

Physical and Chemical Characterization of Greater Yam (*Dioscorea alata*) and Jack Bean (*Canavalia ensiformis*) - Based Composite Flour

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Abstract. Indonesia is a tropical country that has great potential in agriculture. Tubers and legumes as examples of the potential commodities are needed to be more developed. Flour production is one of the best alternatives to be chosen as the downstream stage of the tubers and legumes utilization. Greater yam (*Dioscorea alata*) and jack bean (*Canavalia ensiformis*) were used in this study. This study was conducted to determine the best formula of composite flour based on physical, chemical, and functional characterization of composite flour produced. Variations of formula used was the ratio of greater yam flour and jack bean flour, which were 85:15 (F1), 70:30 (F2), 55:45 (F3), respectively, and this study was conducted using completely randomized design (CRD). The formula variations did not show any significant effect on the water absorption capability, water holding capacity (WHC), oil holding capacity (OHC), swelling power, and starch content of the composite flour. However, the formula variations had a significant influence on the colour, proximate parameters, amylose and amylopectin content, resistant starch content, dietary fibre, total phenol, and antioxidant activity of the composite flour produced. Considering the results of physical, chemical, and functional characteristics of composite flour, formula (F1) was selected as the best composite flour developed from greater yam and jack bean flours.

1. Introduction

Indonesia is rich in legumes and tubers. Local tubers have been consumed as a source of carbohydrates from earlier times and proved to have a bit trigger for a degenerative disease in the past [1]. Legumes is a cheap source of protein, it also contains carbohydrates, cholesterol, high-fiber, low in fat, and high concentration of unsaturated fatty acids [2].

Greater yam is one kind of potential tubers. The productivity is 40 tons per hectare, it could grow above the sea level to more than 1500 above sea level and from the moist soil (swamp) to marginal land [3]. Heretofore greater yam only considered as a wild plant that is limited use [4]. Greater yam contain nutrients such as carbohydrates are quite large, which is 24.6% [5]. Most carbohydrates are in the form of starch consisting of amylose and amylopectin. Amylose content in greater yam is in the range of 19-20% [6]. Greater yam also contains micronutrients such as flavonoids, saponins, and phenolic compounds that are beneficial to the body so that it can be considered as selected tuber for daily consumption [7]. Greater yam has a low glycemic index and fiber content is high [8]. Despite having the functional potential and good nutritional value, but greater yam contain only small content of protein in the amount of 0.32 to 2% [9].

Jack bean is one of the local legumes that can be used as a source of vegetable protein with a carbohydrate content of 55% and 24% protein [10]. Jack bean also contains anti nutritional compound in the form of phytic acid and glucocyanide toxin. Jack bean can be processed into food products such as flour and the derivatives products such as cakes, cookies and other bakery products, crackers, tempeh and some other products. Moreover, jack bean is a commodity available in large quantities on the market that in the year 2010-2011 was recorded on the land area of 24 hectares, 12 districts in Central Java has produced 216 tons of jack bean in every harvest [11].



Functional potential owned by greater yam and jack bean made the commodity can be used as an alternative to a functional food that can be consumed by the public. Many previous studies about substitution of wheat flour as the main purpose of composite flour's production, but not much is discussed about the functional potential of composite flour. Therefore, this study was conducted to learn more about the functional potential possessed by composite flour from greater yam (*Dioscorea alata*) and jack bean (*Canavalia ensiformis*) based on their physical and chemical characteristics. Then, the best formula based on physical and chemical characteristics (functional characteristics was included) would be determined.

2. Materials and Methods

2.1. Making Composite Flour

In the making of greater yam flour, there was a pretreatment where the sliced greater yams were soaked in a solution of Na-metabisulfite 0.3% for 20 minutes to prevent browning. The sliced greater yams that have been soaked then washed, dried in a cabinet dryer (temperature of 50°C for 24 hours), powdered, and sieved (80 mesh). In the making of jack bean flour there was a pretreatment where the beans were soaked in water for three days with water changes every 12 hours, aiming to reduce the levels of HCN. Jack beans that have been soaked and then boiled, peeled, chopped, dried in a cabinet dryer (temperature of 60 ° C for 10 hours), powdered, and sieved (80 mesh).

The formula used in the making of composite flour was the ratio between greater yam flour and jack bean flour, ie 85:15 (F1), 70:30 (F2), and 55:45 (F3). The three formulas of composite flour were made by mixing greater yam flour and jack bean flour in a plastic jar. Then a plastic jar was shaken up until greater yam flour and jack bean flour mixed homogeneously.

2.2. Method of Analysis

Several analysis were conducted on composite flour. Physical properties tests were conducted on water absorption capacity / WHC by filtration method [12], water holding capacity by centrifugation method [13], oil holding capacity [14], swelling power by centrifugation method [15], and color test with chromameter [16]. Chemical analysis were conducted on water content by thermogravimetric method [17], ash content in the dry method [17], protein content by Kjeldahl method [17], fat content by Soxhlet extraction method [17], carbohydrate content by difference, starch content [18], amylose and amylopectin content by the spectrophotometric method [18], and resistant starch [19]. Analysis of functional properties were conducted on antioxidant activity by DPPH radical-scavenging activity [20], dietary fiber by multienzyme method [21], and total phenolic by Folin Ciocalteu method [22].

3. Results and Discussion

3.1. Physical Characteristics

3.1.1. Color.

Color analysis conducted using chromameter to get the value of L *, a *, and b *. Then the °Hue was calculated with the formula °Hue = arc tan (b * / a *).

Table 1 Lightness (L*), Yellowness (b*), Redness (a*) and °Hue of Greater Yam (*Dioscorea alata*) and Jack bean (*Canavalia ensiformis*) - Based Composite Flour

Parameter	Composite Flour**		
	F1	F2	F3
L*	70.78 ± 0.03 ^a	71.47 ± 0.08 ^b	72.23 ± 0.05 ^c
a*	2.75 ± 0.005 ^a	2.61 ± 0.05 ^a	2.62 ± 0.06 ^a
b*	14.79 ± 0.01 ^a	15.01 ± 0.03 ^b	15.33 ± 0.08 ^c
°Hue	79.49 ± 0.01 ^a	80.16 ± 0.15 ^b	80.30 ± 0.17 ^b

Value in the same line followed by different letter was significantly different (p=0,05)

** Proportion of greater yam flour:jack bean flour were F1=85:15, F2=70:30, F3=55:45

Table 1 shows the test result of each color composite flour formula. F3 has the highest lightness level (L^*), while F1 had the lowest lightness level. The highest level of b^* owned by F3 because the proportion of jack bean flour most compared to other formulas. Jack bean flour had more white color (b^* higher) than greater yam flour. Highest $^{\circ}$ Hue owned by F3, meaning the intensity of the yellowish red getting stronger. Comparison of the three color composite flour with greater yam flour and jack bean flour could be seen in Figure 1.



Figure 1 The Color of Composite Flour (F1, F2, F3), Greater Yam Flour (a) and Jack Bean Flour (b)
(Proportion of greater yam flour:jack bean flour are F1=85:15, F2=70:30, F3=55:45)

Figure 1 shows that greater yam flour and jack bean flour had a different color with composite flour. Greater yam flour had yellowish red color that appear as shades of brown. Greater yam flour color was darker than jack bean flour that had a bright yellow color. The more proportion of greater yam flour in composite flour caused the color to become darker. F1 with the most proportion of greater yam flour had the darkest color (low of L^* and low of $^{\circ}$ Hue) compared to F2 and F3. Table 1 showed that the $^{\circ}$ Hue of F1, F2, and F3 were in the range of 50° - 90° , indicated that the composite flour had a yellowish red color range. Increasingly approaching 90° then the color of flour produced would be more bright (yellow).

3.1.2. Water Absorption Capability (WAC), Water Holding Capacity (WHC), Swelling Power, and Oil Holding Capacity (OHC)

Table 2 shows that the variation in the proportion of greater yam flour and jack bean flour had no effect on WAC, WHC, OHC, and swelling power. However, when seen in Figure 2,3 and 4, WAC likely to increase from F1 to F3, as well WHC and swelling power. Instead OHC value tend to decline as more proportion of jack bean flour.

Table 2 Water Absorption Capacity (WAC), Water Holding Capacity (WHC), Oil Holding Capacity, and Swelling Power of Greater yam (*Dioscorea alata*) and Jack bean (*Canavalia ensiformis*) - Based Composite Flour

Flour*	WAC (%)	WHC (g/g)	OHC (%)	Swelling Power (g/g)
F1	77.79 ± 0.52^a	2.40 ± 0.02^a	1.08 ± 0.006^a	4.99 ± 0.06^a
F2	78.04 ± 6.34^a	2.54 ± 0.05^a	1.07 ± 0.02^a	5.31 ± 0.16^a
F3	78.32 ± 0.32^a	2.56 ± 0.07^a	1.01 ± 0.04^a	6.06 ± 0.52^a

Value in the same line followed by different letter was significantly different ($p=0,05$)

* Proportion of greater yam flour:jack bean flour were F1=85:15, F2=70:30, F3=55:45

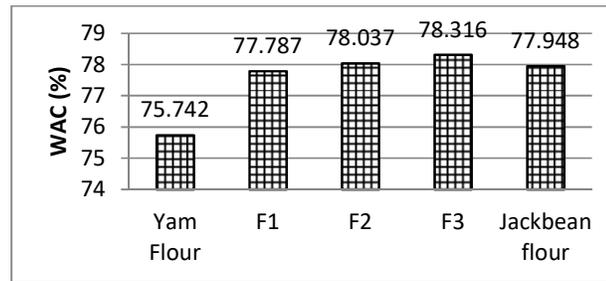


Figure 2 Water Absorption Capacity (WAC) of Greater Yam Flour, Jack Bean Flour, and Composite Flour (Proportion of greater yam flour:jack bean flour were F1=85:15, F2=70:30, F3=55:45)

Figure 2 and Figure 3 show that the water absorption and water holding capacity of jack bean flour was higher than greater yam flour. The high water absorption of jack bean flour was caused by the high protein content of jack bean flour (19.796%) which was higher than greater yam flour (7.410%), according to preliminary research. There were several factors that could affect the WAC and WHC a food ingredient. Besides the presence of protein in a food, the WAC is affected by the composition and physical properties of the starch granules after adding water [23]. Based on preliminary research, jack bean flour had a higher protein content than greater yam flour, whereas the starch content of greater yam flour was higher than jack bean flour. Protein is a factor which could determine the ability of flour to bind water [24]. The higher the protein content of a food will increase the value of water holding capacity (WHC). A low fiber and starch content may cause low absorption ability of water into the flour [25]. WAC and WHC composite flour was higher than basic flour essentially thought to be caused by the high protein of jack bean flour and higher starch content of greater yam flour.

Figure 4 shows that the swelling power of composite flour was likely to increase as more and more jack bean flour. Swelling power is a property that is influenced by amylopectin. The more branch chain of amylopectin are contributing to increase the swelling power [26]. Based on this explanation, it can be said that the swelling power will increase as the higher amylopectin content or lower amylose content. Amylose content of greater yam flour was higher (28.072%) than jack bean flour (22.885%), based on preliminary research, so that the more proportion of greater yam flour would increase amylose content in composite flour which had decreased the swelling power.

Figure 5 shows that oil holding capacity (OHC) of greater yam flour higher than jack bean flour. The high OHC of greater yam flour affected by amylose content of greater yam flour that was higher than jack bean flour (preliminary research). OHC of composite flour was lower than the OHC of basic flour. This presumably because the protein from leguminosae flour was hydrophilic. Other studies showed that the composite flour oil absorption capacity would decrease with the addition of a legume flour [27]. It is also reinforced with a statement saying that the flour made from the legume naturally have a protein with a hydrophilic side which is more dominant than the hydrophobic, so that the oil absorption capacity flour made from legume becomes lower [28]. Thus, the addition of jack bean flour in the production of composite flour would further lower the value of oil holding capacity.

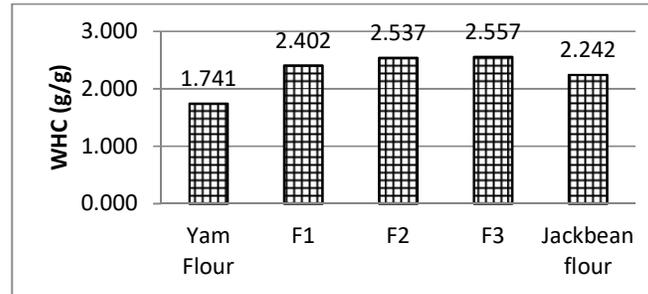


Figure 3 Water Holding Capacity (WHC) of Greater yam Flour, Jack bean Flour, and Composite Flour

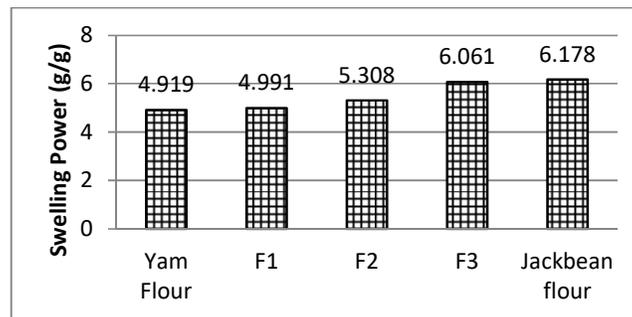


Figure 4 Swelling Power of Greater yam Flour, Jack bean Flour, and Composite Flour

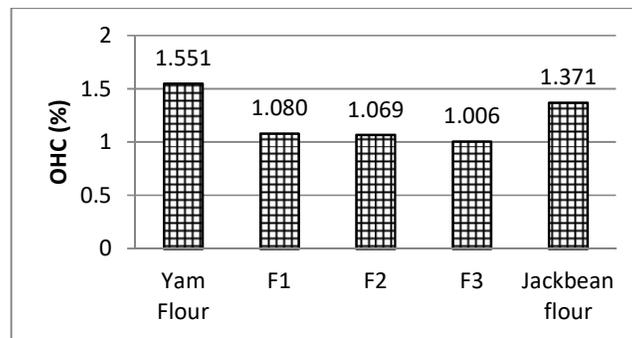


Figure 5 Oil Holding Capacity (OHC) of Greater yam Flour, Jack bean Flour, and Composite Flour

(Proportion of greater yam flour:jack bean flour were F1=85:15, F2=70:30, F3=55:45)

3.2. Chemical Characteristics

The moisture content of the composite flour was affected by the moisture content of basic flour. Soaking was one of steps in the making of greater yam flour or jack bean flour, so that water was not only naturally derived from the material but also from water immersion. Jack bean flour added in the making of composite flour increased the moisture content (Table 3), it was supposed that the protein of jackbean flour was hydrophilic. Composite flour from legumes have a protein with hydrophilic dominant side [28].

The ash content and carbohydrate content of composite flour decreased from F1 to F3 (Table 3). These because the ash content of jack bean flour was lower (1.261%) than greater yam flour (4.294%), and carbohydrate content of jack bean flour was lower (66.567%) than greater yam flour (82.143%).

The protein and fat content of composite flour increased from F1 to F3 (Table 3). This because the protein content of jack bean flour was higher (19.795%) than greater yam flour (7.41%), and fat content of jack bean flour was higher (4.463%) than greater yam flour (0.431%). The proximate data of basic flour was based from preliminary research.

Table 3 Chemical Characteristics of Greater yam (*Dioscorea alata*) and Jack bean (*Canavalia ensiformis*) - Based Composite Flour

Parameter	Composite Flour*		
	F1	F2	F3
Moisture (%)	8.78 ± 0.02 ^b	8.51 ± 0.02 ^a	10.03 ± 0.02 ^c
Ash (%)	4.05 ± 0.01 ^c	3.53 ± 0.01 ^b	2.93 ± 0.02 ^a
Fat (%)	1.14 ± 0.02 ^a	1.70 ± 0.03 ^b	2.22 ± 0.01 ^c
Protein (%)	11.34 ± 0.02 ^a	14.14 ± 0.02 ^b	16.06 ± 0.006 ^c
Carbohydrate (%)	74.69 ± 0.03 ^c	72.11 ± 0.04 ^b	68.77 ± 0.05 ^a
Amylose (%)	20.38 ± 0.07 ^b	21.25 ± 0.09 ^c	17.23 ± 0.09 ^a
Amylopectin (%)	48.84 ± 0.41 ^b	46.09 ± 0.49 ^a	51.07 ± 0.43 ^c
Starch (%)	69.22 ± 0.34 ^a	67.34 ± 0.40 ^a	68.30 ± 0.51 ^a

Value in the same line followed by different letter was significantly different (p=0,05)

*Proportion of greater yam flour:jack bean flour were F1=85:15, F2=70:30, F3=55:45

Amylose and amylopectin content of greater yam flour were higher than jack bean flour, based on preliminary research. The addition of greater yam flour would increase the level of amylose and amylopectin content. However, amylose content of F1 with the more proportion of greater yam flour was even lower than the amylose content of F2. The amylose content of F3 was the lowest of which it was appropriate to amylose ratio of the constituent (basic flour). In general, Table 3 showed that formula variation caused decreasing in amylose content of composite flour compared to the basic flour.

The starch contents of three composite flour were higher than the greater yam flour (64.913%) and jack bean flour (54.033%). The production of composite flour was done mechanically and did not have the factors that caused increasing level of starch. Therefore it is necessary to do further research, especially concerning the molecular structure of starch, to find out how increasing level of starch could occur.

3.3. Functional Characteristics

Resistant starch (RS) content of greater yam flour was slightly higher (6.26%) than jack bean flour (5.975%), so the addition of greater yam flour would increase resistant starch content of composite flour. Resistant starch content of composite flour was appropriate to the resistant starch content of basic flour (Table 4).

Resistant starch content of composite flour was higher than the RS content of basic flour. Improved RS can occur due to heating and chemical modification [29], the crystallization of amylose (Eerlingen et.al., 1993), and bonding between amylose and lipid [30]. High RS content in the composite flour thought to cause high dietary fiber content of composite flour. Resistant starch is included in the dietary fiber [31]. Dietary fiber in the composite flour is dominated by insoluble dietary fiber. Insoluble dietary fiber is known to dominate on seven different types of legumes [32], and the lima bean [33]. Total dietary fiber and insoluble dietary fiber content of composite flour were higher than in the basic flour. However, increasing levels of resistant starch and dietary fiber in this study was still unclear.

Soluble dietary fiber slows gastric emptying time, whereas insoluble dietary fiber has an influence on human faecal mass. The content of dietary fiber in food, either soluble or insoluble, may be a prebiotic. Many studies reported data that supported the role of dietary fiber in triggering the growth of lactic acid bacteria (*Lactobacillus*) having metabolic properties such as bifidobacteria to produce

short-chain fatty acids and repair the immune system [34]. The content of dietary fiber in the composites flour (Table 4) showed that both had the potential to be a prebiotic flour and to help improve metabolism.

Table 4 Functional Characteristics of Greater Yam (*Dioscorea alata*) and Jack Bean (*Canavalia ensiformis*) - Based Composite Flour

Parameter	Composite Flour*		
	F1	F2	F3
Resistant starch (%)	19.22 ± 0.04 ^b	19,10 ± 0.04 ^b	18.11 ± 0.04 ^a
Soluble dietary fiber (%)	2.31 ± 0.02 ^a	2,50 ± 0.02 ^b	2.57 ± 0.02 ^b
Insoluble dietary fiber (%)	41.59 ± 0.12 ^c	40,64 ± 0.17 ^b	39.63 ± 0.26 ^a
Dietary fiber n(%)	43.90 ± 0.11 ^b	43,14 ± 0.15 ^b	42.20 ± 0.24 ^a
Total Phenolics (%)	1.58 ± 0.005 ^c	0.99 ± 0.003 ^b	0.79 ± 0.001 ^a
Antioxidant activity (% / sample weight)	49.10 ± 0.15 ^c	47.40 ± 0.19 ^b	45.82 ± 0.45 ^a

Value in the same line followed by different letter was significantly different (p=0,05)

*Proportion of greater yam flour:jack bean flour were F1=85:15, F2=70:30, F3=55:45

Total phenolics content of greater yam flour was 1.75% and total phenolic of jack bean flour was 0.13% (preliminary research). Based on the total phenolics content of basic flour, the addition of greater yam flour to the composite flour would increase the total phenolics content (**Table 4**). Phenolic compounds known to contribute significantly to its antioxidant activity, the higher content of the phenolic group compound, the greater the antioxidant activity is [35]. Antioxidative mechanism of phenolic compounds is the provision of an electron donor to oxygen and alkyl radicals to form stable radical phenocyl [34].

The antioxidant activity of greater yam flour amounted to 52.93% and jack bean flour antioxidant activity amounted to 15.63% (preliminary research). The more greater yam flour on composite flour increased antioxidant activity (Table 4). The antioxidant activity of composite flour included in the scale of moderate, it was between 20-50% [36].

4. Conclusion

In consideration of the purpose of study, based on physical, chemical, and functional characteristics, then F1 with the proportion of greater yam flour : jack bean flour = 85 : 15, assessed as the best formula of composite flour.

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