Physicochemical properties of purple sweet potato flour fortified with legumes

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Abstract. The popularity of purple sweet potato continues to increase annually. Natural sweetness, attractive color, and high antioxidant were alleged as the main allurement of its products. Nevertheless, there are some lacks on the nutritional properties of purple sweet potatoes, such as low in protein and lipid. This shortcoming could lead to a serious malnutrition problem if there is no nutritional complement from another source. In this condition, fortification could serve as a strategy that addressed to improve the nutritional value of sweet potato products. As a source of protein and bioactive compounds, legumes are potential to be a carrier on the fortification process. This study was aimed to determine the physicochemical properties of sweet potato flour fortified with legumes. A completely randomized design with four fortification treatment was used, i.e. soybean, mungbean, cowpea, and without fortification as a control treatment. The results showed that among other legumes, soybean is the most effective carrier on fortification of sweet potato flours. Purple sweet potato flours that were fortified with 10% soybean have the highest nutritional properties, specifically protein (8.65%), lipid (3.02%), and amylose (32.09%). Legume fortification would also reduce the carbohydrate fraction and generated darker colors in the sweet potato flours.

1. Introduction
Sweet potato, as one of the highest non-rice carbohydrate source in the world after maize and cassava, has an important role in providing global food needs. In recent decades, the popularity of sweet potatoes becomes increase, especially for the purple-fleshed type. Attractive color and its bioactive compound encourage the food industries to compete in developing various derived products of sweet potato. The intense purple color in sweet potatoes flesh is due to the accumulation of anthocyanins [1]. The anthocyanins also have many beneficial functions for the health, especially regarding its ability as an antioxidant [2].

Unfortunately, sweet potato is low in protein, which is range about 3-6% dry basis [3]. This shortcoming could lead a serious malnutrition problem, which associated with protein deficiency, on the population that depends primarily on the sweet potato as a major food material without any protein source as complements. Considering that the malnutrition cases due to protein deficiency in Indonesia are quite high, that is above 30%, this circumstance should be handled properly. In this situation, fortification could serve as a basic strategy that addressed to improve the nutritional value of sweet potato based products.
Fortification is defined as an addition of one or more certain ingredients or nutrients to a food product, which aims to prevent nutrient deficiencies in a particular population [4]. Food fortification program has been implemented in several countries for many years and shown a positive contribution in improving the nutritional status of adults and children [5]. Commonly, a fortification process uses staple foods as vehicles to carry a lacking nutrient in the population diet [4].

Selection of appropriate fortificant is the most important component to ensure the fortification program success [6]. In the fortification of sweet potato products, the legumes are potential to be used as a carrier in its process. Legumes are known as nutritious food, not only because of its protein content but also other substances such as dietary fiber, vitamin, and bioactive compounds [7,8]. Some research evinced that legumes were effective to improve the nutritional value of cereal products [7,9]. However, there is a lack of information about their effectiveness in sweet potato products. Therefore, it is important to monitor the effects of legume fortification on the physicochemical changes of purple sweet potato flour.

2. Materials and Methods

2.1. Preparation Materials
Purple sweet potato and legume were respectively obtained from local farmers in Semarang and Grobogan regency. The legumes that were used i.e. soybean variety of Grobogan, mungbean variety of Vima, and white cowpeas.

2.2. Sample preparation
The tubers were washed to remove all the dirt, then peeled and sliced into small chips. After slicing, the sweet potato chips should keep immersing underwater to avoid discoloration before draining. Then, the sweet potato chips were dried in the cabinet dryer (45±5°C, 24 h) and subsequently milled (Fomac FCT-Z200) and sieved into 80 mesh.

Legumes that were used as fortificant, should remove from the husks first. The husk removal technique in soybean and mungbean were done by soaking them into the water for 8 and 24 hours, respectively. In particular, husk removal of cowpea was done by boiling for 10 minutes because of its harder husk. Water volume that was used for soaking or boiling is four-fold the total weight of legumes. Hereinafter, the legumes were washed, drained, and dried in the cabinet dryer (45±5°C, 24 h). Dried legumes subsequently milled and sieved into 80 mesh.

2.3. Fortification process
Fortification of sweet potato flour was done by addition of 10% legume flour. The level of fortification was determined by considering customer acceptance and the production cost. Some research reported that product fortified with 10% legumes were generally well accepted, but a higher level of legume fortification would lead a negative score for appearance, taste, and texture [9,10].

For each treatment, legume flours were mixed with sweet potato flour by using homogenizer in low velocity during 60 seconds. All treatments were replicated three times. Fortified flours were packed in 0.08 mm polyethylene (PE) bag and stored in an airtight container before further analysis.

2.4. Data collection and analysis
Analysis of fortified flour comprised physical and chemical properties. The color index became a physical attribute of fortified flour. This variable was analyzed by using Hunter Lab Scan Spectrocolorimeter (Hunter Associates Lab, Inc., Reston, VA, USA) with the CIELAB system. The L index represents the lightness, index of a* represents the chromatic color of redness/greenness, and index of b* represents the chromatic color of yellowness/blueness. The chemical analysis consisted of moisture content, protein, total lipid, total carbohydrate, and amylose [11]. Each variable of chemical attributes was represented on a dry basis.
2.5. **Statistical analysis**

Experimental data were analyzed using one-way analysis of variance (ANOVA). Further analysis using Duncan Multiple Range Test at $p \leq 0.05$ was carried out to determine the differences between legumes were used in the fortification process. SPSS 17.0 statistical software (SPSS Inc., Chicago, IL, USA) was used in all statistical analysis.

3. **Results and Discussion**

3.1. **Moisture content**

The effect of legume fortification on sweet potato flour moisture content is summarized in Figure 1. There was a significant difference in the moisture content of purple sweet potato fortified with different legumes ($p \leq 0.05$). The moisture content of sweet potato flours that fortified with soybean and mungbean were significantly higher than unfortified sweet potato flour and sweet potato flour fortified with cowpea. Moisture content enhancement on fortified sweet potato flour might be related to the fiber content of the legumes. Some research suggested that the high fiber on legumes could contribute to an increase of water holding capacity, which is resulting in moisture content improvement in the final product [12,13].

![Figure 1. Moisture content of purple sweet potato flour fortified with legumes.](image)

3.2. **Protein content**

The obtained result showed in Figure 2 indicates that adding different legumes to sweet potato flour have significantly increased the protein content ($p \leq 0.05$). This result confirms that the addition of legumes is suitable in supplementing the tuber protein. Soybean fortification was achieved the highest protein content of sweet potato flour, with the protein increasing reached 2.2 fold. This is not surprising since soybeans are known as the best protein source among other legumes [14]. The protein content of soybean, mungbean, and cowpea is 34.9, 22.2, and 22.9% respectively [15].

3.3. **Lipid content**

Variations were observed in the lipid content of sweet potato flour fortified with different legumes (Figure 3). Utilization of soybean as fortificant exhibited the highest lipid content in sweet potato flours than other legume treatments ($p \leq 0.05$). This is reasonable because soybean has relatively high lipid content compared with other legumes [16]. In contrast with the high lipid content of soybean, the lipid content of cowpea is relatively low about 1.3-1.9% [17]. This could explain why the addition of cowpea has no significant effect on the lipid content of sweet potato flour.
Figure 2. Protein content of purple sweet potato flour fortified with legumes.

Figure 3. Lipid content of purple sweet potato flour fortified with legumes.

3.4. Carbohydrate content
The effect of legume fortification on sweet potato flour carbohydrate is summarized in Figure 4. Legumes fortification generated a significant decrease (p ≤ 0.05) in carbohydrate of sweet potato flour, with the highest reduction of carbohydrate was occurred in sweet potato flour fortified with soybean and mungbean. The degradation of carbohydrate in sweet potato flour due to legume fortification might be related to protein fraction increase and higher fiber [16]. Low carbohydrate level in fortified sweet potato flour could increase its functional properties. The American Diabetes Association has noticed that low carbohydrate diets are very worthwhile in controlling weight gain [18].

3.5. Amylose content
The amylose content of sweet potato flour was significantly increased by the addition of legumes (p ≤ 0.05). In general, legume starches have higher amylose content than tuber starches [19]. The amylose content of legumes was about 30 to 70% [20], while that sweet potato ranged from 8 to 23% of the total amount of starch [21,22].

The highest amylose content of fortified sweet potato flour was resulting from the addition of soybean and mungbean, followed by cowpea (Figure 5). Soybean and mungbean starch have been
reported to have higher amylose content than cowpea [19,23]. In most cases, the higher amylose will produce a solid dough [24]. Some research also has shown that high amylose plays an important role in enhancing the functional properties of the product. The dense structure of amylose molecules affects slow digestion of starch in the intestine, therefore it was often fathomed having a similar function with dietary fiber and resistant starch.

![Carbohydrate content of purple sweet potato flour fortified with legumes.](image1)

**Figure 4.** Carbohydrate content of purple sweet potato flour fortified with legumes.

![Amylose content of purple sweet potato flour fortified with legumes.](image2)

**Figure 5.** Amylose content of purple sweet potato flour fortified with legumes.

3.6. Color index

There were significant differences in the color of sweet potato flour due to legume fortification (Table 1). Soybean fortification decreased the lightness of the sweet potato flour, whereas mungbean and cowpea fortifications enhanced the brightness of the sweet potato flour instead. However, the utilization of soybean as a fortificant could enhance the index of redness and yellowness on sweet potato flour.

Addition of mungbean and/or cowpea increased the lightness score of sweet potato flour and this might be related with the saponin content of each legume [25]. Meanwhile, high protein amount of soybean might have a role in triggering the reaction of reducing sugars with amino acids, hence the fortified sweet potato flour becomes darker and the redness was increasing [25]. Fiber enhancement
due to legume addition might also have a contribution in decreasing the lightness value of purple sweet potato flour [26].

| Color index          | Fortificant   |
|----------------------|--------------|
|                      | Control      | Soybean       | Mungbean     | Cowpea       |
| Lightness (L)        | 70.12±0.09 b | 69.52±0.23 a  | 70.98±0.07 c | 70.90±0.07 c |
| Redness-greenness (a*)| 6.25±0.06 b  | 6.64±0.09 c  | 6.05±0.02 a  | 6.05±0.04 a  |
| Yellowness-blueness (b*) | 11.74±0.05 b | 12.46±0.01 c | 11.79±0.03 b | 11.47±0.12 a |

4. Conclusion
Legume fortification was efficacious in enriching the nutritional value of purple sweet potato flour. Fortification sweet potato flour with legumes is not only effective to enhance protein, lipid, and amylose content but also to reduce carbohydrate fraction. Among other legumes, soybean had a better capability to improve the nutrition of sweet potato flour. Physically, soybean fortification rendered purple sweet potato flour become darker than unfortified sweet potato flour. However, this actually increases the attractiveness of sweet potato products.

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