

Comparison of dietary fiber characteristics prepared from cassava pulp using acid-heat treatment and extrusion process

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Abstract. The development of dietary fiber from potential local resources is carried out by utilizing cassava pulp to increase its added value and application. Acid-heat treatment and extrusion process were employed to convert cassava pulp into dietary fiber. This study purposed to determine the characteristics of the chemical compositions, physicochemical functional properties, and yield of dietary fiber products resulting from acid-heat treatment and extrusion process. Dietary fiber produced by the acid-heat treatment had a total dietary fiber (TDF) content of 89.24%, starch content of 9.7%, water holding capacity (WHC) of 12.07 g/g, oil holding capacity (OHC) of 3.99 g/g, swelling capacity of 17.8 ml/g, bulk density of 0.2 g/ml, and 50% yield. While the dietary fiber produced by extrusion process had a total dietary fiber content of 50.86%, starch content of 47.28%, water holding capacity of 9.96 g/g, oil holding capacity of 0.81 g/g, swelling capacity of 12.99 ml/g, bulk density of 0.6 g/ml with a yield of 90%. Acid-heat treatment was effective for removing starch components and increasing TDF, as well as improving WHC and OHC values. The extrusion process could not remove starch components and did not increase TDF and OHC, but could improve WHC value by swelling the starch granules.

1. Introduction

Cassava pulp is a solid residue (side product) of tapioca industries that has abundant amounts in Indonesia and relatively cheap [1], yet it is not optimally utilized. A total of 7.8 million tonnes of domestic cassava were used to produce tapioca in 2013 and the number increased annually [2]. The dry cassava pulp generated reaches 1 million tons/year. Cassava pulp will generate environmental problems as solid waste if it is not managed further [3]. Until present days, the usage of cassava pulp in Indonesia is limited as raw materials for feedstuff [1], fermentation substrates [4], mosquito coils, sauces, and other uneconomical products.

Cassava pulp contains 55.5% of starch and 35.2% of total dietary fiber, hence, it has high potential as a food fiber source [5]. Moreover, cassava pulp also has low-fat content of 0.12% [6] and 1% [5], so rancidity can be avoided while in storage.

Dietary fiber is an important food component that has proven to give health benefits for evading chronic diseases such as cancer, heart disease, and diabetes mellitus [7][8]. Dietary fiber is also part of plants that can be eaten or analog with carbohydrates; resistant to digestion and absorption in small intestines; and partially or fully fermented inside the colon [9]. At present, the rich fiber-based food products market is highly competitive, so it is

important to explore alternative and sustainable dietary fiber sources, especially from the byproducts of food processing industries [10].

Several treatments need to be carried out on cassava pulp to obtain the functional properties of dietary fiber. Preparing dietary fiber from cassava pulp can be done by acid-heat treatment or extrusion process. The acid heat treatment is an acid hydrolysis process that allows the reduction of the starch content from 60% to 15% and escalates the Total Dietary Fiber (TDF) content from around 30% to 70% [11]. Additionally, this treatment is expected to modify the fiber structure from crystalline to a more amorphous structure [12]. Another consideration for selecting acid-catalyzed hydrolysis is that it requires a relatively cheaper cost. Extrusion treatment was carried out to modify the starch granules and fiber components so that their physicochemical properties changed. Extrusion was distinguished by the usage of barrel temperature, below 70°C for cold extrusion and above 70°C for hot extrusion [13]. Operation conditions in the extrusion process for food material included barrel temperature, moisture content, screw rotation speed, and shear stress [14].

This study purposed to investigate the characteristics of dietary fiber prepared from cassava pulp using the acid-heat treatment and extrusion process, namely chemical composition and physicochemical characteristics of Water Holding Capacity (WHC), Oil Holding Capacity (OHC), Swelling Capacity (SC), and bulk density. In addition, the comparison of dietary fiber production technology with acid-heat treatment and extrusion process was also studied.

2. Materials and methods

2.1. Materials

The cassava pulp was procured from PT. Sinar Pematang Mulia II, a big scale tapioca industry in Lampung Province, Indonesia. Sulphuric Acid (H_2SO_4), Sodium Hydroxide (NaOH) and other chemicals were purchased from *Merck*.

2.2. Preparations and characterizations of cassava pulp

Cassava pulp (fine fiber) from the extraction unit in tapioca industry (moisture content 85-90%) was squeezed with a screw press until its moisture decreased to $\pm 50\%$, then it was sun-dried to obtain moisture content of $\leq 13\%$. Further, the dried cassava pulp was floured and sieved with 40 mesh particle sizes. The initial characterizations were conducted to determine the chemical compositions of the dried cassava pulp, such as starch content, TDF, protein, fat, and ash.

2.3. Dietary fiber preparation using acid-heat treatment

The acidified water was made by mixing H_2SO_4 (density: 1.835 g/ml) at a concentration of 2% v/w cassava pulp and 666 ml of water in 2L Tank. Then, 200 grams of the cassava pulp were added to the acidified water and stirred to reach a homogenous slurry. After that, the slurry was put in an autoclave, and the reaction was carried out at a temperature of 127°C for 45 minutes. The slurry was filtered using filter cloth and separated from the hydrolyzate

(sugar syrup). The cake (fiber) obtained was washed and the pH was raised to pH 6 by adding 5% NaOH solution, then washed and filtered again. The fiber product was dried in the oven at 60°C until its moisture content was relatively constant.

2.4. Dietary fiber preparation using extrusion process

The dried cassava pulp of 15 kg was adjusted for its moisture up to 35%. The feed was extruded with a LT70 Twin Screw Extruder (Shandong, China) at a temperature of 75°C (hot extrusion). The rotational speed of the major screw was set at 60 rpm and the feeding screw at 30 rpm. The flakes were produced as extrudate, then it was sun-dried. The quality of the extrudates was determined based on the extrudate properties, which include bulk density, moisture content, and water holding capacity [14]. The dried flakes were then milled and sieved with the particle size of 80 mesh.

2.5. Dietary Fiber Raw Materials and Products Characterizations

2.5.1. Chemical Composition Analysis.

Soluble Dietary Fiber (SDF) dan *Insoluble Dietary Fiber (IDF)* were determined with enzymatic-gravimetry from AOAC Method 993.19 and 991.42. TDF was measured by adding IDF and SDF values. Moisture content, protein, fat, and ash were determined using AOAC Method [15]. Starch content was determined using enzymatic hydrolysis method [16].

2.5.2. Physicochemical Analysis.

Physicochemical analysis methods include Water Holding Capacity [17], Oil Holding Capacity [18], the Swelling Capacity [19], and the Bulk Density method [20].

2.5.3. Morphology.

The Morphology of dietary fiber raw materials and products were analyzed using Scanning Electron Microscope (EVO MA 10, *Carl Zeiss, Germany*) at 750x magnification.

3. Result and discussion

3.1. Chemical compositions of cassava pulp

Dried cassava pulp in 40 mesh size was used for this research. The chemical compositions of cassava pulp (dry basis) consisted of 47.34% starch, 50.2% TDF (43.6% IDF and 6.6% SDF), protein (1.72%), fat (0.25%), and ash (0.52%). The major components of cassava pulp were starch and fibers, but there were small portions of protein, ash, and fat [5] [6] [21] [22] [23]. Low-fat content can avoid materials from rancidity, sourness and extend shelf life during storage [24]. The diversity of chemical composition of cassava pulp, in particular depends on the unit of cassava peeling and the starch extraction technology used in the tapioca industry.

3.2. TDF, IDF, and SDF content of dietary fiber product

The comparison between fiber and starch contents (dry basis) for each treatment is shown in Table 1.

Table 1. Fiber and starch content in dietary fiber produced from acid-heat treatment and extrusion process

Components	<i>Cassava pulp</i>	<i>Dietary Fiber</i> (Acid-heat treatment)	<i>Dietary Fiber</i> (Extrusion)
<i>TDF (%)</i>	50.20	89.24	50.86
<i>SDF (%)</i>	6.60	3.84	6.62
<i>IDF (%)</i>	43.60	85.40	44.24
Starch (%)	47.34	9.7	47.28

Table 1 shows that TDF increased significantly from 50.2% to 89.24%, but starch content decreased from 47.34% to 9.7% in dietary fiber produced from acid-heat treatment. This was caused by hydrolysis of the starch in the cassava pulp with acid as the catalyst, becoming a hydrolyzate in the form of sugar syrup which was then separated into byproducts.

Meanwhile, there were no significant changes in TDF and starch contents in dietary fiber produced from extrusion treatment (Table 1). There was no starch hydrolysis during extrusion, however, modification structures of starch granule (swelling) occurred because of the presence of water, heat, and pressure during extrusion. After the extrusion process, the materials experienced structural change such as starch gelatinization [14]. Starch gelatinization is a disruption of the molecular order in starch granules that results in granular swelling, melting of crystals, loss of birefringence, development of viscosity and solubility [16]. As the extrusion proceeded, cassava pulp absorbed the water (35% moisture content) and the starch granules swelled. As the heat was continuously supplied to the materials, the starch component underwent gelatinization [25]. Gelatinization temperature of material determine the best temperature used during extrusion. Gelatinization temperature was affected by several factors, for instance, granule size, amylose, amylopectin, heating instrument condition, and also food material content like fat, dietary fiber, resistant starch, and protein [26].

3.3. Physicochemical characteristics

The physiological effect was associated with the physicochemical characteristics of dietary fiber and its fractions [27]. The characteristics comparison between cassava pulp and dietary fiber produced from acid heat treatment and extrusion process are presented in Table 2.

Table 2. Physicochemical properties of cassava pulp and dietary fiber produced from acid heat treatment and extrusion process

<i>Properties</i>	Untreated Cassava Pulp	<i>Dietary Fiber</i> (Acid Heat treatment)	<i>Dietary Fiber</i> (Extrusion)
<i>Water Holding Capacity (g/g)</i>	4.78	12.07	9.96
<i>Oil Holding Capacity (g/g)</i>	1.84	3.99	0.81
<i>Swelling Capacity (ml/g)</i>	7.64	17.8	12.99

Table 2 shows that there was a significant increase in the physicochemical properties of cassava pulp after the conversion into dietary fiber products. Dietary fiber obtained from the acid-heat treatment has the highest WHC compared to untreated cassava pulp and dietary fiber obtained from the extrusion process. The content of TDF in dietary fiber obtained from the acid-heat treatment has the highest value because acid hydrolysis removed starch component extensively [25] and increased the purity of dietary fiber. This indicates the fiber component that can absorb/hold the water is also increasing, so that the WHC becomes the largest. WHC in dietary fiber obtained from the extrusion process also increased even though the TDF content was relatively not increased much. This is due to the starch granules experienced swelling which results in being able to hold more water. Dietary fiber, especially IDF, has the property of being able to hold water [27]. The value of WHC and swelling capacity follows the trend of dietary fiber content in the material. WHC is a measure of the amount of water retained by the fiber after being subjected to pressure such as centrifugation [28]. WHC properties need to be measured before dietary fiber is used as a functional food.

OHC is a physico-chemical property of fiber materials that can be applied in food formulations. The porosity of the fiber structure is the main factor affecting the ability of the fiber to bind oil [28][29]. In addition, hydrophobicity, number of lipophilic sites and capillary attraction are also complex factors that affect OHC [30]. Materials that have high OHC are able to act as emulsifiers in formulated foods. Dietary fiber obtained from the acid-heat treatment showed the highest OHC value compared to untreated cassava pulp and dietary fiber obtained from the extrusion process. In the acid-heat treatment, almost all of the starch was hydrolyzed and separated from the fiber matrix, so that dietary fiber was obtained with the porous fiber structure and had absorption properties/able to hold large amounts of oil [12]. The value of OHC in dietary fiber obtained from the extrusion process was lower than OHC of untreated cassava pulp, presumably because the starch component was still high (47.28%) and has experienced swelling which makes it easier to absorb water and reject oil (hydrophobic).

Dietary fiber obtained from the acid-heat treatment and extrusion process had IDF as the main component and had the high WHC and swelling capacity. However, the content of SDF in dietary fiber products is quite low, namely 3-6%. With these characteristics, those dietary fiber are more suitable for use in the food industry application, for instance the bread industry, processed meat (sausage, meatballs, and nuggets), low-calorie foods, as a substitute for fat, high-fiber foods, and emulsifying agents. However, the dietary fiber product is not suitable for use in fiber drink applications due to its low SDF content and solubility properties.

3.4. Comparisons of acid heat treatment and extrusion process

Processing dietary fiber with acid heat treatment and extrusion had its own advantages and drawbacks as it is shown in Table 3.

Table 3. Characteristic Comparisons of Dietary Fiber obtained from Acid-Heat Treatment and Extrusion Process

Extrusion	Acid Heat
High yield (90%)	Low Yield (50%)
No <i>by-product</i>	Sugar Syrup as <i>by-product</i>
High WHC (10g/g)	High WHC (12g/g)
Low OHC (0.81 g/g)	High OHC (3.99 g/g)
High Bulk density (0,6 g/ml)	Low Bulk density (0.2 g/ml)

Table 3 shows that the production of dietary fiber by the extrusion process had the advantage of high yield and bulk density, but its OHC value was very low so it is not suitable for use as an emulsifier in industrial applications. On the other hand, the production of dietary fiber with the acid-heat treatment had the advantage of high WHC and OHC values, so that the application in industry is wider, but the yield and bulk density were relatively lower.

3.5. Morphology

Analysis results morphology of untreated cassava pulp and dietary fiber prepared from cassava pulp was shown in Figure 1. The starch granules in the untreated cassava pulp were isolated in fiber matrixes (Figure 1a). Further, the acid heat treatment caused the degradation of the matrixes that were indicated by organized formation of fiber structures. In details, the fiber structures were constructed by starch hydrolyzation that caused its separation from fiber matrixes. Therefore, the resulted dietary fiber had porous fiber structures (Figure 1b).

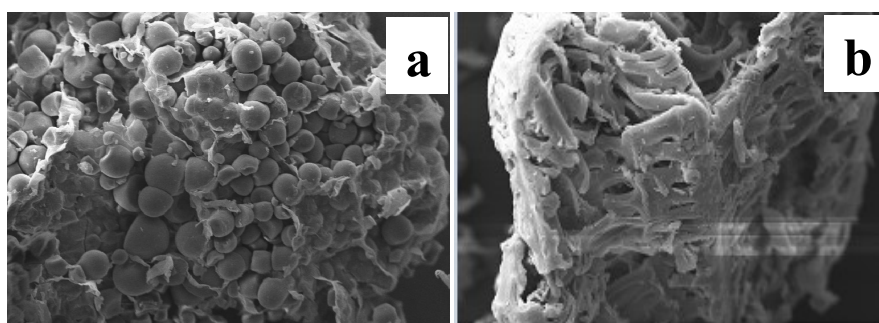


Figure 1. Scanning Electro Microscope images of untreated cassava pulp (a); cassava pulp after acid heat treatment (b)

4. Conclusion

Cassava pulp is one of potential sources that could be converted into dietary fiber through acid heat treatment or extrusion process. The acid heat treatment was effective to remove starch components and increase TDF content, WHC and OHC properties. Extrusion process could not eliminate starch component and increase the TDF, yet it was able to rise the WHC properties value even its OHC value decreased. Acid heat treatment also modified the fiber

structures of the cassava pulp as it is indicated by its morphological changes, but extrusion process modified the starch by granule swelling and starch gelatinization which result in increase of WHC properties.

5. References

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