Effect of particle size on the physicochemical property of the peel powder from *Aloe barbadensis*

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Abstract. *Aloe barbadensis* (Aloe vera) has long been used in food, cosmetic and pharmaceutical industries. In order to maximally extract soluble sugars, different drying methods, such as heat-drying (HD), air-drying (AD), vacuum freeze drying (VFD), and microwave drying (MD), on the sugar content were investigated in the present work. Besides, the relationship between the particle size and the physicochemical property of the peel powder obtained by ultramicro-pulverization was also explored. The results showed that different drying method did have significant effect on the soluble sugar content. HD, AD, and VFD possessed similar sugar content (approximately 8.27, 8.46, and 8.46 g/100g, respectively). The highest sugar content was found in MD (9.36 ± 0.30 g/100g), indicating that MD was the most effective way to extract sugars from Aloe vera peel among these four methods. The particle size of the peel powder after dried by MD was affected by the crusher time and power. The higher the power, and the longer crusher time, the smaller particle size of the powder. Along with the decreasing of particle size, the color parameter (B value) of the peel powder significantly decreased from 24.47 to 16.90 (P < 0.05). The water holding capacity also decreased when the D (0.5) reduced due to the lower binding capacity of small size particle towards water. As the reduction of D (0.5) value, the water holding capacity decreased (from 6.21% to 3.52%). The present work could provide valuable information for the comprehensive utilization of the by-products of Aloe vera.

Keywords: *Aloe barbadensis*; Peel; Drying method; Particle size; Physicochemical property

1. Introduction

Aloe vera, which is a cactus-like plant, has been planted worldwide. For the relatively high nutritional value, it has been widely used in medical, cosmetic and food industries. Aloe contains a variety of active components, including anthraquinone compounds, organic acids, polysaccharides, peptides, amino acids, proteins, vitamins, minerals, biological active enzymes. Evidence had showed that Aloe possessed many benefits towards some diseases, including but not limited to anti-inflammatory [1, 2], antifibrotic effect in alleviating the fibrosis and inflammation [3], protection of reducing the production after exposure to...
ultraviolet radiation [4], hepatoprotective activity against carbon tetrachloride (CCl4) induced hepatotoxicity [5].

During the processing of Aloe, the related by-products such as peels and spikes, generated with a relatively high amount. It had been reported that the main active compounds extracted from the peel were mainly oligosaccharides and polysaccharides. The obtained sugars showed good bio-activity, for suppressing the expression of delayed type hypersensitivity (DTH) responses and reducing the amount of IL-10 as demonstrated in vivo [4]. These compounds also showed chemo-preventive effect for the inhibitory effect on BPDE-1-DNA adducts [6]. Taken together, it could be easily to understand that the Aloe vera peels could be an excellent source for providing the bioactive compounds, among which pectin was one of the most important one. However, huge amount of Aloe vera peel (the outer green skins) and spikes obtained during the processing of Aloe vera gel and juice have always been discarded without further use, resulting the resource waste. Thus, it was of vital to improve the comprehensive utilization of Aloe vera peel. Recent studies showed different applications of Aloe vera, such as modified Aloe leaf powder could promote the absorption Ni(II) ions from aqueous solution [7]. Besides, the morphology of the nanoparticles could be regulated by controlling the amount of Aloe vera extract, which could be a novel, cheap, and convenient method for the commercial production of cupric oxide (CuO) nanoparticles [8].

Previously, pectin, extracted and characterized from the peel, exhibited good antioxidant property, indicating the potential high economic value of Aloe vera peel. Commercial pectin is mainly extracted from citrus peel [9, 10], orange peel, lemon peel, apple peel, etc. Others such as sunflower[11], peach[12] cactus peel [13] also contain rich pectin. At present, milling are the most conventional process of the extraction techniques after drying. It had been reported that there were various drying methods, such as conventional methods such as heat-drying and air-drying; spray drying[14], microwave drying[15], freeze drying (FD), and refractance window (RW) drying methods [16]. However, the effects of different drying methods on the yield of soluble sugar have not been systematically reported.

Additionally, according to the previous report [17], particle size could be the effect of the thermal parameters for the oxidation of graphite. Furthermore, there are reports shows when particle size was altered distributions through regrinding and blending, flour functionality changed[18]; a novel and large particle size ZSM-5 has effect on Si/Al ratio and ammonium exchanging of the conversion of methanol to propylene [19]. As a result, the relationship between particle size and its property of Aloe vera peel still need to be further studied.

The present work aims to: a) explore the different drying methods on the content of soluble sugar; b) investigate the effect of crusher parameter on the particle size of peel powder; c) explore the effect of particle size on the properties of peel powder.

2. Materials and methods

2.1. Material and chemicals

Material: Fresh Aloe vera was washed, then the peel was separated. The obtained peel was stored under -80 °C until use.

Chemicals: Sodium hydroxide, sodium tartrate, phenol, sodium sulfite, potassium ferricyanide, zinc acetate, glacial acetic acid, methyl red indicator, anhydrous ethanol, concentrated hydrochloric acid, 3, 5-dinitrosalicylic acid (DNS) reagent, glucose standard (alighting reagent).

2.2. Drying of aloe peel

Pretreatment of experimental materials: Fresh aloe peel (about 500 g) were cut into small pieces, removed the aloe pulp, washed with clean water, and finally put into the hot water bath (80 ± 1 °C) kept for 10 min to inactivate the enzymes. Then the peels were removed from the hot water bath and extra water was removed by gauze. Different drying methods were shown as follows. Heat-drying (HD): Peels were dried at 60 °C for 24 hours in the electrical blast drying oven until the moisture content reduced under to 10%. Air-drying (AD): Peels were dried in the ventilated place for more than 48 hours, until
the moisture content is reduced under to 10%. Vacuum freeze drying (VFD): Peels were frozen at -50 °C for 24 hours. After peels being frozen to solid, quickly spread out on the shelf of vacuum freeze dryer. Peels were dried in vacuum for 24 hours until moisture content reduced under to 10%. Microwave drying (MD): Microwave oven with medium output was used for drying peels for 3 min, and then air dried for 2 min. Two processes were alternated until moisture content reduced below to 10%.

Determination of water content: At the beginning of the determination, approximate 1.0g of the sample was weighted by halogen moisture meter, and then halogen moisture meter was rapidly heated to 180 °C, cooled to 100 ~ 105 °C after 1 min, for the evaporation of the water. During the alternation of two processes, instrument display screen continuously displays the moisture content of the sample. At the end of drying, the final moisture content of the sample was showed on the display screen. Each sample was measured 5 times, and the moisture content of the sample was calculated.

Determination of soluble sugars: The contents of soluble sugars were measured as previously described with minor modification by HPLC [20]. Samples (2 g) were mashed. Mashed tissues were mixed with 30 mL of type-1 filtered water and then incubated in a water bath (80 °C, 60 min). Then suspension was centrifuged at 10,000 g for 20 min at room temperature, and its supernatant was collected and filtrate was collected as sample solution. HPLC (Shimadzu Prominence, Japan) analysis was performed and the mobile phase consisted of acetonitrile: water (82.5:17.5, v/v) was degassed by ultrasonic bath prior to use. Each run was completed within 30 min. The flow rate was 1 mL/min. The concentration of sugar was expressed in g/100g on a fresh weight basis.

2.3. Superfine grinding

2.3.1 Pretreatment. After drying, materials were dried at 60 °C in a constant temperature blast drying oven. After grinding aloe peels to a high particle size, materials were sieved by 60 mesh standard screen, and fine powder was obtained. The average particle size D (0.5) which measured by laser particle size analyzer was 192.61μm.

2.3.2 Superfine grinding of aloe peel. The parameters of mass ratio was 1:4 and the material ratio was 8:1. To investigate to effects of time and rotation speed on superfine grinding, five parameters of time of planetary ball mill were 60 min, 120 min, 180 min, 240 min and 300 min and the parameters of speed were 400 RPM, 450 RPM, 500 RPM, 550 RPM, and 580 RPM.

2.4. Determination of superfine grinding of aloe peel

2.4.1 Particle size distribution. The particle size distribution of peel powder was determined using laser diffraction according to AFNOR standard NF X11-666 (1984)[21]. It was performed by Mastersizer 2000E laser granulometer was used to determine the particle size distribution. Samples were made in triplicate for each sample, using 10–20 g sample weight for dry particle size distribution and 1–2 g in ultra-pure water for hydrated particle size distribution. The grand refractive index of aloe peel superfine-grinding powder was determined at 1.52. Recorded D (3,2), D (4,3), D (0.5) of powder.

2.4.2 Color. According to Lario [22], the color coordinates were determined: lightness (L), redness (A, red–green) and yellowness (B, yellow–blue). Color determinations were made by spectrophotometer, 11 mm aperture of the instrument for illumination and 8 mm for measurement. Spectrally pure glass was put between the samples and the equipment.

2.4.3 Water holding capacity. Peel powder (0.5g peel powder) was hydrated with 50 mL ultra-pure water in a centrifuge tube at room temperature. After centrifuged (5000r/min, 10 min), supernatant was decanted, carefully inverting from the tube and the sediment was left to drain in the tube. WHC was calculated as the amount of water retained by the sediment (g/g dry weight) after drain. Method was according to Robertson [23].
WHC (Water holding capacity) (g/g) = (M₃ - M₁ - M₂)/M₂
M₁: weight of 50mL centrifuge tube
M₂: weight of sample
M₃: weight of sediment and centrifuge tube

2.4.4 Water solubility. Sample was hydrated in 50mL ultra-pure water (according to the ratio of 1/50) and placed in water bath (80 ± 1°C) for 30 min. After centrifuge (5000r/min, 10min), supernatant was decanted, carefully inverting to a beaker and dried by electric blast chamber (105 °C) until dried material was obtained.
WSI (Water solubility index) (%) = (m₂ - m₁)/m × 100%
m: weight of sample
m₁: weight of and beaker
m₂: weight of dried material and beaker

2.5. Statistical analysis
Three parallel samples were set up for all the experimental groups, and the results were reported as mean ± standard deviation (SD). Statistical analyses were performed with Originlab2016 and Endnote. Duncan’s multiple range tests at a 95% confidence level (P<0.05) were performed to identify significant differences using SPSS (Version 24.0, IBM, SPSS Inc., Armonk, NY).

3. Result and discussions

3.1. Evolution of soluble sugar content by different drying methods
Before the extraction of soluble sugar form the peel power, the fresh peel should be firstly dried. The effect of different drying method on the content of soluble sugar was exhibited in Figure 1.

![Figure 1. Effect of different drying method on the content of soluble sugar. Different lowercase denote significant difference (P < 0.05).](image)

Despite the different drying method and the related parameters, no statically significant difference (P > 0.05) was observed among HD, AD, and VFD. While significant (P < 0.05) difference was observed between MD and the other three methods on the content of soluble sugar. Despite the variation of temperature, time and the machine used, HD, AD, and AFD showed similar extraction efficiency towards the soluble sugar content. HD obtained the lowest sugar content (approximately 8.27 ± 0.22 g/100g). AD and VFD showed similar results towards soluble sugar content (8.46 ± 0.26 and 8.46 ±
0.12 g/100g, respectively). Whereas the MD showed the highest content (9.35 g/100g) of soluble sugar content among the selected drying methods. The highest content observed by MD might be attributed to the increasing activity of vacuolar invertase which is a key enzyme regulating the levels of sucrose, glucose and fructose in plant tissue lead to decreasing of reducing sugars[24], as well as increased drying rates and substantial shortening of the drying time[25], which indicates that the shorter the drying time is, the higher content of soluble sugar is extracted. For the relatively higher content, MD was chosen as the drying method in the present work.

![Figure 2](image)

**Figure 2.** Different crusher times and power on the (A) surface area average particle size (D(3, 2)), (B) volumetric mean particle size (D (4,3)), and (C) average particle size (D (0.5)) of peel powder.

3.2. *Evolution of the particle size of peel power during grinding process by different time and power*

As known, different crusher parameters played an important role on the particle size of the obtained powers. The effects of crusher parameter on the particle size of Aloe vera peel powder were explored. As plotted in Figure 2, the main effects of particle size, crusher time and power, were determined by three standards. Standard A is the weighted average particle diameter D (3, 2); standard B is the volume weighted average particle diameter D (4, 3) and standard C is the median diameter D (0.5). As with the increase of time and the increase of rotational speed (from 400 r/min ~ 580 r/min), powder surface area of three standard were all decreased. The average particle size (D (0.5)) was up to 13.52 μm when crushed at 580 r/min for 5 h. Crusher time had slight effect on particle when it was less than 120min, whereas particle size decreased with the time increased after 180min, which indicated that the effect of particle size is time-dependent. With the increasing of rotational speed, the higher speed that crusher was set, the narrower particle size distribution can be achieved. As the figures show, when the crusher was set at 580 r/min, the narrowest particle size had been obtained. The result may contribute to the
higher power, the greater the shear strength. Whereas the shear strength also increases with the decreasing particle size[26] which is a possible reason for the slight changing between 120min -180min.

3.3. Relationship between the particle size and the properties of peel powder

According to figure 3, it showed that: The L of superfine powder increased significantly (from 57 to 75) with the reduction of the average particle size while B was decreasing (from 24.47 to 16.9). A of red and green degrees changed slightly, which indicates that superfine-grinding powder surface became shinier with reduction of particle size and the degree of yellow decreased. There may be three reasons for the result. Firstly, as the average particle size decreased, the particles became more uniform and finer. Secondly, as the cell wall fully broken, the specific surface area was increased and the powder internal components such as protein spilled. Thirdly, due to the large amount of heat generated by the friction of mechanical force in the process of superfine grinding, pigment substances decomposed and transformed, resulting in the change of the powder color. Figure 3 also showed that the superfine grinding had a significant effect on the water holding capacity of aloe peel powder. As the decreasing of particle size, the water holding capacity decreased (from 6.21% to 3.52%). According to the result, it indicates that some soluble substances were dissolved due to the increasing cell rupture, and some long-chain structures were broken into short-chain structures due to high-speed abrasive impact shearing, which reduced the binding force of some active substances to water, resulting in the decreasing water holding capacity. By comparing 25 groups of the coarse powder of aloe vera peel at all levels in external properties of superfine grinding powder. Tactility and state had changed dramatically after grinding and it was clearly to be found that several changes with the reduction of particle size from the visual and tactile senses: color of powder changed from darkness to lightened; the texture of powder became more uniform and delicate; the smell were getting stronger. Additionally, as the particle spacing of powder became narrower, a little agglomeration occurred. The situation was much easier to occur when the particle size is less than 50μm. At the same time, the sense of particle disappeared, the viscosity increased.

Figure 3. Relationship between the D (0.5) and the variation of color (A) and water hold capacity (B) of peel powder.

4. Conclusion

Overall, the results showed that MD was the best drying method for aloe vera among these four methods. Besides, with the decrease of particle size, which due to the increase of rotational speed and time, color of the powder changed significantly, especially L and B of the powder as well as water holding capacity and water solubility decreased.
This paper mainly focused on the extraction of soluble sugar, the relationship between the particle size of fruit peel powder and the physicochemical properties after superfine grinding, and finally determined the optimal process conditions for the extraction of soluble sugar, and explores the potential value of aloe peel. The present work could provide useful information for the comprehensive utilization of aloe peel. Further work is needed to investigate the utilization of different by-products for different materials.

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