Effect of Superfine Grinding on Physicochemical Properties of Apple Pomace

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Summary: The effect of superfine grinding on the physicochemical properties of apple pomace was investigated in this study. The optimal ultrafine powder could be obtained under the conditions of motor speed 450 rpm and fan speed 300 rpm, whose particle size, water-solubility index, angle of repose, total phenolic content and total sugar content were 10.23±0.42 μm, 33.65±0.91%, 39.36±1.59°, 12.62±0.34 mg GAE/g and 136.14±3.1 mg/g, respectively. Compared with the traditional powder, the significant increase of water-solubility, total phenolic content and total sugar content could be found while the decrease of angle of repose could be observed. It could be concluded that the bioavailability of functional and nutritional ingredients of apple pomace could be significantly improved by superfine grinding.

Keywords: Apple pomace, superfine grinding, physicochemical properties, ultrafine powder, traditional powder

Introduction

The yield of apple in China is the highest in the world. With the increase of apple yield, the production of apple juice also rises. Apple pomace is the main waste fraction of apple juice production. Usually, 1000 kg processing of apple will yield 200-250 kg of apple pomace, which contains numerous bioactive compounds including dietary fiber [1-2], polyphenols [3-4], Vitamins (especially, V_{B6} and V_C). At present, apple pomace is mainly used as feed [5] or discarded [6], which pollutes the environment. There is always a demand to develop new technology to make full use of apple pomace.

Superfine grinding, as a new kind of processing technology, has attracted more and more attention, which can make material size below 30 μm and improve the particle granularity and crystalline texture [7-9]. The ultrafine powder possessed better fluidity and uniform granularity. And its appearance, water holding capacity, oil holding capacity and water soluble index were superior to those of traditional powder [7]. After superfine grinding treatment, the taste and availability of red date, mushroom, pleurotus eryngii and dried bamboo shoot could be improved [8-12]. To the best of our knowledge, there is no report about the effect of superfine grinding on physicochemical properties of apple pomace, which was just the object of this study.

Experimental

Materials

Apple pomace was provided by Hubin juice factory (Sanmenxia, China). Other chemicals used were of analytical grade.

Powder Preparation

The apple pomace was dried at 80 °C for 2 h. The dried pomace was cooled and ground for 40 s with a traditional grinder (FW177, Tianjin Taisite Instrument Co., LTD). The powder between 80 and 100 mesh was collected as group A, and 160-200mesh as group B. The raw pomace material was ground by a superfine pulverizer (YSC-701, Beijing Yanshan Zhengde Machinery Equipment Co., LTD) at the motor speed 450 rpm and fan speed was 200 rpm, 300 rpm, 400 rpm, respectively, and the corresponding ultrafine powder group C, D and E could be obtained. Five kinds of powder were shown in Table-1.

Table-1: The apple pomace powders after grinding.

NO.	Samples
A	80-100 mesh
B	160-200 mesh
C	motor speed 450 rpm, fan speed 200 rpm
D	motor speed 450 rpm, fan speed 300 rpm
E	motor speed 450 rpm, fan speed 400 rpm

Particle Size Measurement

The particle size of five apple pomace powders was measured by using an 80i upright microscope (Nikon Corporation, Japanese). The magnification of the image was set at 100 times. For each group, 100 samples were measured with triplicate.

Determination of Water Holding Capacity

Water holding capacity (WHC) was determined according to the method reported by

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zhang *et al*. (2012) [9]. Firstly, 1.00 g powder (M_1, g) was poured into a 100 mL beaker, and 50 mL distilled water was added to disperse the powder at ambient temperature. The dispersion was incubated with magnetic stirring for 30 min, and then was centrifuged at 4000 rpm for 30 min. The resulting supernatant was removed and the sediment (M_2, g) was weighted again. WHC was calculated as following formula:

$$\text{WHC (g/g)} = \frac{M_2 - M_1}{M_1}$$

Determination of Water Solubility Index

Water solubility index (WSI) was determined according to the method of Mateos-Aparicio *et al* with minor modification [13]. The powder (M_1, g) was dispersed in a 200 mL beaker by adding 50 mL distilled water at ambient temperature. Then the dispersion was incubated in a water bath oscillator at 90 °C for 30 min, and followed by cooling to room temperature. Then the dispersion was centrifuged at 3000 rpm for 15 min. The supernatant was removed and the sediment was dried to constant weight at 80 °C. WSI was calculated as following formula:

$$\text{WSI (\%)} = \frac{(M_1 - M_2) \times 100}{M_1}$$

Determination of Angle of Repose

The angle of repose (α) was defined as the maximum angle subtended by the surface of a heap of powder against the plane which supported it. The angle of repose was measured according to the method reported by Ileleji *et al*. with minor modification [12]. Firstly, 50 mm funnel was fixed vertically above a piece of graph paper with the distance of 3 cm from the paper. Draw a dot (L1) just below the centre of the funnel's bottom, and then the test powder was continuously poured into the funnel until the tips of the powder cone touched the bottom of the funnel, and draw a dot (L2) again at the edge of the cone. The radius (R) of the cone was obtained from the distance between L1 and L2. The angle of repose (α) was calculated as the following formula:

$$\alpha = \arctan \frac{3}{R}$$

Determination of the Oil Holding Capacity

Oil holding capacity (OHC) was determined according to the method reported by Sangnark *et al*. with minor modification [14]. Firstly, 4.00g powder (M_1, g) was poured into a 100 mL beaker, and 20 mL peanut oil was added to disperse the powder. The dispersion was incubated with magnetic stirring for 30 min, and then was centrifuged at 4000 rpm for 30 min. The supernatant oil was removed and the free oil attached to the sediment (M_2, g) was removed with the filter paper. OHC was calculated as following formula:

$$\text{OHC (g/g)} = \frac{M_2 - M_1}{M_1}$$

Determination of the Content of Polyphenols

The content of polyphenols was quantified by a Folin-Ciocalteau method reported by Renard (2001) [15].

Determination of the Content of Polysaccharide

The content polysaccharide was quantified by the phenol-sulfuric method reported by Dong *et al*. (1996) [16].

Statistical Analysis

All experiments were done in triplicate and the results were expressed as mean ± standard deviation (SD). The difference between means was determined by Duncan's multiple range tests by using the DPS7.05 statistics software. Results were considered statistically significant at $p < 0.05$.

Results and Discussion

Particle Size Analysis

The particle size distributions of the powders obtained by traditional and superfine grinding were shown in Fig. 1. All the particle sizes of group C, D and E were below 25 μm. With the increase of the fan speed, the particle size decreased. When the fan speed was 400 rpm, the smallest particle size of apple pomace powder could be obtained by group E (10.23±0.42 μm). But the particle sizes of group A and B were as high as 254.36±8.62 μm and 62.53±2.63 μm, respectively. Therefore, the particle sizes of apple pomace powder from superfine grinding were far below those of traditional grinding. It was also found that superfine grinding could lead to the narrower size distribution and more uniform size, which coincided with the result of Zhang *et al*. (2012) [9].

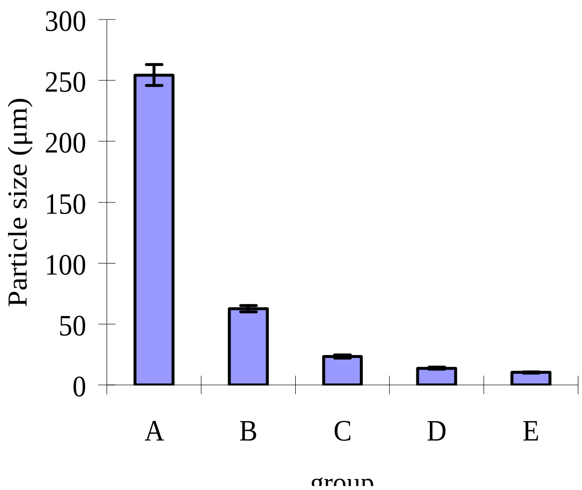

Fig. 1: Determination of the particle size of apple pomace powders (*n*=4).

Hydration Properties

The hydration properties including WHC and WSI of the powders were shown in Fig. 2. With the decrease of the particle size of apple pomace powder, the WHC values gradually decreased. The maximum WHC value of routine grinding powder was observed by group A (8.76±0.26 g/g). However, The WHC values of superfine powder from group C, D and E were reduced from 4.51±0.21 g/g to 4.36±0.16 g/g. And there was no significant difference between group C, D and E, which could be attributed to the broken microscopic spatial structure of the apple pomace. And the WHC of the powder from group C, D and E in our study was higher than the result of Liu *et al*. [17]. For the comprehensive effect of spatial structure and specific surface area, the WHC changed in a certain range when the particle size of the powder was below a certain size.

The WSI and the solubility of the powder could also influence the hydration properties of the powders. As shown in Fig. 2, with the decrease of the powder's particle size, the WSI of the powders gradually increased, and the value ranged from 19.52±0.75% (group A) to 33.65±0.91 % (group E), which suggested the value of the WSI of group E was about 72.39 % higher than that of group A. There was no significant difference between the WSI values of group D and E while the significant difference between the WSI values of group C and E could be found. Moreover, the WSI of the powder from group C, D and E in the study was also higher than the result of Liu *et al*. [17]. It could be found the decrease of particle size led to the increase of the solubility of the powders, which could be attributed to the smaller particle size and the bigger specific surface. Moreover, the bigger the powder's surface contacted with the water, the easier the ingredients of the pomace were soluble in water.

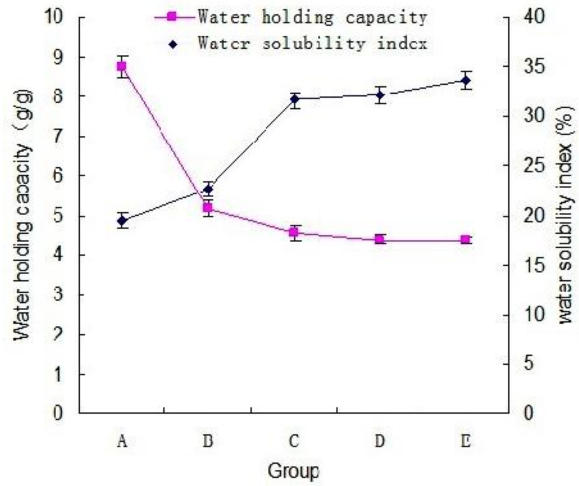

Fig. 2: Effects of different grinding methods on the hydration properties of apple pomace powders (*n*=4).

Based on the above analysis of WHC and WSI, the ability of capillary water absorption of superfine powder decreased and the swelling was the most important behavior in hydration properties. Therefore, in order to obtain the optimal hydration properties, the fan speed of 400 rpm was selected for superfine grinding.

Angle of Repose

The angle of repose is used to describe the fluidity of the powder. As shown in Fig. 3, the micronized powders had the lower angles than the traditional powders. The maximum angle of repose (79.75±3.12°) was obtained by group A while the minimum angle (39.36±1.59°) was found by group E. Compared with group A, the angle of group E decreased by 50.65%. The significant differences among the angles of group C, D and E could be observed. It was easy to conclude that the smaller the particle size was, the better the fluidity of the powder was. A similar observation was presented for wheat bran powder by Wang *et al*. [7]. Because the micro-spatial structure of the apple pomace was changed by superfine grinding, and the specific surface area increased, the electrostatic effect enhanced. As a result, the powder's fluidity was improved. The better the fluidity of the powder was, the stronger the aggregation power in powder's surface was. The better absorbability and more uniform particle size could be obtained. The above analysis showed that the angle of repose of the micronized powders became lower and the fan speed of the superfine pulverizer should be set at 200 rpm.

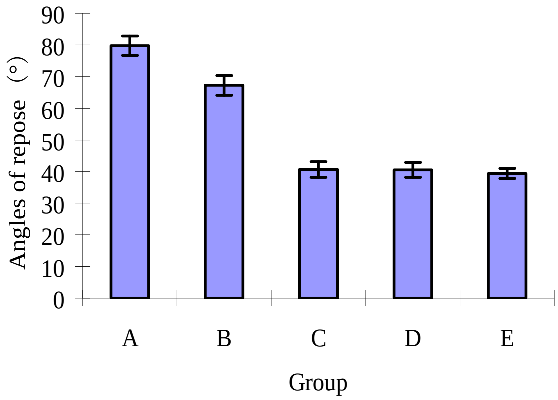

Fig.3: Effects of different grinding methods on the angles of repose of apple pomace powders (*n*=4).

Oil Holding Capacity

The dietary fiber has high oil holding capacity (OHC), which plays an important role in weakening greasiness and increasing satiety. As shown in Fig. 4, the OHC of the superfine powders reduced slightly with the decrease of the particle size compared with the WHC. The maximum value of OHC (1.55±0.07 g/g) occurred at group A. The OHC values of group D and E were 1.35±0.05 g/g and 1.35±0.06 g/g, respectively. Compared with group A, the OHC values of group D and E decreased by 12.90%. There was no significant difference between the OHC values of group D and E, which was in agreement with the report of Li *et al*. (2014) [18]. Normally, the oil absorbing ability of the high dietary fiber food could be enhanced with the decrease of the particle size. The fact that the OHC of the superfine powders decreased slightly with the reduction of the particle size might be attributed to the void space between the superfine powder's particles, which was smaller than that of traditional grinding. As a result, the fill of oil was limited. And the OHC *in vivo* of the superfine powder needs to be carried out.

Total Phenols

Apple pomace was rich in polyphenols. Fig. 5 showed the results of the total phenol contents of five powders. It could be observed that the total phenol contents of group C, D and E was far higher than those of group A and B. The maximum occurred at group E (12.62±0.34 mg GAE/g), and the minimum was found by group A (8.26±0.21 mg GAE/g). Compared with group A, the total phenol level of group E increased by 52.78 %. There was no significant difference between the total phenol contents of group D and E while the significant difference between the total phenol contents of group C and E could be found. When the fan speed of the superfine pulverizer was set at 300 rpm, the maximum could be obtained.

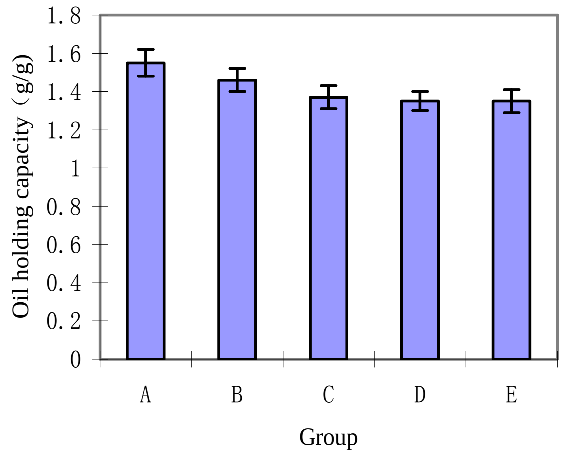

Fig. 4: Effects of different grinding methods on the OHC of apple pomace powders (*n*=4).

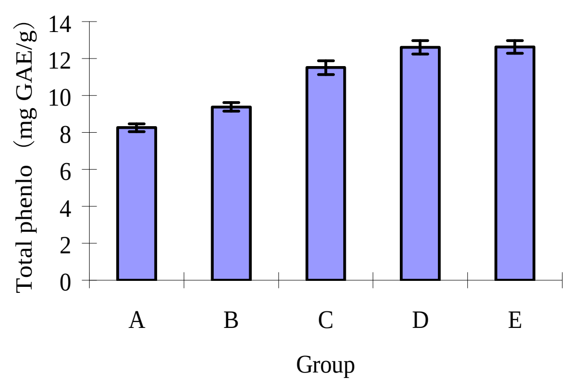

Fig.5: Effects of different grinding methods on the total phenol of apple pomace powders (*n*=4).

Polysaccharide Solubility

The polysaccharide solubility of five powders was shown in Fig. 6. It was found that the polysaccharide solubility increased with decrease of article size. The maximum occurred at group E (110.65±2.8 mg/g), and the minimum was found by group A (110.65±2.8 mg/g). Compared with group A, the polysaccharide solubility of group E increased by 19.09 %. The smaller of the particle size of the powder was, the larger of the specific surface was. Similarly, Zhou *et al*. also indicated that the polysaccharide solubility of the ultrafine powder from jujube was higher than that of traditional grinding powder [19]. As a result, the extraction of polysaccharide from superfine powder was easier. Moreover, during superfine grinding, the cell wall of the powder was also destroyed, which promoted the polysaccharide extraction.

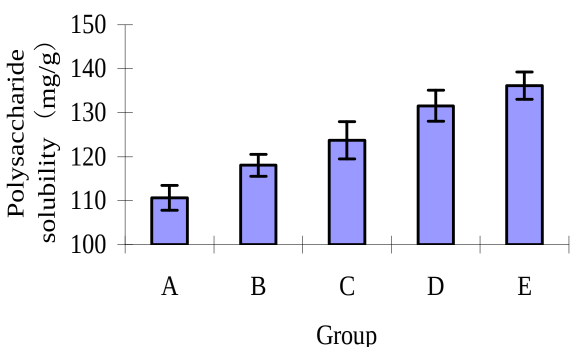

Fig. 6: Effects of different grinding methods on solubility of polysaccharide of apple pomace powders (*n*=4).

Conclusions

In this study, physicochemical properties of apple pomace powders prepared by superfine grinding and routine grinding were compared. The optimal superfine powder of apple pomace could be obtained at motor speed 450 rpm and fan speed 300 rpm. All the particle sizes of group C, D and E from superfine grinding were below 25 μm and the minimum was 10.23±0.42 μm. The physicochemical properties of the superfine powders, such as water solubility index, angle of repose, total phnenol and polysaccharide solubility, were superior to those of traditional grinding powders. Compared with group A, the WSI of group E increased by 72.39 %, the angle of repose of group E decreased by 50.65 %, the total phenol content and polysaccharide solubility of group E increased by 52.78 % and 19.09 %, respectively. On the other hand, the OHC value of the superfine powders was slightly lower than that of group A. The OHC values of group D and E decreased by 12.90 %. The obtained apple pomace powders prepared by superfine grinding could be used as food additive and functional food.

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