Equivalence Test between the Physicochemical Properties of Transgenic and Non-Transgenic Soy Flour

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Summary Soybeans are a source of plant-based protein with a fairly complete composition of essential amino acids. Most of the soybean raw material in Indonesia originates from the United States of America where around 75% of the soybeans are transgenic soybeans (Roundup Ready GMO). One of the easily produced and practical soybean products is soy flour. The purpose of this study was to compare the physicochemical properties of flour made from three types of soybeans: local soybeans, imported transgenic soybeans, and imported non-transgenic soybeans. The study was conducted in two phases: the preliminary study, where the physicochemical properties of the three varieties of soybeans were assessed, and the main study which involved the production of soy flour and the analysis of their physicochemical properties. The results of the preliminary analysis revealed that the local soybeans had greater length and width dimensions, volume, bulk density, 100-seed weight, and protein content than transgenic and imported non-transgenic soybeans. The statistical analysis demonstrated that soybean variety had a significant effect on the physicochemical properties of the flour produced, namely the yield, color, water activity, bulk density, repose angle, moisture, ash, protein, fat, and mineral content, and the antioxidant capacity parameters. On the other hand, soybean variety did not have a significant effect on the carbohydrate and total phenolic content. Based on the physicochemical properties, local soy flour had a number of properties that were equivalent to those of imported soy flour and was even superior in its protein content and antioxidant capacity.

Key Words isoflavone, soybean, protein, antioxidant

Soybeans are a plant-based protein source that is fairly affordable with higher protein content than other legumes (1). Raw soybeans contain an average of 35% protein, and in some superior varieties, the protein content could reach 40–44% (2). Soybeans are rich with the amino acids lysine and threonine. The high lysine amino acid content is the reason why soybeans are very suitable for combining with carbohydrate sources considering that staple foods low in lysine.

In addition to having a high protein content, soybeans also contain a flavonoid compound, isoflavone. Isoflavone is a functional component which is beneficial for health by preventing oxidative damage to the cell membrane, preventing cardiovascular diseases, reducing the risk of breast and prostate cancers, reducing the level of low density lipoprotein (LDL) and increasing the level of high density lipoprotein (HDL), reducing the systole and diastole, and can be used in estrogen-replacement therapy (3).

Approximately 70% of the raw soybeans in Indonesia are imported, mostly from the United States. This is because the demand for soybeans in Indonesia is not balanced by the production level (4). Therefore, to fulfill the high demand for soybeans, Indonesia imports soybeans from the United States. According to Panthee (5), 75% of the soybeans produced in the United States are RR (Roundup Ready) transgenic soybeans which are resistant to the herbicide glyphosate.

Both imported transgenic and non-transgenic soybeans are preferred by the tempe producers in Indonesia because they are bright in color and a large in size, resulting in tempe that is more attractive and has a larger volume (6). The study by Astawan et al. (7) revealed that the local soybeans from the Grobogan variety are similar in size and protein content to imported soybeans. It is expected that in the future the local Grobogan variety soybeans could compete with the quality of imported soybeans.

One of the soybeans products that can easily and practically be processed, is not costly, and has a long shelf life, is soy flour. Soy flour is an intermediate product which can be used as a main ingredient, complementary ingredient, or a substitute for other flours or other ingredients to improve the nutrient content or functional properties. The superiorities of soy flour include being easy to store and having many applications in various processed products. According to Raghuvanshi and Bisht (8), soy flour can be used as the main in-
The Equivalence of Transgenic and Non-Transgenic Soy Flour

The main ingredient used in the production of soy flour was transgenic and non-transgenic soybeans imported from the United States and local Grobogan soybeans which were obtained from the Indonesian Tempe and Tofu Producer Cooperation (KOPTI) in Bogor. The equipment used in this study consisted of equipment to produce soy flour and equipment for analyzing the physicochemical properties.

Study phases. This study was divided into two phases: the preliminary study and the main study. The preliminary study was conducted by analyzing the physicochemical properties of the three different soybean varieties, namely the dimension and volume of the soybeans (9), bulk density (10), 100-seed weight, impurity percentage, and proximate analysis (11). The main study consisted of the soy flour production phase and the analysis of their physicochemical properties. The soy flour production process began with sorting the soybeans, the first washing, an 8-hour soaking, the second washing, boiling for 30 min, dehulling, the third washing, drying using a cabinet dryer at 60˚C for 6 h, grinding, and sifting. The physicochemical properties of soy flour analyzed were color, water activity (aw), bulk density (10), repose angle (12), proximate analysis (11), mineral content (calcium, potassium, magnesium, and phosphorous) (13), total phenolic content and antioxidant capacity (14).

Experimental design. The experimental design used was the Completely Randomized Design with soybean varieties as the treatments, each repeated twice. The soybean varieties used were the local Grobogan soybeans, transgenic and non-transgenic imported soybeans. The data were processed using the SPSS 20.0 program with One-Way ANOVA test and a follow-up test with Duncan’s test at a confidence level of 95 or 99%.

RESULTS

The physical characteristics of the soybeans

The physical characteristics of the soybeans are shown in Table 1. The analysis of variance revealed that soybean varieties had a very significant effect (p<0.01) on the physical characteristics of soybeans. In general, the three types of soybeans used had a length of 7.12–8.53 mm, a width of 5.41–6.07 mm, and thickness of 6.67–6.92 mm. The volume of the three types of soybeans ranged between 147.60 and 168.63 mm³. The volumes of the transgenic and non-transgenic soybeans were not significantly different.

The chemical characteristics of the soybeans

The proximate composition of soybean seeds is shown in Table 2. The analysis of variance revealed that soy-
bean varieties had a very significant effect \((p<0.01)\) on the moisture, protein, fat, and carbohydrate content. The result also showed that soybean varieties had a significant effect \((p<0.05)\) on the ash content.

**The physical characteristics of the soy flour**

The yield was calculated by comparing the weight of the soy flour produced to the weight of the dry soybeans used. The calculation of the yield was conducted in order to discover the amount of weight lost during processing. The analysis of variance revealed that the soybean variety had a very significant effect \((p<0.01)\) on the soy flour yield. The soy flour with the highest yield was the transgenic variety which was not significantly different from the local variety’s yield (Table 3).

**The chemical characteristics of the soy flour**

The proximate composition of soybean flours is shown in Table 4. The analysis of variance revealed that soybean varieties had a very significant effect \((p<0.01)\) on the moisture, ash, and fat content of soybean flours. The result also showed that soybean varieties had a significant effect \((p<0.05)\) on the protein and carbohydrate content of soybean flours.

**The total phenolic content and antioxidant capacity of the soy flour**

The result of total phenolic content and antioxidant capacity measurements of the soy flours are shown on Table 5. The analysis of variance revealed that soybean variety did not have a significant effect \((p>0.05)\) on the total phenolic content of the soy flours. The soy flours had total phenolic contents ranging between 68.94 and 73.25 mg GAE/100 g. The highest total phenolic content was found in the transgenic soy flour, followed by the non-transgenic soy flour and lastly the local soy flour. Meanwhile, it revealed that soybean variety had a very significant effect \((p<0.01)\) on the antioxidant capacity of the soy flours. The highest antioxidant

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### Table 3. Yield and physical characteristics of soybean flours.

| Parameter          | Soybean variety       |
|--------------------|-----------------------|
|                    | Transgenic | Non-transgenic | Local    |
| Yield (%)**        | 58.3±0.64b  | 51.33±1.10a   | 54.53±0.53ab |
| Color              |            |               |          |
| \(L^*\)            | 69.65±0.71b | 67.53±0.88a  | 68.45±0.93ab |
| \(a^*\)            | 0.09±0.01a  | 0.34±0.03b   | 0.78±0.13c  |
| \(b^*\)            | 17.25±0.56a | 15.62±0.4b   | 14.77±0.34a |
| Whiteness*         | 65.09±0.89b | 63.95±0.62a  | 65.14±0.70b |
| Water activity**   | 0.31±0.03b  | 0.25±0.00a   | 0.27±0.01ab |
| Bulk density (g/mL)** | 0.34±0.01a | 0.36±0.01b   | 0.34±0.00a  |
| Repose angle**     | 29.11±1.67a | 31.78±0.91b  | 31.77±2.62b |

Values on the same row that are followed by different superscript letters mark significantly different \((* p<0.05)\) or very significantly different \((** p<0.01)\) results with the One Way ANOVA test.

### Table 4. Proximate composition of soybean flours.

| Soybean variety | Moisture (% wb)** | Ash (% db)** | Protein (% db)* | Fat (% db)** | Carbohydrate (% db)* |
|-----------------|-------------------|--------------|-----------------|--------------|----------------------|
| Transgenic      | 4.23±0.08b        | 2.89±0.12a   | 43.99±2.54a     | 27.37±0.6b   | 25.75±1.86a          |
| Non-transgenic  | 4.52±0.12c        | 3.43±0.02c   | 45.13±2.25a     | 28.88±2.37b  | 22.56±0.17a          |
| Local           | 3.03±0.07a        | 3.18±0.03b   | 48.91±1.8b      | 23.10±1.37a  | 24.82±3.16a          |

Values on the same column that are followed by different superscript letters mark significantly different \((* p<0.05)\) or very significantly different \((** p<0.01)\) results with the One Way ANOVA test.

### Table 5. Total phenolic content and antioxidant capacity of soybean flours.

| Soybean variety | Total phenolic (mg GAE/100 g)* | Antioxidant capacity (mg AEAC/100 g)** |
|-----------------|--------------------------------|---------------------------------------|
| Transgenic      | 73.25±6.11a                    | 36.28±0.50b                           |
| Non-transgenic  | 73.08±1.09a                    | 30.07±1.20b                           |
| Local           | 68.94±1.30a                    | 39.64±1.08b                           |

Values on the same row that are followed by different superscript letters mark significantly different \((* p<0.05)\) or very significantly different \((** p<0.01)\) results with the One Way ANOVA test.
capacity was found in the local soy flour, followed by the transgenic soy flour, and lastly the non-transgenic soy flour.

The soy flours’ mineral content

The minerals content of soy flours is shown in Table 6, in which the analysis of variance revealed that soybean variety had a very significant effect ($p<0.01$) on the mineral content of the soy flours. Based on Table 6, the non-transgenic soy flour had the highest calcium, potassium, magnesium, and phosphorous content among the three types of soy flour. The potassium content in the soy flour ranging between 396.62 and 512.69 mg/100 g, and the phosphorous contents ranging between 526.92–660.35 mg/100 g.

**DISCUSSION**

The physical characteristics of the soybeans

The physical characteristics of the soybeans (Table 1) showed that local Grobogan soybeans had the greatest volume ($p<0.01$). This was in line with the results of the study by Astawan et al. (7) which found that the local Grobogan soybeans had the greatest volume among transgenic, non-transgenic, and local (Anjasmaroa, and Argomulyo) soybeans. That the local Grobogan soybeans have a large volume is one of their benefits because around 93% of tempe producers prefer soybeans with large seeds so that they may produce tempe with a greater volume. Based on the study by Kibar and Ozturk (15), the length, width, thickness, and volume of soybeans are directly proportionate to the moisture content. The dimension information (length, width, and height) of the soybeans are necessary for designing cleaning and grading machines (16).

The bulk densities of the three types of soybeans were significantly different ($p<0.01$). The greatest bulk density was demonstrated by the local soybeans. This was because the local soybeans had the greatest weight and volume among the other types. According to Milani et al. (17), bulk density is one of the physical characteristics that is necessary for discovering the amount of pressure needed to press the soybeans in storage (in bin walls). Moreover, bulk density information is also useful in planning the packaging and shipping process, estimating the warehouse volume, and designing processing machinery. A high bulk density could decrease the packaging and shipping costs significantly (18).

According to Yuwono et al. (19), the 100-seed weight could be used to state the size of the seeds. The 100-seed weights of the transgenic and non-transgenic soybeans were not significantly different. This was supported by the data on the volume of the two types of soybeans which were also not significantly different. The local soybeans had the greatest 100-seed weight. Based on the seed-size classification according to Susanto and Saneto (20), the sizes of the three types of soybeans are classified as large because they exceeded 13 g.

The impurity percentages of the three types of soybeans were very significantly different. The percentage of impurity is the ratio between contaminants (everything besides good soybeans) and soybeans that are suitable for processing into soy flour. The impurities here are pieces of twigs, corn seeds, stones, soybeans hulls, wood chips, bad soybeans (rotten, irregularly shaped, having a purplish-green hue), et cetera. From the three types of soybeans, the local soybeans had the highest impurity percentage.

According to Astawan et al. (7), the impurity percentage is influenced by differences in the contaminants and the soybean harvesting age. The higher impurity percentage found in local soybeans compared to transgenic and non-transgenic soybeans could be due to the post-harvest handling that was not as good as that of the imported soybeans. This could be because of inadequate post-harvest processing equipment. According to Ginting and Tastra (21), the low usage of mechanized technology in soybean post-harvest could influence soybean impurity. The less than optimum use of soybean threshing machines can raise the percentage of contaminants in soybeans.

The high impurity percentage of Grobogan soybeans could also be because the farmers and wholesalers did not sort the soybeans. This is because there is no difference in price levels (at farmer level) between sorted and unsorted soybeans, rendering quality to be the least of the market’s concern. Moreover, the high demand for soybeans in Indonesia and the manipulations of prices by the sellers with no regard for the quality of the soybeans has led many of the farmers to mix soil, sand, or pods to their soybeans to raise the selling price (21).

According to Pesu et al. (22), the storage process could also affect soybean impurity. Soybeans that are

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### Table 6. Mineral content of soy flours.

| Mineral (mg/100 g db) | Soybean variety |
|-----------------------|-----------------|
|                       | Transgenic   | Non-transgenic | Local |
| Calcium               | 182.25±3.46a   | 251.63±7.25b  | 195.67±8.12a |
| Potassium             | 396.62±20.63a  | 512.69±7.38c  | 442.11±13.25b |
| Magnesium             | 138.91±4.88a   | 228.86±13.47b | 157.00±1.02a  |
| Phosphorus            | 526.92±2.87a   | 660.35±17.03c | 583.65±4.21b  |

Values on the same row that are followed by different superscript letters mark very significantly different ($p<0.01$) results with the One Way ANOVA test.
stored in polyethylene sacks or metal tins have a smaller number of insects and microorganisms than those stored in bamboo and clay pots. The pest factor (insects and microbes) could affect the seed quality.

**The chemical characteristics of the soybeans**

According to Muchtadi (23), the chemical composition of soybeans could vary based on the variety and growing conditions (climate and location). In addition, the moisture absorbance level of different soybean varieties could affect their chemical composition. Based on the analysis of variance, the samples of the three types of soybeans had very significantly different (p<0.01) moisture contents (Table 2). The difference in the soybeans’ moisture content could be affected by differences in the soybean handling, drying, storing, and distribution process by the supplier (7).

Based on the Indonesian National Standard (SNI) on soybeans quality standard (24), the maximum moisture content for soybeans for grade 1 is 13% and for grades 2 and 3 is 14%. The transgenic and non-transgenic soybeans samples were classified as grade 1 because the moisture content was far below 13%. This signified that the soybeans had undergone a good post-harvest handling process. The local soybean sample had the highest moisture content compared with the other soybeans. This showed that the post-harvest handling process was poor. According to White (25), soybeans with a moisture content of 13–14% have a shelf-life of 6–9 mo and soybeans with a moisture content of 10–11% have a shelf-life of 4 y before undergoing processing.

The ash content of a certain food material indicates its mineral content, purity, and hygiene of the food material (26). The analysis of variance revealed that soybean variety had a significant effect (p<0.05) on ash content (Table 2). This could be seen from the ash content of imported non-transgenic soybeans which was the lowest among the three soybean varieties. The ash content between soybeans could differ because of the difference in variety, plant maturity, planting treatments (27), and planting area (28). The ash contents of the local soybeans and imported transgenic soybeans were not significantly different from one another. A high ash content could be due to unhygienic processing. This was in line with the impurity data which revealed non-transgenic soybeans had the lowest impurity percentage and ash content among the other soybeans.

According to Antarlina et al. (29), soybeans have a higher protein content than other legumes and its protein content is influenced by its variety. The analysis of variance revealed that soybean variety had a very significant effect (p<0.01) on the protein content. According to Kumar et al. (30), the protein content of soybeans varied between 34–48%, depending on the genotype, growing conditions, and cultural practices of the crop. The highest protein content was found in the local soybeans, followed by the non-transgenic soybeans, and lastly the transgenic soybeans (Table 2). The local soybean’s higher protein content compared to that of the other soybeans is an added value so that the utilization of local soybeans could be maximized. The high protein content of a certain food material is usually related to that material’s more rapid water absorption (31).

The three types of soybeans had significantly different (p<0.05) fat contents, between 21.26 and 22.84% (Table 2). The reduction of the soybean volume due to drying could also affect the fat content. A 3% volume reduction of the soybeans could increase the fat content of the soybeans by 2.29%. Therefore, soybeans with a high fat content could be obtained through drying soybeans with a high moisture content at temperatures exceeding 90˚C (32). According to Muchtadi (23), in general, an increase in 1% protein in soybeans would be followed by a decrease of approximately 0.5% of the fat content. Therefore, an increase in protein in soybeans would be followed by a decrease in the fat and carbohydrate content.

Carbohydrate content in the three types of soybeans was calculated by the “by difference” method. The three types of soybeans had carbohydrate contents that were very significantly different (p<0.01), ranging between 31.64 and 38.45% (Table 2). The carbohydrate content in soybeans consists of two groups, insoluble fiber (a mixture between complex polysaccharides and their derivatives) and water-soluble sugars (sucrose, stachyose, and raffinose) (23).

**The physical characteristics of the soy flour**

The assessment of the soy flour color was conducted using a Chroma meter where the value was stated in the Hunter notation system. The L, a, b values obtained from the Hunter notation were also stated in the whiteness value through the equation in Debusca et al. (33). The analysis of variance showed that soybean variety had a very significant effect (p<0.01) on the L, a, and b values and had a significant effect (p<0.05) on the whiteness index of the soy flour (Table 3). The color displayed by soy flour could be a result of the Maillard reaction and caramelization due to the heating at a high temperature (34). The highest L and whiteness indices were found in the non-transgenic soy flour. The color parameter revealed that the L index of the local soybeans was not significantly different from that of the transgenic and non-transgenic soybeans. The whiteness index of the local soybeans was not significantly different from that of the transgenic soybeans. This proved that the local soy flour had lightness (L) and whiteness indices that were not significantly different from those of the imported soybeans.

The water activity (a_w) value is one of the factors that determine the stability and durability level of foods. The a_w value of a certain food material influences chemical reactions, enzyme activity, and microbial growth in the food material (35). The water activity for the three soy flours were significantly different (p<0.01) at a range of 0.27–0.31 (Table 3). Non-transgenic soy flour had the lowest a_w value which was not significantly different from that of the local soybeans. In general, the flours produced had high durability because the a_w of the products were less than 0.6, so molds, yeasts, and bacteria are unable to grow (35).
Bulk density is one of the factors that need to be considered because it strongly influences the packing process, material handling, and the production process in the food industry. The higher the bulk density of a product, the denser and more compact the product is (36). The bulk density of soybeans could be inversely proportionate to the ash value (37). The bulk densities of the soy flours were very significantly different \((p<0.01)\) from each other at a range of 0.34–0.36 g/mL (Table 3). The highest bulk density was found in the imported non-transgenic soy flour. This was because the lowest ash value was also demonstrated by the non-transgenic soy flour. The second highest soy flour bulk density was demonstrated by the local soy flour whose value was not significantly different from that of the transgenic soy flour. A high bulk density could decrease shipping, distribution, and packing costs and reduce the warehouse volume required for storage (38).

The repose angle calculation is very important in designing the angle of the hopper tank. The analysis of variance revealed that soybean variety had a very significant effect \((p<0.01)\) on the repose angle of the soy flour at a range of 29.11–31.780 (Table 3). According to Chang et al. (37), a material is declared to have a good repose angle (has free flowability) if the repose angle is less than 350. Therefore, the three soy flours produced had free flowability in the material moving and mixing process.

The chemical characteristics of the soy flour

According to Gandhi (39), high-quality soy flour would have a maximum moisture content of 10%. Based on Table 4, the three soy flours produced had moisture contents that were very significantly different \((p<0.01)\), between 3.03 and 4.52%. This signified that the soy flour quality based on the moisture content parameter was fairly good because the moisture content was far below 10%. Low moisture content in a product could make the product more resistant to bacteria or other microorganisms, extending the product’s shelf life. The local soy flour had the lowest moisture content among the three soy flours. This demonstrated that the local soy flour had the highest durability among the three soy flours.

The ash content indicates the mineral content of a certain food material. The ash content of the soy flours ranged between 2.89 and 3.43%. According to Gandhi (39), good soy flour has a maximum ash content of 6.5%. Extremely high ash contents indicate poor hygiene in the processing conditions. The analysis of variance showed that the soybean variety had a very significant effect \((p<0.01)\) on the ash content of the soy flour. The ash content of the soy flours was the highest in non-transgenic soy flour, followed by the local soy flour, and lastly the transgenic soy flour.

Protein is an important macronutrient which is the main benefit of soybean products. According to Gandhi (39), the minimum protein content for good quality soy flour is 35% \((\text{w/wb})\). The protein contents of the soy flours produced in this study were significantly different from each other \((p<0.05)\) with a range of 43.99–48.91%. The local soy flour had the highest protein content among the three soy flours. This demonstrated that one of the superiorities of the local soy flour was that it had higher protein content.

The analysis of variance revealed that soybean variety had a very significant effect \((p<0.01)\) on the soy flours’ fat content. According to Gandhi (39), good quality full-fat soy flour has a minimum fat content of 18%. The three types of soy flour had fat contents ranging between 23.10 and 28.88%. The highest fat content was found in non-transgenic soy flour which was not significantly different from that of the transgenic soy flour. The lowest fat content was found in the local soy flour, which was associated with the fact that its protein content was the highest.

The calculation of the carbohydrate content of soy flours was conducted by the “by difference” method. The analysis of variance demonstrated that soybean variety did not have a significant effect \((p>0.05)\) on the carbohydrate content of the soy flours. The carbohydrate content in the soy flours ranged between 22.56 and 25.75%.

The total phenolic content and antioxidant capacity of the soy flours

According to Pratt and Birac (40), soybean seeds, soy flour, soy protein concentrate, and texturized soy protein contain polyphenolic compounds which are mostly in the form of isoflavones and derivatives of cinnamic acid (chlorogenic acid, caffeic acid, p-coumaric acid, and ferulic acid). These polyphenolic compounds also have antioxidant activity. Chlorogenic acid and its isomers are the most abundant compounds compared to the other derivatives of cinnamic acid. One of the most sought-after bioactive components in soybeans is the isoflavones. Isoflavone is a class of flavonoids which functions as a primary antioxidant due to its ability to donate its hydrogen ion so that it could inhibit the free radical chain reaction in lipid oxidation (41). Isoflavones in non-fermented soybean products such as soy flour, soymilk, and tofu are generally in the form of glycosides, consisting of 64% genistein, 23% daidzein, and 13% glycitein (2).

Based on Table 4, the result of the total antioxidant was inversely proportionate to the total phenolic content. This signified that the results of the total phenolic content and antioxidant capacity did not always have a positive correlation. This could be due to the drying factor, the extraction method, antioxidant testing reagent, and the interaction between antioxidant reactions (42).

In the study by Sakhthivelu et al. (43), the antioxidant activity was measured using the DPPH which had a low correlation value with the total phenolic content. This was suggested to be because the high isoflavone content in the total phenolic content was not balanced by the antioxidant capacity value which could be caused by a number of minor non-isoflavonoid phenolic components such as caffeine, chlorogenic, syringic, ferulic, sinapic, coumaric, gentisic, vanillic, and hydroxybenzoic acids. In addition, certain soybeans with higher antioxidant activity than others could have a lower
total phenolic content. This could be possible because high antioxidant activity could be caused by the high proanthocyanidin content (44).

A high isoflavone content does not always produce a high antioxidant activity. A primary antioxidant has a good antioxidant activity score if it donates its hydrogen atom to lipid radicals quickly (41). The total isoflavones content could have a negative correlation with its antioxidant activity. Glucose that is bound to an aglycone could reduce the antioxidant activity by 50–100 times. In soybeans, the genistein content, which has the highest antioxidant activity, is low. Less than 5% of the isoflavone content in soybeans is in the form of aglycone. Therefore, the antioxidant activity could be low (43). Soybeans and low-fat soy flour have an aglycone content of less than 5% of the total isoflavone (45).

The soy flours' mineral content

The mineral content in soybeans could be affected by the fertility level of the soil where they were grown (46, 47). If the soil contained a fairly high amount of a mineral, that mineral content in the soybeans is also high. Soybeans originating from South America or Brazil grow on soil that has a relatively high iron and aluminum content. Therefore, soybeans originating from that area contain a relatively large amount of iron and aluminum (46). Variations in the mineral concentration in soybeans could also be due to the weather conditions during the soybean planting (46).

Soybeans require 50–90 kg/ha of calcium to support growth, both for regulating nodulation and for regulating soil pH (47). Based on Table 6, the calcium content in the soy flour produced in this study was not very high, only approximately 182.25–251.63 mg/100 g. Calcium plays a role in the growth of bones and teeth, the regulation of muscle relaxation and contraction, the regulation of the nervous system, blood pressure, and immune system (48). Statistical analysis revealed that the calcium content of transgenic soy flour and local soybeans were not significantly different.

The potassium content in the soy flour was fairly high, because potassium is the second most abundant mineral absorbed by soybeans after nitrogen (49). According to Xiao-guang et al. (50), potassium is one of the nutrients needed by soybeans to activate certain enzymes and control cellular osmoregulation and the photosynthesis process.

Similar to potassium, magnesium is also needed by chlorophyll in the photosynthesis process and as a cofactor in activating a number of enzymes (47). In humans, magnesium plays an important role in regulating functions in the heart, bones, and arteries, while potassium is needed to regulate blood pressure (30). Duncan’s follow-up test revealed that the magnesium contents in transgenic soy flour and local soy flour were not significantly different.

The phosphorous contents in the soy flours were relatively high, approximately 526.92–660.35 mg/100 g. According to Porter and Jones (46), the phosphorous content in soy flour is available in the form of phytic acid (70%) and phospholipids. A high phytic acid content in soybean products could interfere with mineral (iron, zinc, etc) and protein absorption.

In conclusion, local soybeans are superior to imported soybeans because their size, bulk density, 100-seed weight, and protein content were the highest. However, the high impurity percentage and moisture content are the local soybeans weaknesses. Local soy flour had similar yield, lightness index, and water activity to imported soy flour, similar whiteness index and bulk density to the transgenic soy flour, and a repose angle similar to the non-transgenic soy flour.

Based on its chemical properties, local soy flour was superior to imported soy flour because its moisture content was the lowest and its protein content and antioxidant capacity were the highest. The type of soybeans did not have a significant effect on the carbohydrate content and the total phenolic content of the soy flour. The local soy flour had a similar calcium and magnesium content to the transgenic soy flour, and potassium and phosphorous contents between those of the transgenic soy flour and the non-transgenic soy flour. Therefore, based on its physicochemical properties, the local soy flour had properties equivalent to imported soy flour and was even superior in its protein content and antioxidant capacity.

Disclosure of state of COI

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