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Characterization of stipe and cap powders of mushroom (*Lentinus edodes*) prepared by different grinding methods

Zipei Zhang [a], Huige Song [a], Zhen Peng [a], Qingnan Luo [a], Jian Ming [a], Guahua Zhao [a,b,*]

[a] College of Food Science, Southwest University, Tiansheng Road 1, Chongqing 400715, PR China
[b] Key Laboratory of Food Processing and Technology of Chongqing, Chongqing 400715, PR China

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ABSTRACT

The effects of micronization methods, mechanical and jet millings, on the physico-chemical properties of mushroom (*Lentinus edodes*) powder were investigated in contrast to shear pulverization. The powders of dried mushroom cap and stipe were prepared to obtain six powders. Compared to shear pulverization, mechanical and jet millings effectively reduced particle size and brought about a narrow and uniform particle size distribution. With the same material, powders from mechanical and jet millings had higher values in soluble dietary fiber content, surface area, bulk density, water soluble index and nutrient substance solubility, but lower values in the angles of repose and slide, water holding and swelling capacities than shear pulverized powder. These indexes were tightly dependent on particle size with absolute coefficients beyond 0.8330. With the same grinding method, cap powders possessed higher values in water soluble index, swelling capacity, bulk density, protein and soluble dietary fiber than stipe powders.

1. Introduction

Lentinus edodes, belongs to the family of *Tricholomataceae*, is famous for its high nutritional value and medicinal properties like anticancer, antidiabetic, hypotensive, antinociceptive, anti-inflammatory, hypocholesterolemic (Wasser, 2005; Carbonero et al., 2008). Also, it is important nutritionally because of its higher protein, dietary fibers and important mineral contents (Khan et al., 2009). Due to their high moisture contents (typically greater than 85 g/100 g), fresh mushrooms start deteriorating immediately after harvest and have to be processed to extend their shelf life and for off-season use. Drying is an inexpensive method that can extend the shelf life of mushroom (Walde et al., 2006). Mushrooms have been commonly dried as harvested or divided into small pieces prior to drying. The resulting products are mainly used as cooking material. To extend the application of mushrooms, dried mushrooms can be further processed into a powder form which could be incorporated into various foods as a functional food additive with distinct flavor (García-Segovia et al., 2011). The degree of the above described utilization is decided by the physico-chemical properties of the powder, which are tightly depended on the particle size and the method applied in powder production. The commonly used methods could be classified as routine grinding and micronization. Routine grinding, such as shear pulverization, produced larger size particles than micronization, such as mechanical and jet millings. Superfine powders obtained from micronization have properties that are not found in powders from conventional grinding methods (Tkacova and Stevulova, 1998; Zhao et al., 2009). With these superior characteristics, the superfine powder might find a wider scope of applications than conventional particle materials (Huang et al., 2007). Moreover, effects of micronization treatment on the characteristics of gained powders may be different, which depends on the grinding methods and raw materials (Chau et al., 2007).

The edible part of mushroom (*L. edodes*) consists of cap and stipe, which account for approximate 75% and 25% of the mushroom on dry basis (Gao et al., 2010). Proximate composition analysis implied that they are very different in chemical composition. In contrast to cap, stipe has a higher fraction of insoluble crude fiber (about 38 g/100 g) which is difficult to chew thereby limiting their utilization in foods (Jiang et al., 2010). In most mushroom processing factories, the stipes of *L. edodes* are not fully utilized and treated as a waste. The disposal of them causes many environment problems mainly due to their large volume and high organic material content (Yen et al., 2007). Micronization has been proved as an effective approach to modify the texture of fiber rich plant food materials (Wang et al., 2009; Zhao et al., 2009).

Abbreviations: DF, dietary fiber; EMC, equilibrium moisture content; IDF, insoluble dietary fiber; JMC, jet milled cap powder; JMS, jet milled stipe powder; MMC, mechanically milled cap powder; MMS, mechanically milled stipe powder; SC, swelling capacity; SDF, soluble dietary fiber; SPC, shear pulverized cap powder; SPS, shear pulverized stipe powder; WHC, water holding capacity; WSI, water solubility index.

* Corresponding author at: College of Food Science, Southwest University, Tiansheng Road 1, Chongqing 400715, PR China. Tel.: +86 23 68 25 03 74; fax: +86 68 25 19 47.
E-mail address: zhaogh@swu.edu.cn (G. Zhao).

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The present work aims to observe the differences in physicochemical properties of cap and stipe powders of mushroom (*L. edodes*) produced by shear pulverization, mechanical and jet millings.

2. Methods

2.1. Materials

Fresh mushroom (*L. edodes*) was purchased from a local market (Chongqing, China) in October 2010. Insect and disease-free samples were chosen and cleaned. The caps and stipes were manually separated and hot-air dried in an oven (DHG-9140, Qixing, Shanghai, China) at 45 °C for 32 h and 38 h, respectively. Under these conditions, the moisture contents of cap and stipe were reduced to 10 g/100 g and 11 g/100 g, respectively. Moisture contents were determined according to an AACC method (No. 44-19). All chemicals used were of analytical grade.

2.2. Powder preparation

The shear pulverized cap and stipe powders of mushroom were prepared with the aid of a DFT-200 high-speed pulverizer (Linda, Wenling, China). Pulverization process lasted for 30 s. This ensured that all particles of the powder passed through an 80 mesh sieve with average particle sizes of cap and stipe of 54.77 μm and 40.90 μm, respectively. Shear pulverized powders were then ground and sheared by the strong force between the lapping wheel and rail of a YSC-701 type micronizer (Yanshanzhengde, Beijing, China) for 8 min to result in mechanically milled powders. Jet milled powders were obtained by processing shear pulverized powders in a LNJ-120 jet mill (Liuneng, Mianyang, Sichuan, China) using compressed air at 145 psi. As a result, six different powders were obtained as: shear pulverized cap (SPC) and stipe (SPS) powders; mechanically milled cap (MMC) and stipe (MMS) powders and jet milled cap (JMC) and stipe (JMS) powders. The proximate composition of powders, including moisture, ash, protein, fat, soluble dietary fiber (SDF) and mineral elements (Pb, Cd), were measured by using AOAC methods (1998).

2.3. Particle size and bulk density measurement

The particle size of six mushroom powders was measured by a Mastersizer 2000 E laser particle size analyzer (Malvern instrument Ltd., UK). The bulk density was determined by pouring gently 2 g of mushroom powder into a 10 mL measuring cylinder, and then holding the cylinder on a vortex vibrator for 1 min to obtain a constant volume of the sample. The volume of the sample was recorded against the scale on the cylinder. The bulk density value was calculated as the ratio of mass of the powder and the volume occupied in the cylinder (Bai and Li, 2006).

2.4. Determination of the angles of repose and slide

The angle of repose (θ) was defined as the maximum angle subtended by the surface of a heap of powder against the plane which supported it (Taser et al., 2005). The angle of repose was measured according to the method reported by Zhang et al. (2005) with minor modification. Firstly, filler was fixed vertically above a piece of graph paper with the distance (H) from the paper to the outlet of the filler was 1 cm. Then the test powder was continuously poured into the filler and went out freely until the tip of the powder cone touched the outlet of the filler. The diameter ($2R$) of the cone was read against the scale of the paper. The angle of repose (θ) was calculated as the following formula: $\theta = \arctan H/R$.

The slide angle (α) was determined according to the procedure described by Zhou and Ileleji (2008) with some slight modifications. Five grams (5.000 g) mushroom powder were exactly weighed and separately poured on a rectangular glass plane with a length of 130 mm. After that, the glass plane was gradually lifted until the surface of the mushroom powder began to slide. The vertical distance (H) from the top of inclined glass plane to horizontal was measured. The angle of slide (α) was calculated as the following formula: $\alpha = \arcsin H/L$.

2.5. Hydration properties determination

Water holding capacity (WHC) was determined with the sequence of steps stated here (Anderson, 1982). Firstly, a cleaned centrifuge tube (M, g) was weighed and approximate 0.5 g powder (M_1, g) was poured into it. Water (M_2, g) was added to disperse the powder with a powder/water ratio of 0.05/1 (w/w) at ambient temperature. The dispersion was incubated in a water bath at 60 °C for 30 min and immediately followed by cooling in an ice-water bath for 30 min. Then, the tube was centrifuged at 5000 rpm for 20 min. The resulting supernatant was removed and the centrifuge tube with sediment (M_3, g) was weighed again. WHC was calculated as following formula: WHC (g/g) = $(M_3 - M)/M_1$.

Water solubility index (WSI) was determined by an AACC method of No. 44-19. The powder (S_1, g) was dispersed in a centrifuge tube by adding water with a powder/water ratio of 0.02/1 (w/w) at ambient temperature. Then the dispersion was incubated 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 (S_2, g) and subjected to dry at 103 ± 2 °C, and the evaporating dish with residue was weighed again (S_3, g). WSI was calculated as following formula: WSI (%) = $(S_3 - S_2)/S_1 \times 100\%$.

Swelling capacity (SC) was determined according to a previously reported method (Lecumberri et al., 2007). The initial of 1 g powder was recorded when poured into a graduate cylinder and its occupied bed volume (V_1) was recorded. Then 10 mL of distilled water was added into the tube and the tube was shaken until a homogeneous dispersion achieved. The dispersion was incubated in a water bath at 25 °C for 24 h to allow the complete swelling of the powder. The new volume (V_2) of the wetted powder was then recorded. WSI was calculated as following formula: SC (mL/g) = $(V_2 - V_1)/M$.

2.6. Determination of protein and polysaccharide solubility

Power sample (0.5 g) was weighed into a pre-weighed centrifuge tube. Fifteen millilitres of distilled water was added into the tube and the tube was shaken until a homogeneous dispersion achieved. Then, the tube was incubated in a water bath (60 °C for protein solubility and 80 °C for polysaccharide solubility) for a required time varied from 10 min to 90 and 100 min separately. After incubation, the tube was taken out, cooled and weighed. The lost water during incubation was compensated to obtain the weight of the tube as it was before incubation. After 20 min lay-aside at ambient temperature, the tube was subjected to centrifugation at 4500 rpm for 10 min and the supernatant was collected for further measurements.

The amount of protein in above-obtained supernatant was determined by a Coomassie Brilliant Blue method as developed by Bradford (1976). The polysaccharide in the supernatant was quantified by a phenol–sulfuric acid method (Dubois et al., 1951). Protein solubility (%) was expressed as the percentage of the mass of protein of the supernatant to that of the powder and polysaccharide solubility (%) was expressed as the percentage of