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Effect of superfine grinding on properties of ginger powder

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ABSTRACT

The superfine grinding could produce a narrow and uniform particle size distribution in dry ginger. The physical–chemical properties of five types of ginger powders with particles size of 300, 149, 74, 37 and 8.34 μm were investigated. The size was smaller for ginger powders, greater for the surface area (from 0.331 to 1.320 m^2/g) and bulk density (from 0.3069 to 0.3426 g/ml) and smaller for the angle of repose (from 51.50° to 46.33°) and slide (from 45.80° to 39.50°). The values of water absorption index (WAI), water solubility index (WSI) and protein content significantly increased with decreasing the size of ginger particles ($p < 0.05$). Interestingly, the values of WAI, WSI and protein content of ginger powder with a particle size of 8.34 μm during soaking reached 0.52 g/g, 33.70% and 84.93% for 60 min, respectively. SEM observations revealed the shape and surface morphology of five types of ginger powders.

1. Introduction

Ginger (*Zingiber officinale*), a member of the tropical and subtropical Zingiberaceae, is widely used around the world in foods as spice, and extensively used in Traditional Chinese Medicine to treat headaches, nausea and colds. In Chinese, Ayurvedic and Western, the ginger also was applied in the treatment of arthritis, rheumatic disorders and muscular discomfort (Dedov et al., 2002; Wang and Wang, 2005; Tapsell et al., 2006). Due to these properties, ginger has gained considerable attention of as a botanical dietary supplement in the USA and Europe in recent years, and especially for its use in the treatment of chronic inflammatory conditions.

The ginger contains biologically active constituents including the main pungent principles, the gingerols and shogaols. Jolad et al. (2004, 2005) examined the components of ginger, and identified a total of 115 compounds, including [6]-, [4]-, [7]-, [8]-, [10]-gingerol and [12]-shogaol etc. Recent studies have showed that the ginger protease could be applied in the tenderization of meat, and improve the quality of meat (Hashimoto et al., 1991; Naveena and Mendiratta, 2001). Wang and Ng (2005) found an antifungal protein in ginger rhizomes, and this protein had the stronger antifungal activity toward various fungi. However, the nutritive components of ginger have not been studied thoroughly.

Superfine grinding technology is a new technology, which is a useful tool for making superfine powder with good surface properties like dispersibility and solubility (Tkacova and Stevulova, 1998). The surface of superfine powders could undergo some changes, which had brought out the following outstanding characteristics that bulk materials do not possess. With these characteristics, namely, surface effect, mini-size effect, quantum effect, macroquantum channel effect, optical property, magnetic property, mechanical property, chemical and catalytic properties compared to conventional particle materials. Because of these notable characteristics, ultrafine powders have found many applications in ceramics, electric materials, chemicals and papermaking fields as well as in the pharmaceutical field (Yoshizawa and Hiroshi, 1991; Song et al., 2002). Nowadays superfine grinding technology has also been applied in biotechnology and food material, but only rarely. Zhang et al. (2005) found that the superfine powder of mushroom (*Agrocybe chaxingu* Huang) had good fluidity, water holding capacity and solubility, and was well suited to manufacture instant and convenient foods. Win and Stevens (2001) confirmed that the chitin superfine powder appeared to be a good substrate for the fungal deacetylase. Jin and Chen (2006) found in their investigations that the fiber size of superfine grinding rice straw powder had positive relations with enzymatic hydrolysis due to the cellulose accessibility. Rajkhowa et al. (2008) reported that the length of silk fiber via ultrafine grinding was reduced, and they also found the axial spitting and fragmentation of micro structure of silk fiber due to superfine milling. The studies suggested that the superfine grinding was a good way to fractionate bio-materials into easily bio-converted and hydrolyzed part. While very limited information is available on the effect of the superfine grinding on physical–chemical properties of ginger.

The aim of our work is to investigate the application of the superfine grinding technology in ginger, and specific surface area, water holding capacity, water solution index, bulk density and protein solubility of different sized ginger particles. We have compared to the physical–chemical properties of ginger superfine powders with coarse ginger particles.

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2. Materials and methods

2.1. Materials

Ginger was obtained from the local farmer in Laiwu country, Shandong Province, China, then sorted, cleaned and cut into small pieces. Excess water was drained off using a net, and subsequently the pieces were place in a mechanical drier at 40 °C. The drying was continued till the water content reached less than 9% for 6 h. The water content was determined by using AACC method No. 44–19 (AACC, 1995). The dried ginger was milled coarse particles by a disc-mill, which were screened through different sized sieves to separate granulates ($d < 1$ mm) (300 and 140 μm); the superfine powders with the size of 74, 37 and 8.34 μm were obtained in an HMB-701 type micronizer (Huanyatianyuan Machinery Company, Beijing, China), The planetary rubbing mill (power 0.75 kW) was a vertical batch type mill. Three rubbing rings were vertically equipped with pot holders on the turntable. The inner volume and diameter of the cylindrical shape pot were 300 ml and 400 mm, respectively. The pot was made of wear-resistant zirconia, and the rubbing rings with diameter of 300 mm were also made of the same material. The sample was mainly ground with pressure, collision and abrasion between rubbing rings and inner bottom of pot. The revolution speed of turntable was unfixed at 2500–2800 rpm/min. The particle size distribution of ginger particles was determined using laser diffraction according to AFNOR standard NF X11-666 (1984). It was performed with a Mastersizer IP granulometer (Instruments 2000, UK). Diffraction pattern analysis was carried out in air on a stream of dry powder. Determinations were repeated three times. The particle size distributions of the powder were: D_{90} = 300, 149, 74, 37 and 8.34 μm as delivered by supplier. Three measurements were carried out for each ginger powder.

2.2. Determination of surface properties

The specific surface area (m^2/g) of the ginger particles was determined by measuring the adsorption of nitrogen at 77 K according to the Brunauer–Emmett–Teller (BET) principle (Sousa et al., 2002b) and using ASAP 2010 instrument (Micromeritics instrument Co., USA). Moreover, the volume and size of pores of precipitated materials were examined. The measurements were repeated four times after degassing of each sample for 24 h at 40 °C. The reproducibility measured on a reference sample of alumina (alumina CRM 169) on different days was 0.106 ± 0.009 m^2/g, i.e. a variation coefficient of Ca. 8.5%.

2.3. Bulk density

The bulk density (g/ml) was the density including pores and interparticle voids. Five types of ginger powders were filled in a 10 ml volumetric flask (W_1) up to the mark and were weighed (W_2) separately. The bulk density of the ginger powders was calculated (Bai and Li, 2006) as follows:

$$d_0 = \frac{W_2 - W_1}{10} \quad (1)$$

where W_2 was the total weight of the ginger powder and flask, and W_1 was the weight of the flask only. The experiments were repeated five times and the measurement of each sample was repeated three times.

2.4. Test procedure for the angle 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 using the sequence of steps stated here. Firstly, a filler was fixed above some graph paper so that the distance of the paper from the outlet of the filler (H) was 3 cm, and the filler was vertical to the paper. Then the ginger powder of different size was separately poured into the filler until the tip of the powder cone touched the outlet of the filler. The diameter ($2R$) of the cone was measured for each type powder. The angle of repose (θ) was calculated as the following formula:

$$\theta = \mathrm{arctg}(2R/H) \quad (2)$$

The slide angle was determined according to Ileleji and Zhou (2008) method with some slight modification. The 5.000 g ginger samples with the different size were separately weighed. Then ginger powder was poured on glass plane with a length (L) of 130 mm and width of 100 mm. The sliding angle of repose was estimated by gradually lifting the glass plane until the surface of the ginger powder began to be slide. The angle between the inclined glass and horizontal was called the angle of slide. The vertical distance (H) between the top of inclined glass plane and the horizontal was measured. The angle of slide (α) was calculated as the following formula:

$$\alpha = \arcsin(H/L) \quad (3)$$

2.5. Test procedure for water holding capacity

This parameter was determined using the method of Anderson (1982). Firstly, the weights of cleaned centrifuge tubes (M) and different sized samples (M_1) were measured. Then the samples (M_1) were dispersed in water (M_2) according to M_1:M_2 = 0.05:1 at 20 °C and poured into the centrifuge tubes placed in a water bath at 60 °C. The tubes were held for 10, 20, 30, 40, 50 and 60 min separately and then they were placed in cold water for 30 min, followed by centrifugation for 20 min at 5000 r/min. The supernatant liquid was removed and the centrifuge tubes with the powders (M_3) were weighed again. The formula to calculate water holding capacity (WHC) is as follows:

$$\mathrm{WHC(g/g)} = \frac{M_1}{M_3 - M} \quad (4)$$

2.6. Test procedure for water solubility index (WSI)

The different sized samples (S_1) were measured. Then the samples (S_1) were dispersed in water (S_2) according to S_1:S_2 = 0.02:1 at ambient temperature and put into the centrifuge tubes placed in a water bath at 80 °C, and shaken for different time intervals of 10, 20, 30, 40, 50 and 60 min. The WSI was reported as percentage, and determined by using AACC method of No. 44-19 (AACC, 1995). The resulting mixture was centrifuged at 6000 rpm for 10 min. Excess water of the clear supernatant solution was drained off by evaporation. Then the samples were dried at 105 °C and weighed (S_3).

$$\mathrm{WSI}(\%) = \frac{S_3}{S_1} \times 100\% \quad (5)$$

2.7. Test procedure for solubility of protein

Total nitrogen of the ginger powder was estimated by Kjeldahl's method (Wathelet, 1999). The crude protein content (C) was calculated multiplying the nitrogen content by the approximate factor 6.25 (Wathelet, 1999).

The weights of different sized samples (W_1) were accurately weighed, and put into the previously weighed tubes and mixed