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Physicochemical characteristics of kimchi powder manufactured by hot air drying and freeze drying

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ABSTRACT

Kimchi powder was manufactured by hot air drying at different temperature of 55 °C, 60 °C and 65 °C, and freeze drying until it reached about 10% moisture content. The water absorption index (WAI) and water soluble index (WSI) of freeze dried powder was higher than those hot air dried kimchi powder. Moreover, L^*, a^* and b^* values of hot air dried kimchi powder were lower than those of freeze dried kimchi powder. During hot air drying, the browning index increased with increasing drying temperatures. The highest browning index was found in samples dried at 65 °C with inoculation of mixed *Leu. mesenteroides* and *Lb. sakei*. The freeze drying showed the lowest browning index compared to hot air drying (55 °C, 60 °C and 65 °C). In addition, the kimchi powder prepared by freeze dryer clearly received higher scores for overall acceptance than sample prepared by hot air dryer on sensory evaluation. Consequently, the kimchi inoculated *Leu. mesenteroides* as the starter has a similar quality with the naturally fermented kimchi. These results suggested that freeze drying method is more suitable for producing high quality kimchi powder than hot air drying.

1. Introduction

Kimchi is a fermented vegetable food and it is one of the most popular side dishes in Korea (Cho et al., 1997). Also, it has been recently introduced to many counties in the world and became a famous food (Cheigh, 2004; Lee et al., 2008). Chinese cabbage or radish are used as the major materials and seasonings including red pepper, garlic, ginger, green onion, and fermented anchovy sauce are generally used as the minor materials for kimchi production. The taste, the rate of the fermentation, and the properties of kimchi are dependent on the kinds of ingredients and seasoning used (Cho et al., 1997). Microorganisms involved in the fermentation of kimchi are originated from its ingredients (Pyo and Oh, 2011). Raw ingredients are utilized as the sources of nutrients and substrates for biological or biochemical reactions. Therefore, kimchi is characterized with its palatability, giving sour, sweet, and carbonated taste (Park, 1997). Recently, many researches on kimchi have pointed the superiority of kimchi out as a nutritive food (Cheigh and Park, 1994). Even though kimchi has many kinds of biological activities, it is difficult to integrate with other foods due to their high salted water contents (Lee et al., 2008).

To work with other foods, extend shelf life and become more cost effective during transport, kimchi is dehydrated by various methods such as hot air drying and vacuum freeze drying. Hot air drying involves a continuously flowing hot stream of air to remove the surface moisture of kimchi while freeze drying reduces the surrounding pressure to allow the frozen water in the material to directly sublimate from the solid to gas phase after freezing material with low temperature. (Meda and Ratti, 2005; Suvarnakuta et al., 2005; Hu et al., 2013). Hot air drying offers significant dehydrated products but the quality of dried product is usually significantly reduced compared to the original product. Vacuum freeze drying is considered the best method of dehydration with the high quality compared to other drying methods, but generally considered as a very expensive method (Ratti, 2001).

Recently, kimchi powder has been developed as food ingredients and seasonings to other products such as snacks (Cho, 2004; Cho et al., 2004; Kim et al., 2015), noodles (Cho and Kang, 2003), seafood buns (Kang et al., 2001), fermented sausages (Han et al., 2001; Lee and Kunz, 2005; Lee et al., 1990), and breakfast sausages (Cho, 2005; Lee et al., 2008) by adding kimchi powder. However, very few studies were conducted regarding the physicochemical characteristics of kimchi powder which were produced by hot air and freeze drying under different drying conditions. Therefore, the aim of this study is to evaluate the chemical and sensory properties of kimchi powder which are produced by different temperature of hot air drying and freeze drying.

Abbreviations: WAI, water absorption index; WSI, water soluble index; ANOVA, analysis of variance

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2. Materials and methods

2.1. Preparation of kimchi samples and starter culture

Kimchi was prepared using Chinese cabbage and other ingredients according to a traditional standard method and compositions. The raw materials were purchased from a local grocery marketplace in Korea. The cabbage was cut into 4–5 cm lengths and the other minor ingredients were added and blended by blender (NFM-8860, NUC, Korea) using the following ratio; cabbage: radish: green onion: sugar: red pepper powder: garlic: ginger: anchovy sauce = 100:13:2:1:3.5:1.4:0.6:2.2. The final salt concentration was adjusted to 2.5–3.0% using 10% solar salt solution. The prepared kimchi were divided into five groups; 1) Inoculation with both *Leu.mesenteroides* and *Lb.sakei* after sterilization with gamma (γ)-irradiation (KMSG), 2 and 3) Inoculation with *Leu. mesenteroides* and *Lb. sakei*, respectively, after sterilization with irradiation (KMG and KSG), 4) Natural fermentation without inoculation and irradiation (KSF), and 5) Sterilization without inoculation (CON). Ten 500-ml plastic containers of each group containing 450 g of the kimchi were anaerobically packed and used for further research.

The γ-irradiation of kimchi was carried out at the Korea Atomic Energy Research Institute (KAERI) in Jeongeup, Korea. The kimchi samples were irradiated in a cobalt-60 irradiator (Point source AECL, IR-79, MDS Nordion International Co., Ltd., Ottawa, ON, Canada) with 40 kGy absorbed doses at ambient temperature. *Leuconostoc mesenteroides* (KCTC 13302) and *Lactobacillus sakei* (KCTC 13416) were purchased from Korea Biological Resource Center, as a starter culture. *Leu. medenteriodes* and *Lb. sakei* were sub-cultured twice in deMan Rogasa Sharpes (MRS) broth at 30 °C and 37 °C for 2 days, respectively. The 10 mL of the suspension was centrifuged at 3000 × *g* (4 °C) for 15 min, and then collected cells were washed in a sterile 0.85% NaCl solution twice. The number of microbes was adjusted to 1×10^7 CFU/mL and inoculated to kimchi samples. The ripening and fermentation of kimchi was carried out for 24 hours using an incubator (IB-600M, JEIO TECH, Korea) at 30 °C. Kimchi samples were collected every three hours after incubation and immediately measured for their pH and total acidity. All experiments were performed under standard aseptic condition.

2.2. Manufacturing of kimchi powder

Kimchi powder was manufactured using each fermented kimchi which reached the pH 4.1–4.3 and total acidity 0.7–0.8%. Kimchi samples were collected and put into open pans and dried in a hot air dryer (NA-20, NOA Co., Korea) at 55 ± 2 °C, 60 ± 2 °C and 65 ± 2 °C, respectively. On the other hand, kimchi samples were also dried by freeze dryer (Freeze-dryer, Bondiro DC1316 Iishin Lab Co., LTD). The samples were dehydrated until they reached a constant weight (~10% final moisture) for 12 h at 55 ± 2 °C, for 10 h at 60 ± 2 °C and for 8.5 hours at 65 ± 2 °C, and for 24 h at freeze dryer, respectively. Finally, hot air and freeze dried kimchi were finely pulverized to a particle size of 80 mesh and the powder was kept in the freezer at −80 °C until further used. All processing was conducted in triplicate.

2.3. Moisture content

The moisture content of a dried sample was determined using an oven dry method (AOAC, 2005). About 3.0–4.0 g of the dried sample was dried at 105 °C until a constant mass was reached in a hot air oven (FO-600M, Jeio Tech Co. Ltd, Kimpo Kyeonggi-do, Korea). The moisture content was determined by weight difference and expressed as a percentage of the initial sample weight.

2.4. Water soluble index (WSI) and water absorption index (WAI)

Water solubility index (WSI) and water absorption index (WAI) were determined according to the method described by Anderson et al. (1969). Two and a half grams of kimchi powder and 30 mL water were vigorously mixed in a 50 mL centrifuge tube; the mixture was incubated in a water bath at 30 °C for 30 min, and centrifuged at 3000 × *g* for 15 min. The supernatant was collected in a pre-weighed Petri dish and the residue was weighed after oven drying at 105 °C overnight. The amount of solids in the dried supernatant as a percentage of the total dry solid pellet remaining after centrifugation was divided by the amount of dry sample. WAI and WSI were calculated by:

$$WAI = \frac{(\text{Sediment} + \text{Weight of Tube}) - (\text{Weight of Tube})}{\text{Sample Dry Weight}}$$

$$WSI = \frac{(\text{Weight of Container} + \text{Dried Supernatant}) - (\text{Weight of Container})}{\text{Sample Dry Weight}}$$

For WAI and WSI, two determinations were carried out for each treatment sample.

2.5. Color and browning index

The kimchi powder was transferred into different glass cells and measured with a Color Difference Meter (CM-3500d, MINOLTA Co., Ltd., Japan). The results were expressed as L^* (lightness), a^* (redness) and b^* (yellowness) values. The measurement of color was repeated in duplicate (Petracci and Fletcher, 2002).

Browning index was determined using the method described by Krishnan et al. (2010) with slight modification. One gram of dehydrated kimchi powder was extracted with 40 mL of distilled water and 10 mL of 10% trichloroacetic solution in a beaker. The extract was filtered through a Buchner funnel with Whatman No. 2 filter paper. After the solution stood for 2 hours at room temperature, its concentration was determined based on its absorbance at 420 nm (Optizen 2120UV, Mecasys, Korea).

2.6. Sensory evaluation

Sensory evaluation was conducted by the 40 semi-trained sensory panelists, except for overall acceptance which had 50 panelists that participated in it, from the Department of Food Science and Technology at Chonnam National University (Gwangju, Korea). Samples of each kimchi powder were compared in terms of color, flavor, appearance, texture, taste and overall acceptance on a 7-point hedonic scale from 7 (like very much) to 1 (dislike very much), by the method of Meilgaard et al. (1987).

2.7. Statistical analysis

There were five kinds of manufactured kimchi powder samples which carried out triplicate analyses. Results were expressed as mean values ± standard deviation. To detect the differences among the samples, ANOVA and Duncan's multiple-range test were used for data analysis ($p < 0.05$) (SPSS, 2008; SPSS Inc., Chicago, IL, USA).

3. Results and discussion

3.1. Moisture content

The moisture content of kimchi powder manufactured with different drying temperatures is shown in Table 1. The moisture content of kimchi powder ranged from 10.82% to 7.86%. The moisture content of general commercial kimchi powder is below