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Characterization of *Hericium erinaceum* powders prepared by conventional roll milling and jet milling

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ABSTRACT

Four types of powder were prepared from freeze-dried fruiting bodies of the edible mushroom *Hericium erinaceum* by 2 different methods-conventional roll milling and the superfine grinding method of jet milling-at 3 different speeds, to compare their physicochemical properties and extraction of proteins and polysaccharides. Jet-milled powders prepared at 16,000 rpm (JMP1), 9000 rpm (JMP2), and 5000 rpm (JMP3), and roll-milled powder (RMP) had an average particle size of 5.5, 12.9, 25.2, and 243.6 μm, respectively. The reduction of particle size resulted in increased specific surface area, porosity, and bulk density. Among the 4 powders, JMP1 showed the highest bulk density (0.17 g/ml). The water solubility index of *H. erinaceum* powder increased from 35.2% in RMP to 53.1% in JMP1. Similarly, the swelling capacity of JMP1, JMP2, JMP3, and RMP was 11.28 ml/g, 7.36 ml/g, 6.26 ml/g, and 5.9 ml/g, respectively. The extractions of proteins and polysaccharides from *H. erinaceum* powders were also improved by the application of jet milling. These results suggest that the superfine grinding method of jet milling could provide more opportunities for mushroom powders to be incorporated in a wider variety of functional food applications.

1. Introduction

Mushrooms are thought to be a good source of nutrition comparable to meat products in terms of a high content of proteins, dietary fiber, and important minerals as well as a low content of lipids (Khan et al., 2009). *Hericium erinaceum* is a well-known edible and medicinal mushroom of the *Hericium* family in oriental countries. In previous studies, various biological functions of *H. erinaceum* have been investigated in relation to antimicrobial effects (Kim et al., 2000), anti-tumor activities (Mizuno, 1996, 1999), immunomodulatory effects (Liu et al., 2002), antioxidant properties (Mau et al., 2002), cytotoxic effects (Kuwahara et al., 1992), hypolipidemic effects, and promotion of the synthesis of nerve growth factor (NGF) (Kawagishi et al., 1994; Lee et al., 2000). In spite of increasing usage and applications of *H. erinaceum*, most investigations have focused on its functional properties, while studies on the processing of *H. erinaceum* are limited.

The processing of *H. erinaceum* is challenging because fresh mushrooms start decaying immediately after harvesting owing to their high water content. Thus, to extend their shelf-life and off-season use, other processes are needed; drying is one of the most widely used methods (Walde et al., 2006). Dried mushrooms can be further processed into a powder form, which can be incorporated into various foods as a functional food additive with distinct flavors (García-Segovia et al., 2011). The physicochemical properties of the powder, which highly depend on the particle size and the method used during powder production, play an important role in the degree of the above-mentioned utilization (Zhang et al., 2012). Commonly used methods for producing powder can be categorized into routine grinding and micronization (superfine grinding). Routine grinding methods produce a larger particle size compared to micronization techniques such as jet milling. Superfine grinding is a new process technique, which is a useful tool for making superfine powder with good surface properties, dispersibility, and solubility (Tkacova and Stevulova, 1998). Even though this new technique requires high amount of energy and relatively expensive, the out coming products is undeniable. The surface of superfine ground powder can undergo some changes, which bring out some advantageous properties not shown by crude particles. Owing to these favorable characteristics, superfine powder might be more applicable in a wider scope than conventional particle materials (Huang et al., 2007). However, the effects of micronization treatment on the characteristics of powders may be different,

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depending on the grinding methods and raw materials (Chau et al., 2007). Zhao et al. (2009) reported that superfine ginger powder had good fluidity, water-holding capacity, water solubility index, and protein solubility. These improved qualities were also observed in a study on the preparation technology of superfine ground powder of *Agrocybe chaxingu Huang* by Zhang et al. (2005). Chau et al. (2007) also found that micronization treatments of carrot insoluble fiber improved its physicochemical properties (e.g., water-holding capacity, swelling capacity, oil-holding capacity, and cation-exchange capacity), glucose adsorption capacity, α-amylase inhibitory activity, and pancreatic lipase inhibitory activity. These studies suggest that the superfine grinding is a better way to incorporate food powders into various food applications. Despite these data, very limited information is available on the effects of superfine grinding on the physicochemical properties of mushroom powders, especially on *H. erinaceum*.

In response to the increase in mushroom powder applications in food industries, there is a need for detailed information about their handling and processing characteristics, especially for food powder applications. Thus, this study aimed to compare the physicochemical properties and extraction of proteins and polysaccharides of *H. erinaceum* powders prepared by conventional roll milling and jet milling to determine their differences as influenced by particle size.

2. Materials and methods

2.1. Samples

H. erinaceum mushroom samples were provided by the Mush-Art farm in Seoul, South Korea in May 2012. Fresh mushrooms were immediately freeze-dried and stored at −20 °C before the experiments.

2.2. Powder preparation

After freeze-drying, mushrooms were milled using a roll-mill machine from Dong Kwang Industry Co., Korea to produce conventional roll-milled powder (RMP). RMP was further processed to produce superfine powder by jet milling using a fluidized bed jet mill (CGS 10, Netzsch-Condux Mahltechnik GmbH, Hanau, Germany) with 3 different speeds, 16,000 rpm, 9000 rpm, and 5000 rpm, resulting in 3 different powders, JMP1, JMP2, and JMP3, respectively.

2.3. Particle size, bulk density, and porosity

Particle sizes were determined by a particle size analyzer using Malvern Masterizer 3000 laser diffraction equipment (Malvern Instrument Ltd., UK). The bulk density of mushroom powder was determined by the method described by Bai and Li (2006). Powder (1 g) was poured gently into a 10 ml measuring cylinder, and then, the cylinder was held on a vortex vibrator for 1 min to obtain a constant volume of the sample, which was recorded against the scale on the cylinder. The bulk density value was calculated as the ratio powder mass and the volume occupied in the cylinder. The porosity of the mushroom powders was measured using an automated mercury porosimeter (AutoPore IV 9520). Evacuation pressure was 100 μmHg, and evacuation time was 20 min. The mercury filling pressure was 0.52 psia with an equilibrium time of 10 s.

2.4. Scanning electron microscopy (SEM) and colorimetry

Photos of powder particles were captured using scanning electron microscopy S-3400N (Hitachi) to observe the morphological differences in shapes and surfaces of *H. erinaceum* roll-milled and jet-milled powders. In addition, colors of mushroom samples were measured using the UltraScan PRO color difference meter (Hunterlab, USA).

2.5. Hydration properties

Hydration properties of *H. erinaceum* powders such as water-holding capacity (WHC), water solubility index (WSI), and swelling capacity (SC) were analyzed based on the method by Zhang et al. (2012) with slight modifications.

WHC was determined by a series of steps. Initially, a cleaned centrifuge tube (M, g) was weighed, and then, approximately 0.5 g powder (M1, g) was added to it. Distilled water (10 ml) was added to disperse the powder at ambient temperature. The dispersion was placed in a water bath at 60 °C for 30 min and immediately cooled in an ice-water bath for another 30 min. Then, the tube was centrifuged at 5000 rpm for 20 min. The resulting supernatant was removed and the centrifuge tube with sediment (M2, g) was weighed again.

$$\text{WHC (g/g)} = (M2 - M)/M1.$$

WSI was determined with 0.2 g of powder (S1, g) in a centrifuge tube with 10 ml of distilled water at ambient temperature. The dispersion was placed in a water bath at 80 °C for 30 min, followed by centrifugation at 6000 rpm for 10 min. The supernatant was carefully collected in a pre-weighed evaporating dish (S2, g) and left to dry at 105 °C. The evaporating dish with residue was weighed again (S3, g).

$$\text{WSI (\%)} = (S3 - S2)/S1 \times 100.$$

SC was determined by the following method. The initial 1 g of powder (M) was added to a graduated cylinder and its occupied bed volume (V1) was recorded. Then, 10 ml of distilled water was added to the tube and the mixture was shaken until a homogeneous dispersion was achieved. The dispersion was placed in a water bath at 25 °C for 24 h to allow complete swelling of the powder. A new volume (V2) of the wetted powder was then recorded. SC (ml/g) = (V2 − V1)/M.

2.6. Levels of extracted proteins and polysaccharides

Levels of extracted proteins and polysaccharides were determined according to a previous method described by Zhao et al. (2009) and Zhang et al. (2012) with slight modifications. Powder samples (1 g) were weighted into a centrifuge tube. Distilled water (50 ml) was added and the samples were vortexed until the suspension was homogenous. The tube was then placed in a water bath at 60 °C for protein extraction and at 80 °C for polysaccharide extraction at different time intervals from 30 min to 120 min. The tube was then centrifuged at 5000 rpm for 10 min, and the supernatant was collected for further measurements.

The amount of protein in above-obtained supernatant was determined by the Coomassie Brilliant Blue method developed by Bradford (1976). Polysaccharides in the supernatant were quantified by a phenol–sulfuric acid method (Dubois et al., 1951). Levels of extracted protein (%) were expressed as the percentage of protein mass in the supernatant to that of the powder; polysaccharide extract (mg/g) was expressed as milligrams of polysaccharide in the supernatant per gram of powder sample.

2.7. Statistical analysis

Results are expressed as mean ± standard deviation (SD). Data in triplicate were analyzed by one-way analysis of variance using