Characterization of fiber fraction, physical and chemical properties of coffee flour (*Coffea* sp.) as functional foodstuff for diabetes mellitus patient

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Abstract. Coffee pulp is solid waste from coffee processing, but unfortunately, it has not been utilized optimally, particularly for foods. Objective of the research was to study characterization of fiber fraction, physical and chemical properties of coffee flour as functional dietary material, which is rich in fiber to reduce blood glucose level for diabetes mellitus patients. The research used Arabica and Robusta coffee pulps. Results of the research showed that characterization of fiber fraction for Arabica has soluble dietary fiber 4.78% (db); 4.30% (wb) higher 0.63% (db); 0.55% (wb) in comparison with Robusta. However, the insoluble dietary fiber is 69.16% (db); 62.24% (wb) and total dietary fiber is 73.32% (db); 65.98% (wb) for Robusta is higher 10.78% (db); 9.82% (wb) insoluble dietary fiber and 10.15% (db); 9.26% (wb) total dietary fiber in comparison with Arabica. Granule shape of the flour for Arabica and Robusta have uneven surfaces and diverse sizes of granule. Arabica flour granules are smaller, 12.8-49.8 µm, than Robusta, 48.8-66.8 µm. Testing the chemical properties showed fat level was 4.05% (wb); 4.55% (db), water 10.96% (wb) and ash 9.35% (wb); 10.50% (db) for Arabica are higher 0.08% (wb); 0.12% (db) fat, 0.66% (wb) water and 0.81% (wb); 0.99% (db) ash. However, carbohydrate level was 62.78% (wb); 70% (db) and protein 14.41% (wb); 16.06% (db) for Robusta was higher 1.24% (wb); 0.88% (db) carbohydrate and 0.31% (wb); 0.23% (db) protein in comparison with Arabica. Coffee flour of Arabica has better characterization for fiber fraction, physical and chemical properties, in comparison with Robusta, due to it has higher soluble dietary fiber (SDF) and smaller flour granules, which are potential as functional foodstuff for diabetes mellitus patient.

1. Introduction

Coffee (*Coffea* sp.) is important agricultural commodity in the world [1]. There are three coffee varieties, which are produced in the world, such as: Arabica (*Coffea arabica*), Robusta (*Coffea canephora*) [2], and Liberica (*Coffea liberica*) [3]. Coffee processing may produce residue, for instance, coffee pulp from wet and semi-dried processing for about 29% of the coffee seeds [4], however 40% residue may be resulted from fresh coffee in wet processing [5]. Coffee produced using wet and dry processing will result lignocelluloses [6]. The resulted residues following the extraction process may contain carbohydrate by the composition of 46.8% mannose, 30.4% galactose, 19%
glucose, 3.8% arabinose, and 13.6% protein. Not only carbohydrate and protein, but also other compounds, such as: 3549 mg/kg potassium, 1475.1 mg/kg phosphor, 1293.3 mg/kg magnesium, 777.4 mg/kg calcium, 118.7 mg/kg iron, 40.1 mg/kg mangan, 32.3 mg/kg copper, and 15.1 mg/kg zinc [7]. Phytochemical compound in coffee pulp comprises of phenolic component, alkaloid, terpenoid, carotenoid, enzyme and vitamin [8]. There are other components in coffee pulp in the form of phenolic compounds, such as: 42.2% chlorogenic acid, 21.6% epicatechin, isochlorogenic acid I, II, III for about 5.7%, 19.3%, 4.4%, respectively. 2.2% catechin, 2.1% rutin, 1.6% protocatechuic acid and 1.0% ferrulic acid [1]. Pulp of the red cherry coffee is waste resulted from wet processing, which contains essential components as follow: polyphenols, tannin [9], as antimicrobial, antioxidant [10], and additive substance for dietary products and pharmaceutical products. [11].

Furthermore, coffee pulp can be utilized as cellulolytic bacterial isolation and actinomycetes [12], feedstock, compost, biogas, as well as to produce enzyme, fungi, citric acid, and gibberellic acid through fermentation of Aspergillus sp. and as aromatic substance in food industries [1]. Utilization of coffee pulp as foodstuff has high economic value. Coffee pulp is highly potential as functional foodstuff because it contains high dietary fiber. Chemical compositions of the coffee pulp comprise of 44-50% carbohydrate, 10-12% protein, 2.5% fat, 63% cellulose, 2.3% hemicelluloses, and 18-21% total fiber [13]. Coffee pulp of Arabica contains 65.99% carbohydrate, 11% protein, 1.54% fat, 25.84% cellulose, 4.37% hemicelluloses and 12.46% lignin [14].

Research about characterization of fiber fraction, physical and chemical properties in coffee flour is still difficulty found. Most of the coffee pulps are only utilized as feedstock, bioenergy materials and so on, but potency of such coffee pulp as functional foodstuff is still difficulty found. Coffee flour is highly potential as foodstuff, which is rich in fiber, so that it is suitable for dietetic foods in order to reduce blood glucose level of the diabetes mellitus patients. Food products, which are rich in fiber, are good to be consumed by patients who have degenerative diseases, such as diabetes mellitus. Fiber is plant substance, which is not dissolved by human’s digestive enzyme, the dietary fiber that includes cellulose, hemicelluloses, pectin, and lignin, as well as polysaccharide intracellular such as gum and musilase [15]. Dietary fiber cannot be dissolved in small intestine, but it is partly or entirely fermented in colon, and it will produce short chain fatty acid (SCFA) that include acetic acid, propionate, and butyrate, as well produce gasses such as CO₂, CH₄ and H₂ [16]. Physical and chemical properties of the dietary fiber that relate to physiological effect can be degraded by intestinal bacteria, bond other organic substances, able to restrain water and viscosity, as well as could exchange ions [17].

2. Materials and Methods
2.1. Material
The main materials of this study are coffee pulps of Arabica and Robusta species that derived from farmers in Karangploso of Malang Regency, East Java-Indonesia. Firstly, the coffee pulps are washed thoroughly and indirectly sun-dried for 5-7 days, and then finely ground using flour grinder, and then sift using 80 mesh type Sieves.

2.2. Fiber Fraction Analysis
Fiber fraction analysis was conducted at Laboratory for Foods and Nutrients, UGM that include: soluble dietary fiber (SDF), insoluble dietary fiber (IDF) and total dietary fiber (TDF) using the method (Asp, 1983) [18].

Tools used in the research include: analytic scale, mortar, desiccators, crucible with celite, oven vacuum, furnace, water bath, pH meter, Kjehldal flask, distillation device, and other glass tools. Chemical materials used in the research include: petroleum ether, ethanol 95%, ethanol 78%, acetone, buffer phosphate, termamyl, protease, amyloglucosidase, NaOH solution, HCl solution, celite C-211, pepsin, pancreatin, K₂SO₄, H₂O, H₂SO₄, NaOH, H₃BO₃, MM and MB indicators, as well as aquadest.
2.3. Physical Properties Analysis

Physical properties analysis of the coffee flour granule was conducted at Laboratory of Biology, UMM, that include: shape and size of the flour granules were measured using SEM type Hitachi TM3000 by 1000-1500x enlargement.

2.4. Chemical Properties Analysis

Chemical properties analysis through proximate test was conducted at Laboratory of Chemistry for Foods, BALITKABI of Malang Regency that include: analysis on protein level (AOAC, 2005), fat level, water, ashes (SNI, 1992) and carbohydrate level (by difference).

2.4.1. Analysis on Protein Level (AOAC, 2005) [19]

Chemical materials used in the research include H$_2$SO$_4$, NaOH 30-33%, H$_3$BO$_3$ 3%, HCl 0.1 M, bromcresol green solution, red metal indicator and aquades. There are 3 stages of protein analysis:

1) Destruction

0.5 gram sample was weighed. And then, it was put into Kjeldahl flask. A piece of selenium was put into the flask and then added with 3 ml H$_2$SO$_4$. After that, the flask was put into the heater at 410 °C and supplemented with 10 ml water. Such destruction process was performed until pure solution was resulted.

2) Distillation

The pure solution was cooled and added with 50 ml aquades and 20 ml NaOH 40%, and then it was distilled. Furthermore, the distillate was retained in Erlenmeyer flask 125 ml that contain 25 ml boric acid (H$_3$BO$_3$) 2%, which contains indicator of bromcresol green 0.1 % and methyl red 0.1 % by ratio 2 : 1 and the resulted distillate is bluish green.

3) Titration

Titration was performed using HCl till solution in the Erlenmeyer flask turned into pink. Then the titration volume should be read and recorded.

2.4.2. Analysis on fat level, water, and ashes (SNI, 1992)

1). Fat level

Fat level determination refers to method of SNI 01-2891-1992 item 8.1 and 8.2, sample was weighed and 5 g of it was put into the Erlenmeyer flask 300 mL, and then added with 45 mL aquades and 55 mL HCl solution 25%. After that it was hydrolyzed by closed-reflux for 30 minutes. Solution resulted from hydrolysis was cooled and sift using grease-free filter paper until Cl was completely removed from the filtrate using solution of AgNO$_3$ 0.1 M. After that the filter paper was put into timble and covered the surface with glasswool and dried in oven at 100-101°C for 6 hours, and then put the dried timble in the soxhlet and extracted with petroleum ether for 4 hours. The resulted fat was dried in oven for 1 hour at 100-101°C, and then stored in desiccators that contains silica gel adsorbent for 20 minutes and weighed using analytic scale to reach constant weight.

2). Water Content

Water content determination refers to method of SNI 01-2891-1992 item 5.1 graphimetrically. On a constant empty porcelain disc, 1 g sample was weighed using analytic scale, and then dried in oven at 105°C for 3-4 hours, after that it was stored in a desiccator that contains silica gel adsorbent and weighed using analytic scale to reach constant weight.

3). Ashes Level

Ashes level determination refers to method of SNI 01-2891-1992 items 6.1-6.4 graphimetrically. On a constant empty porcelain disc, 3 g sample was weighed using analytic scale, and then carbonized on a hotplate and reduced to ashes in furnace at 550-600° C. Then, the ash was stored in the desiccator that contains silica gel adsorbent and weighed using analytic scale to reach constant weight.
2.4.3. Analysis on Carbohydrate
Analysis on carbohydrate using by difference method.

3. Results and discussions

3.1. Analysis on fiber fraction (SDF, IDF, and TDF)
The analysis results of fiber fraction on coffee pulps of Arabica and Robusta in dry basis (db) are presented in table 1. Mean of soluble fiber for Arabica is 4.78% (db), which is higher 0.63% (db) than Robusta. However, mean of insoluble fiber is 69.16% (db) and total fiber is 73.32% (db), which shows that Robusta is higher 10.78% (db) for insoluble fiber and 10.15% (db) for total fiber in comparison with Arabica.

| Variety | SDF (% db) | IDF (% db) | Total DF (% db) |
|---------|------------|------------|-----------------|
| Arabica | 4.78 ± 0.33| 58.38 ± 0.23| 63.16 ± 0.56    |
| Robusta | 4.16 ± 0.44| 69.16 ± 0.46| 73.32 ± 0.20    |

The analysis results of fiber fraction on coffee pulps of Arabica and Robusta in dry basis (db) were presented in figure 1.

Figure 1. Fiber fraction of coffee flour in dry basis (db)

The analysis results of fiber fraction on coffee pulps of Arabica and Robusta in wet basis (wb) are presented in table 2. Mean of soluble fiber for Arabica is 4.30% (wb) higher 0.56% (wb) than Robusta. However, mean of insoluble fiber is 62.24% (wb) and total fiber is 65.98% (wb) shows that Robusta is higher 9.82% (wb) for insoluble fiber and 9.26% (wb) for total fiber in comparison with Arabica.

| Variety | SDF (% wb) | IDF (% wb) | Total DF (% wb) |
|---------|------------|------------|-----------------|
| Arabica | 4.30 ± 0.36| 52.43 ± 0.18| 56.72 ± 0.54    |
| Robusta | 3.74 ± 0.49| 62.24 ± 0.50| 65.98 ± 0.14    |

Soluble fiber could restrain water higher than the insoluble fiber, which is determined by solubility in water and pH of the digestive tract, as well as particle size of the fiber [20]. These properties relate to sugar residues and free polar group [21]. Effect of the dietary fiber in slowing down depletion of the abdominal cavity may be beneficial to prevent any increasing blood glucose level. The dietary substances will be released slowly into small intestine, so that the blood glucose level will increase.
gradually. Soluble fiber for diet, stable pH, and gel characteristics will result long-term effect, which is beneficial in controlling glucose and lipid levels against the patients of diabetes mellitus type 2 [22].

Study on fiber fraction (SDF, IDF, TDF) toward coffee flour of Arabica and Robusta is still difficulty found, whereas it contains dietary fiber that is beneficial for health. Besides coffee flour, there are more water-soluble dietary fibers that could decrease blood glucose level. Study on water-soluble polysaccharide in gembili (large purplish edible tuber) by dose 400 mg/kg body weight of mouse may decrease blood glucose level after 28 days. It is presumed that the decrease of blood glucose may be due to water-soluble fiber, which is able to control glucose absorption in blood [23]. Soluble dietary fiber of physilium for about 6.6 g may affect on glychemic response [24]. The application of water-soluble polysaccharide, 50 and 150 mg/kg, on the experiment animal may decrease glucose for about 15.5 % and 28.2 %, respectively [25].

3.2. Analysis of physical properties on flour granule

Analysis result of physical properties on shape and size of coffee flour granule of Arabica used SEM tools by 1500x enlargement is presented in figure 2.

![Figure 2. Shape and size of coffee flour granule of Arabica](image)

Analysis result of physical properties on shape and size of coffee flour granule of Robusta used SEM tools by 1000x enlargement is presented in figure 3.
Figure 3. Shape and size of coffee flour granule for Robusta

The analysis result using SEM showed that coffee flour granule of Arabica has smaller shape and size than Robusta. Surface of flour granules for both Arabica and Robusta have rough and uneven surfaces, as well as diverse sizes. Sizes of the flour granules for Arabica range 12.8-49.8 μm and Robusta range 48.8-66.8 μm.

Studies on characterization of shape and size of the flour granules for Arabica and Robusta were still difficultly found. Other research on flour granules mostly discuss about flours made of other plants, but not relate to coffee. A research on shape of starch granule made of garut, which has round shape and even surface, but after being modified, the shape turned into uneven and rough surface. Starch granule size of garut range 9.35-35.6 μm and the modified starch granule of garut is bigger, 193-439 μm [26]. The starch granule of garut has oval shape, even surface, and range 50-60 μm on average [27]. SEM showed that starch granule of sago has oval shape and even surface, as well as 20-40 μm in diameter [28].

Physical properties, such as color, for Arabica is brighter brown and attractive than Robusta, which is dull brown. Physical property differences (color) of coffee pulps for Arabica and Robusta were presented in figure 4.

Figure 4. Physical property differences (color) of coffee flour for Arabica and Robusta
The granule shape is the typical characteristic of each starch. Both shape and size of the granules are affected by basic material of the flour, so that they have specific shape and size [29]. There are two fractions of starch granule, amyllose is the soluble fraction and amylopectine is the insoluble fraction. Starch granule size relates to width of total longitudinal surface, so that the smaller size of the granule starch is, the wider total surface will be gained. Therefore, the starch divider enzyme has wider area to hydrolyze the starch (amylum) into glucose. When the enzyme works easier, both digestion process and starch-carbohydrate absorption will be faster. If the starch granule is small, it is presumed that the starch will has high IG value [30].

High dietary fiber contributes low IG value [31]. Dietary fiber could slow down food digestion rate and enzymatic activities, so that the digestion process, particularly starch, will slow down and response of the blood glucose will be lower. Soluble dietary fiber (SDF) may slow down digestion in the intestines, give longer feeling of satiated, and slow down the increase rate of blood glucose, so that less insulin is required to transfer glucose into the body cells and turn it into energy. Therefore, the diabetes mellitus patient requires soluble dietary fiber to reduce glucose absorption in the small intestines.

3.3. Analysis of chemical properties (proximate test)
The analysis results with proximate test on coffee pulps of Arabica and Robusta that relate to wet basis (wb) were presented in table 3. Arabica contains 4.04% fat, 10.96% water, and 9.35% ash, which is higher for about 0.08% fat, 0.66% water, and 0.81% ash in comparison with Robusta. However, Robusta contains 14.41% protein and 62.78% carbohydrate, which higher 0.31% for protein and 1.24% for carbohydrate in comparison with Arabica.

| Variety | Water (%) | Protein (%) | Fat (%)  | Carbohydrate (%) | Ash (%)  |
|---------|-----------|-------------|----------|------------------|----------|
| Arabica | 10.96 ± 0.36 | 14.10 ± 0.10 | 4.05 ± 0.14 | 61.54 ± 0.18 | 9.35 ± 0.50 |
| Robusta | 10.30 ± 0.24 | 14.41 ± 0.22 | 3.97 ± 0.24 | 62.78 ± 0.20 | 8.54 ± 0.58 |

The analysis results with proximate test on coffee pulps of Arabica and Robusta that relate to wet basis (wb) were presented in figure 5.

Figure 5. Proximate analysis on coffee flour for wet basis (wb)
3.3.1. Fat Content
Fat content in Arabica flour is 4.05% (wb) higher than in Robusta 3.97% (wb). Flour, which contains high fat is potential to be used as vegetable oil source of foods that have positive effect on health.

3.3.2. Water Content
Water content in Arabica flour is 10.96% (wb) higher than in Robusta 10.30% (wb). Low water content of coffee flour is durable.

3.3.3. Ash Content
Ash content in Arabica flour is 9.35% (wb) higher than in Robusta 8.54% (wb). Ash content shows total content of macro-and-micro minerals in the foodstuff.

3.3.4. Protein Content
Protein content in Arabica flour is 14.10% (wb) lower than in Robusta 14.41% (wb).

3.3.5. Carbohydrate Content
Carbohydrate content is the greatest component in coffee flour. Carbohydrate content in Arabica is 61.54% (wb) lower than in Robusta 62.78% (wb).

The analysis result with proximate test on dry coffee pulps of Arabica and Robusta are presented in table 4. Arabica contains 4.55% fat and 10.50% ash, which is higher 0.12% for fat and 0.99% for ash in comparison with Robusta. While 16.06% protein and 70% carbohydrate in Robusta are higher 0.23% for fat and 0.88% for carbohydrate in comparison with Arabica.

| Table 4. Proximate analysis on coffee flour of Arabica and Robusta for dry basis (db) |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Variety         | Protein (%)     | Fat (%)         | Carbohydrate (%)| Ash (%)         |
| Arabica         | 15.83 ± 0.36    | 4.55 ± 0.24     | 69.12 ± 0.32    | 10.50 ± 0.14    |
| Robusta         | 16.06 ± 0.18    | 4.43 ± 0.10     | 70.00 ± 0.34    | 9.51 ± 0.20     |

Research on chemical properties analysis with proximate test against coffee flour of Arabica and Robusta is still difficulty found. So that, information about chemical properties characterization on coffee flour of Arabica and Robusta is very important for the study that relates to food. Coffee flour is very potential as functional foodstuff to decrease blood glucose level of the diabetes mellitus patients.

4. Conclusion
Coffee flours of Arabica and Robusta have different characteristics of fiber fraction, physical and chemical properties. Characterization of fiber fraction for Arabica shows soluble dietary fiber 4.78% (db); 4.30% (wb) higher 0.63% (db); 0.55% (wb) in comparison with Robusta. However, insoluble dietary fiber 69.16% (db); 62.24% (wb) and total dietary fiber 73.32% (db); 65.98% (wb) on Robusta is higher 10.78% (db); 9.82% (wb) insoluble dietary fiber and 10.15% (db); 9.26% (wb) total dietary fiber in comparison with Arabica. Shapes of flour granule for Arabica and Robusta have uneven surface and diverse sizes of granule. Flour granules of Arabica have smaller size that range 12.8-49.8 µm in comparison with Robusta, which range 48.8-66.8 µm. Chemical properties test showed that Arabica contains fat 4.05% (wb); 4.55% (db), water 10.96% (wb) and ash 9.35% (wb); 10.50% (db), which are higher 0.08% (wb); 0.12% (db) fat, 0.66% (wb) water and 0.81% (wb); 0.99% (db) ash. However, carbohydrate 62.78% (wb); 70% (db) and protein 14.41% (wb); 16.06% (db) in Robusta are higher 1.24% (wb); 0.88% (db) carbohydrate and 0.31% (wb); 0.23% (db) protein in comparison with Arabica. Results of the research showed that coffee flour of Arabica has better characterization for fiber fraction, physical and chemical properties, in comparison with Robusta, due to it have higher soluble dietary fiber (SDF) and smaller flour granules, which are potential as functional foodstuff for
diabetes mellitus patient. Besides that, it is difficult to find a research about characterization of fiber fraction, physical and chemical properties in coffee flour of Arabica and Robusta.

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