_o \cdot M_f - M_m}{M_o + M_f - 2M_m} \tag{2}$$

where M_t indicates moisture content at any drying time point and M_e, M_0, M_m, and M_f indicate equilibrium, initial, middle, and final moisture contents, respectively.

2.4.2. Surface color

The surface color of red ginseng was measured using a colorimeter (JX777, C.T.S. Co., Tokyo, Japan). Surface color was measured on the basis of lightness (L), redness (a) and yellowness (b) values from three parts of the red ginseng body before and after drying, six samples were used to measure the color values. Total color difference (ΔE) was calculated using the following equation [12,13]:

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \tag{3}$$

where ΔE is total color difference and ΔL, Δa, and Δb are changes in lightness, redness, and yellowness, respectively, before and after drying.

2.4.3. Saponin measurement

Approximately 2 g of finely ground sample was extracted with 75% methanol and then dried after dissolution. The dried powder was mixed with 60 mL of ether solution. Any undissolved substance was removed before 50 mL of butanol was added. Subsequently, the extracted saponin solution was dried at 50°C, before being mixed with 10 mL of methanol. Finally the saponin content was analyzed using HPLC (2690, Waters, USA) [14,15].

2.4.4. Antioxidant level

2.4.4.1. Preparation of red ginseng extract. Sample extraction was performed by placing approximately 5 g of finely ground sample with 100 mL of distilled water in a shaker for 24 h at room temperature. Subsequently, the extract was centrifuged at 10,000 rpm for 5 min, and supernatants were filtered through Toyo No. 2 filter paper. The filtrate was diluted with 100 mL of distilled water and then stored at −20°C until analysis [3].

2.4.4.2. Determination of total phenolic content. The samples were analyzed spectrophotometrically to quantify total phenolic content. The extracts (100 μL) were mixed with 2 mL of 2% Na_2CO_2, followed by 100 μL of 50% Folin-Ciocalteu reagent. After 3 min of reaction, absorbance was detected at 720 nm by using a UV visible spectrophotometer (UV-1650 PC; Shimadzu, Japan). These measurements were compared to a standard curve for gallic acid and were expressed as milligrams of gallic acid equivalents per gram of red ginseng [16].