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Physicochemical characteristics of promising soybean lines adapted to acid soil and the tofu produced

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Abstract. *Ginting E, Utomo JS, Kuswantoro H, Han W-Y. Physicochemical characteristics of promising soybean lines adapted to acid soil and the tofu produced. Biodiversitas 22: 5012-5022.* Breeding of soybean varieties adapted to different agro-ecological conditions in Indonesia is essential in terms of increasing domestic production through extensification. About 20 promising soybean lines adapted/tolerant to acid soil have been available, thus it is necessary to study their physical and chemical characteristics as well as the suitability as ingredients for tofu products. Four improved varieties (Grobogan, Tanggamus, Anjasmoro, and Wilis) were used as the checks. The results showed that one line belonged to large-seeded, namely Tgm/Anj-995 (15.13 g/100 seeds), slightly smaller than Grobogan (16.26 g/100 seeds). Eighteen lines were medium (similar to Anjasmoro and Tanggamus varieties), while one line was small-seeded (similar to Wilis variety). Five lines contained higher protein (40.35–41.80% dw) relative to four check varieties (36.03–38.18% dw). Tofu prepared from Tgm/Anj-908 and Tgm/Anj-991 lines had the highest scores for color, aroma, and taste acceptances; however, the texture was slightly firm, followed by the Tgm/Anj-932, Tgm/Anj-995, Tgm/Anj-862, and Tgm/Anj-888 lines, which had a softer texture. Their scores were slightly higher than those of Anjasmoro. This suggests that selected soybean promising lines tolerant to acid soil have better physical and nutritional performances relative to their check varieties, with six lines suitable for tofu ingredients.

Keywords: Acid soil, physical, and chemical characteristics, soybean line, tofu

INTRODUCTION

Physical and chemical characteristics of soybean seed, particularly seed size and color, as well as protein content, considerably dictate the quality of soybean products (Ginting et al. 2009). Large-seeded soybean (>14 g/100 seeds) with a yellow seed color is desired for tempe ingredients as it provides good color and a large volume of product, while black-seeded soybean is suitable for soy sauce preparation. Regardless of the seed sizes, yellow-seeded soybean is preferred as a tofu ingredients due to its creamy white color. Tofu is a protein gel of soybean formed through coagulation of the soymilk, suggesting that the protein content and profile of soybean seeds, particularly the 11S and 7S would affect the yield and hardness/texture of tofu (Ginting et al. 2009; Stanojevic et al. 2011; James and Yang 2016; Meng et al. 2016). Both tempe and tofu play an essential role as protein sources in the Indonesian diet, with a consumption level of 7.61 kg and 8.23 kg/capita/year, respectively (Wahyuningsih 2019), which constitutes 83.7% of the total soybean available for consumption (DICA 2016). Therefore, the availability of soybean varieties with high protein content and tailored for both products should be taken into account in soybean breeding programs.

A number of yellow and medium- to large-seeded soybean varieties (10-14 g/100 seeds) (NSB 2013) have been released with a relatively high protein content (≥ 40% dw) and potential yield >2.5 t/ha (ILETRI 2016), which are suitable for tofu making. These varieties would have such protein contents under optimal growing conditions as chemical composition of soybean seed, such as ash, protein, and fat contents, are considerably dictated by both genetic and environmental factors (Carrera et al. 2011; Rowntree et al. 2013; Carrera et al. 2014; Bellaloui et al. 2020). However, there is a wide variation of agro-ecological condition in Indonesia, ranging from optimal land in Java to marginal lands outside of Java, such as acid, swamp, and saline soils to droughts due to a short rainy season (Lakitan and Gofar 2013). This suggests that soybean varieties that are tolerant to such conditions are warranted.

The annual demand for soybean is about 3.5 million tons, which can be only fulfilled 28% by the national production, while the remainder is imported (Wahyuningsih 2019). Therefore, intensive efforts are made to increase domestic production, particularly through introduction of new high yielding varieties and extensification. Acid soil that constitutes around 69.4% of the total dry land (108.8 million ha) in Indonesia (Rochayati and Dariah 2012) is promising for extending the soybean cultivation area. However, there are limitations that generally occur in acid soil, such as a low pH (<5.5), Al and Mn toxicities, nutrient deficiencies (N, P, K, Ca, Mg, Mo), low ion exchange capacity (Rahman et al. 2018) and low N fixation by symbiotic rhizobia (Mohammadi et al. 2012; Ferguson et al. 2013; Jaiswal et al. 2018) that may affect the soybean productivity as well as the nutrient contents of soybean seeds and ultimately the quality of the food products. Selected soybean promising lines tolerant to acid soil have been obtained through a series of breeding activities (Kuswantoro et al. 2011; Kuswantoro et al. 2014; Kuswantoro 2017; Kuswantoro et al. 2017). Therefore, the physicochemical and sensorial attributes of tofu prepared from these promising lines need to be studied. Tofu is chosen for the product at present study as small to large-seeded soybean is normally acceptable for the ingredients, while only large-seeded soybean is preferred for tempe preparation (Ginting et al. 2009; Elisabeth et al. 2017). It is noted that the seed sizes of soybean cultivars tend to be smaller when grown under marginal or stress conditions (Kobraei et al. 2011; Maleki et al. 2013; Jumrani and Bathia 2018). This information expectedly would be useful for both soybean breeders and food industries once the promising lines are released as new varieties.

MATERIALS AND METHODS

Materials

Soybean seeds consisting of 20 promising lines tolerant to acid soil (derived from the cross of Tanggamus and Anjasmoro varieties) and four varieties as checks (Grobogan, Tanggamus, Anjasmoro, and Wilis) were harvested from Tegineneng Experimental Station in Lampung, Indonesia after three months of planting (February-May). No ameliorant was added even though the soil pH was relatively acidic (4.7). About 33.75 kg of N, 45 kg of P_2O_5, and 37.5 kg of K_2O per ha were applied for fertilization, and optimal cultivation (soil tillage, drainage, weeding, pest and disease control) was performed according to Kuswantoro et al. (2017). Before analysis, the seeds were sun-dried for 2–3 days to achieve a moisture content below 10%. The study was conducted in the ILETRI’s Food Chemistry and Technology Laboratory in Malang, Indonesia. Physical observations included visual seed coat color and seed size (100-seed weight). Chemical analysis was performed for ash (gravimetry method) and fat contents (Shoxtec direct extraction method) according to Indonesian Agency for National Standarization (1992), and protein content using a micro Kjeldahl method (AOAC 2016). The ash, fat, and protein contents were presented in % dw (dry weight-basis).

Preparation of tofu

The tofu was prepared as referred to Yulifianti and Ginting (2013). Soybean seeds were soaked for 8 h at room temperature (soybean to water ratio: 1:3 w/v), then washed and ground using a Waring blender for 5 min with a minor modification of the ratio of bean to water (1:12 w/v), which was formerly 1:8 w/v. This ratio was more suitable for making tofu as the hardness is similar to that of tofu sold in local markets. This slurry was boiled for 10 min, followed by manual extraction and filtration using a filter cloth to obtain the filtrate, which was then boiled again to reach a temperature of 75–80ºC and subsequently coagulated by adding 15 mL of 25% acetic acid and thoroughly stirred. It was then poured into a perforated wooden box which was covered with a filter cloth and pressed with a 1 kg load for 20 min to shape the final tofu.

Physicochemical and sensorial attribute analysis of tofu

Physical observations included the yield of fresh tofu using a formula (tofu weight/soybean seed weight x 100%), hardness level using a texture analyzer (Shimadzu SM-500N-168), and lightness (L*) using a Hunter color reader (Minolta CR-200b). Tofu chemical composition, such as moisture and ash contents were analyzed referring to Indonesian Agency for National Standarization (1992) and protein content following AOAC (2016). The moisture content was expressed in % fw (fresh-weight basis), while ash and protein contents were calculated in % dw (dry weight-basis). Sensorial attributes of fresh and deep-fried tofu (color, texture, aroma, and taste) were detected using a Hedonic test with the participation of 20 untrained panelists.

Statistical analysis

All experiments were conducted in triplicate. A complete randomized design was used for the soybean seed and tofu experiments. Data were statistically analyzed using an analysis of variance (ANOVA; $P<0.05$) and followed by LSD test for differences between lines/varieties using a MSTATC software (Version 1.4, Michigan University).

RESULTS AND DISCUSSION

Physicochemical characteristics of acid soil-adapted soybeans

Varietal differences in seed coat colors affect the color of tofu (Goel et al. 2018). Twenty-four soybean lines/varieties were yellow-seeded, even though the Wilis variety has a slightly greenish-yellow seed color. Most soybean lines had similar yellow seed coats as they were bred from the same parents, namely Tanggamus and Anjasmoro, which are yellow-seeded (ILETRI 2016). This color is desired for major soybean products, such as tempe, tofu, and soymilk (Ginting et al. 2009). Therefore, for the last 20 years, a number of yellow-seeded varieties have been released to meet such requirements, like Argomulyo, Anjasmoro, Grobogan, Panderman, Dena 1, Dega 1, Devon 1, Devon 2, and Detap 1 (ILETRI 2016; ILETRI 2021).

According to NSB (2013), soybean with 100-seed weight around <10 g is considered as small-seeded, 10–14 g is medium, and >14 g is large-seeded. Two check varieties, namely Wilis and Tanggamus, are medium-seeded, while Grobogan and Anjasmoro are large-seeded (ILETRI 2016). However, smaller seed sizes for Grobogan, Anjasmoro, Wilis, and Tanggamus varieties were obtained in this study (Table 1), which are normally 18–19.3 g, 14.8–15.3 g, 8.9–11 g, and 11.0 g/100-grain, respectively (Ginting et al. 2009; Yulifianti and Ginting 2013, ILETRI 2016). This may due to the acidic growing conditions, whereas regular sizes may have been obtained under optimal conditions. Al toxicity associated with acidic soil may reduce uptake of water and nutrients due to the stunting or limited growth of the primary roots (Joris et al. 2013; Kuswantoro et al. 2014), resulting in a reduction in seed yield (dry matter accumulation), sizes, and nutrient composition, as occurs under drought stress (Kobraei et al. 2011; Maleki et al. 2013; Jumrani and Bathia 2018; El Sabagh et al. 2019). Also, soybean lines/varieties have different tolerance levels to Al toxicity (Kuswantoro et al. 2011; Uguru et al. 2012; Liang et al. 2013), thus resulting in variation in their physical and chemical characteristics.

Under acidic soil conditions, the Tgm/Anj-856 line and Wilis variety gave small seed sizes, whereas Tanggamus and Anjasmoro varieties and 18 lines had medium seeds and one line, namely Tgm/Anj-995 and Grobogan variety belonged to large-seeded (Table 1). The Tgm/Anj-995 seed was significantly larger than those of Anjasmoro, Tanggamus, and Wilis varieties. However, it was slightly smaller than Grobogan variety. Currently, Grobogan, Dega 1, and Mutiara 1 varieties are reported to have the largest seed sizes in Indonesia, *c.a.*18 g, 22.98 g, and 23.2 g per 100-seed, respectively (ILETRI 2016, ILETRI 2021). Meanwhile, Tgm/Anj-933 has a similar size to Anjasmoro variety. Tanggamus is an acid-soil tolerant variety that was released in 2001, however it has a medium seed size (11 g/100-seed), while Anjasmoro is a large-seeded (ILETRI 2016). It is likely that the desired characteristics of both varieties were combined to obtain soybean lines that are tolerant of acid soil with larger seed sizes than Tanggamus. In a previous study performed at the same location in Lampung under drought stress conditions, Tgm/Anj-995 line also showed a large seed size (15.90 g/100-seed), while Tanggamus and Wilis (as checks) were small *c.a.* 8.65 g and 7.8 g/100-seed, respectively (Ginting and Kuswantoro 2012). This result shows that the Tgm/Anj-995 line is consistent to be a large-seeded even under acidic and drought stress conditions. Therefore, this line is promising as a large-seeded soybean variety tolerant to acid soil and suitable for areas such as Lampung province. Large seed size is an important trait, particularly for tempe ingredients, giving a positive correlation with the volume development after fermentation (Ginting et al. 2009). Even though seed sizes are less important characters for tofu preparation (Ginting et al. 2009) as the seeds are ground and extracted to obtain the filtrate, large-seeded soybean is yet preferred by farmers/market as it is suitable for both tempe and tofu ingredients. Also, the larger the seed sizes, the less the seed coat proportion, giving a higher yield of tofu. In Japan as well as in Brazil, soybean with > 20 g/100-seed is favored for tofu making (Benassi et al. 2011; Meng et al. 2016).

Table 1. Physical and chemical characteristics of 24 soybean lines/varieties

Soybean genotype	100-seed weight (g)	Ash (%)	Fat (%)	Protein (%)
Tgm/Anj-784	10.54 ± 0.15 kl	4.84 ± 0.13 def	20.16 ± 0.15 fg	35.94 ± 0.77 j
Tgm/Anj-832	13.17 ± 0.55 de	5.31 ± 0.03 a	21.77 ± 0.35 a	36.49 ± 1.14 hij
Tgm/Anj-844	10.63 ± 0.46 jkl	4.51 ± 0.04 k	20.74 ± 0.22 de	37.12 ± 1.04 fghij
Tgm/Anj-847	12.25 ± 0.34 ghi	4.83 ± 0.06 defg	21.91 ± 0.02 a	38.43 ± 0.76 def
Tgm/Anj-856	9.95 ± 0.24 m	4.83 ± 0.13 defg	19.69 ± 0.14 hi	41.13 ± 1.61 ab
Tgm/Anj-857	12.01 ± 0.14 hi	4.67 ± 0.02 hij	20.39 ± 0.06 ef	37.74 ± 0.68 fgh
Tgm/Anj-858	11.18 ± 0.32 j	4.67 ± 0.04 hij	19.72 ± 0.26 gh	40.74 ± 0.46 ab
Tgm/Anj-862	11.98 ± 0.45 hi	4.86 ± 0.03 de	19.51 ± 0.24 hi	41.80 ± 0.32 a
Tgm/Anj-888	12.53 ± 0.31 fgh	4.81 ± 0.04 defg	19.59 ± 0.36 hi	40.35 ± 0.40 abc
Tgm/Anj-889	12.22 ± 0.17 ghi	4.89 ± 0.13 de	21.95 ± 0.06 a	37.27 ± 0.56 fghij
Tgm/Anj-908	11.93 ± 0.08 i	4.88 ± 0.03 de	20.98 ± 0.10 cd	38.26 ± 0.85 efg
Tgm/Anj-909	10.88 ± 0.03 jk	4.79 ± 0.01 efgh	19.47 ± 0.85 hi	40.43 ± 1.40 abc
Tgm/Anj-910	11.01 ± 0.27 jk	4.89 ± 0.04 de	20.47 ± 0.09 ef	37.71 ± 0.10 fgh
Tgm/Anj-919	12.91 ± 0.25 ef	4.71 ± 0.03 ghij	19.48 ± 0.11 hi	39.23 ± 1.01 cde
Tgm/Anj-931	12.74 ± 0.17 efg	5.05 ± 0.03 c	21.56 ± 0.19 ab	38.00 ± 0.69 efg
Tgm/Anj-932	10.58 ± 0.27 kl	5.20 ± 0.01 ab	20.50 ± 0.26 ef	37.65 ± 0.76 fgh
Tgm/Anj-933	13.48 ± 0.36 cd	5.13 ± 0.03 bc	21.61 ± 0.43 ab	36.84 ± 0.52 ghij
Tgm/Anj-957	10.21 ± 0.03 lm	5.20 ± 0.04 ab	21.22 ± 0.41 bc	37.44 ± 1.16 fghi
Tgm/Anj-991	12.74 ± 0.30 efg	5.11 ± 0.04 bc	21.52 ± 0.07 ab	37.47 ± 0.34 fghi
Tgm/Anj-995	15.13 ± 0.60 b	4.60 ± 0.21 jk	19.28 ± 0.09 i	39.83 ± 1.30 bcd
Mean ± std dev [a]	11.90 ± 1.30	4.89 ± 0.22	20.58 ± 0.95	38.48 ± 1.82
Grobogan	16.26 ± 0.16 a	4.73 ± 0.03 fghi	20.28 ± 0.08 f	38.13 ± 1.55 efg
Tanggamus	10.24 ± 0.24 lm	4.82 ± 0.03 defg	20.28 ± 0.18 f	38.18 ± 0.59 efg
Anjasmoro	13.98 ± 0.64 c	4.63 ± 0.01 ijk	20.30 ± 0.07 ef	38.15 ± 0.70 efg
Wilis	9.97 ± 0.44 m	4.92 ± 0.17 d	20.33 ± 0.14 ef	36.03 ± 0.99 ij
Mean ± std dev [b]	12.61 ±2.77	4.77 ± 0.14	20.30 ± 0.11	37.62 ± 1.30
Mean ± std dev [c]	12.02 ± 1.63	4.87 ± 0.21	20.53 ± 0.87	38.33 ± 1.76

Note: Figures within a column followed with the same letters are not significantly different (*P*>0.05). [a b c] is obtained from 20 lines, 4 check varieties and total of 24 lines and check varieties, respectively

Ash represents the mineral content of soybean seed, particularly phosphorus, calcium, iron, sodium, potassium, and magnesium (Bellaloui et al. 2011). Twenty soybean lines had an ash content ranging from 4.51 to 5.31% (dw) and six lines contained ash contents that were higher than those of the four check varieties (Table 1). As they were grown at the same location, these considerable differences were due to the soybean genotype. These values were slightly lower than those from a previous study of 12 soybean lines/varieties (5.11–5.99% dw and 4.93–5.93% dw) grown under drought conditions in two locations in Lampung (Ginting and Kuswantoro 2012). The mineral concentration of soybean seed increases under drought-stress (Bellaloui et al. 2014; Wijewardana et al. 2019) as well as high temperature stress (Qiao al. 2019). In addition to genotype, climate, soil type, and fertility, the application of fertilizer and *Rhizobium* inoculation may contribute to differences in ash content (Elsheikh et al. 2009). As a soybean product, tofu can be a good source of essential minerals, such as Mg, Mn, Na, Cu and Fe (Paz et al. 2021).

Soybean seed with protein content ≥ 40% is preferred for soy food industry and > 42% is desirable for tofu making (Meng et al. 2016). The protein contents of 24 soybean lines/varieties were significantly different (Table 1), which ranged from 35.94 to 41.80% (dw). Five soybean lines showed the highest protein contents, namely Tgm/Anj-862, Tgm/Anj-856, Tgm/Anj-858, Tgm/Anj-909, and Tgm/Anj-888, ranging from 40.35 to 41.80% (dw) that were much higher than those of the four check varieties (36.03–38.18% dw). This reflects the superiority of the above lines regarding protein content when grown under acidic soil conditions and suitable for tofu ingredients. Meanwhile, two lines, namely Tgm/Anj-995 and Tgm/Anj-919, had slightly higher protein contents than Grobogan, Tanggamus, and Anjasmoro, while 11 lines were similar. The remaining two lines contained a protein level that was approximately similar to that of Wilis variety, which showed the lowest value. Tanggamus, an acid-tolerant variety, had a relatively small protein content (38.18% dw), lower than the normal value (44.5% dw) listed in its variety description, as well as that of the Grobogan, Anjasmoro, and Wilis varieties (ILETRI 2016). Zheng et al. (2020) revealed that environmental factors correlated significantly with the seed protein content. Reduced the uptake of water and nutrients due to the stunting of primary roots in relation to acidic soil condition (Kuswantoro et al. 2014) may be attributed to such decrease in protein content. Previously, Maleki et al. (2013) and Wijewardana et al. (2019) also noted that the protein content of soybean seed significantly decreased along with the soil moisture or drought stress levels.

The soybean line/variety significantly affected the fat content of the soybean seeds (Table 1), with the highest value noted in seven lines (21.52–21.95% dw), followed by two lines (20.74–20.98% dw) and four lines (20.16–20.50% dw), which were similar to those of the four check varieties (20.28–20.33% dw). The remaining seven lines had the lowest values (19.28–19.69% dw). The highest fat contents noted in this study were fairly high, similar to that of imported soybean, *c.a.* 21.4–21.7% (d) (Ginting et al. 2009), particularly those from the United States as they are mainly proposed for oil extraction. Domestic varieties normally contain lower fat and higher protein relative to imported soybeans. The four check varieties also showed higher fat content relative to those published in their description (ILETRI 2016). The decrease in protein content of these varieties might be the reason for such findings as both protein and fat contents are negatively correlated (Hwang et al. 2014; Wijewardana et al. 2019). This fact was also obtained at present study with r = -0.649 (Figure 1). Soybean growing conditions, including acid soil may also affect the fat content, which tends to be significantly higher under water stress and elevated temperature conditions (Carrera et al. 2011; Bellaloui et al. 2013; Mourtzinis et al. 2017), as well as when grown at low altitude locations (Shin et al. 2009). The fat contents obtained at present study were within the range values of 105 soybean lines/varieties *c.a.*13.80–22.06% (dw) (Shi et al. 2010) and five Korean varieties *c.a.* 17.5-22.0% (Yoo 2011).

Physical characteristics of the tofu

As most soybean lines in this study were medium-seeded, tofu was prepared to study their suitability as tofu ingredients. The lightness (L*) levels of tofu derived from 24 lines/varieties were significant, with the highest values seen in Tgm/Anj-909 line, four other lines and the Grobogan variety (Table 2). Meanwhile, Tgm/Anj-844, Tgm/Anj-857, and the Wilis variety showed the lowest lightness values. This suggests that lightness, which reflects the whiteness level of tofu, was considerably dictated by the color of the soybean seed coat, particularly in the case of the Wilis variety, which had a yellow-greenish seed color. The brighter yellow the seed color, the higher the lightness level of the tofu.

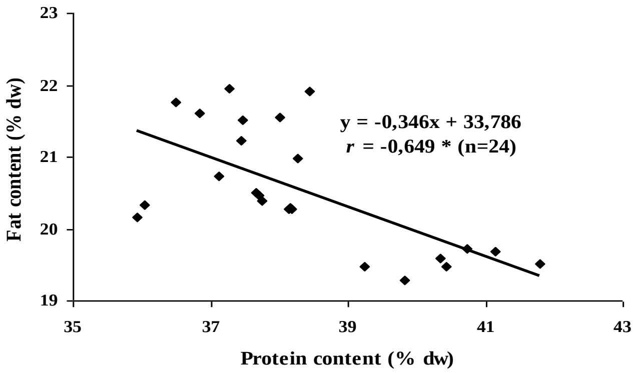

Figure 1. Relation between protein and fat contents of 24 soybean lines/varieties adapted to acid soil

Table 2. Physical characteristics of tofu prepared from 24 soybean lines/varieties

Soybean variety/line	Lightness (L*)	Hardness (Newton)	Yield recovery (% by weight)
Tgm/Anj-784	86.23 ± 0.50 defgh	5.52 ± 0.31 l	212.72 ± 17.68 bcdef
Tgm/Anj-832	84.93 ± 0.55 klm	9.03 ± 0.17 hij	229.79 ± 7.79 ab
Tgm/Anj-844	83.93 ± 1.08 n	8.06 ± 0.71 jk	205.95 ±1.51 def
Tgm/Anj-847	85.87 ± 0.47 fghijk	10.33 ± 1.08 efg	216.78 ± 1.89 abcdef
Tgm/Anj-856	85.50 ± 0.60 ghijk	7.56 ± 0.82 k	219.92 ± 11.45 abcde
Tgm/Anj-857	84.37 ± 0.47 lmn	10.39 ± 0.44 efg	198.61 ± 9.82 ef
Tgm/Anj-858	86.07 ± 0.60 fghij	8.91 ± 0.18 hij	216.62 ± 10.90 abcdef
Tgm/Anj-862	87.47 ± 0.15 ab	10.23 ± 0.62 efg	222.91 ± 9.47 abcd
Tgm/Anj-888	87.17 ± 0.12 abcd	12.40 ± 0.26 c	234.49 ± 12.68 a
Tgm/Anj-889	87.33 ± 0.25 abc	11.10 ± 0.69 de	231.08 ± 0.83 ab
Tgm/Anj-908	85.37 ± 0.60 hijk	4.01 ± 0.63 m	224.38 ± 19.74 abcd
Tgm/Anj-909	87.67 ± 0.25 a	9.55 ± 0.09 gh	235.87 ± 2.96 a
Tgm/Anj-910	85.93 ± 0.32 fghij	2.75 ± 0.50 n	226.10 ± 18.16 abcd
Tgm/Anj-919	85.20 ± 0.87 ijkl	3.07 ± 0.77 mn	214.80 ± 18.79 abcdef
Tgm/Anj-931	86.10 ± 0.96 efghi	10.85 ± 1.03 de	212.73 ± 9.81 bcdef
Tgm/Anj-932	85.90 ± 0.26 fghij	5.72 ± 0.98 l	217.79 ± 17.61 abcdef
Tgm/Anj-933	85.13 ± 1.48 jkl	9.84 ± 0.94 fgh	205.98 ± 15.46 def
Tgm/Anj-957	85.23 ± 0.21 ijkl	11.68 ± 0.17 cd	229.17 ± 7.69 abc
Tgm/Anj-991	87.33 ± 0.55 abc	9.79 ± 0.22 fgh	206.50 ± 9.07 def
Tgm/Anj-995	86.43 ± 0.60 cdefg	13.55 ± 0.23 b	198.87 ± 12.37 ef
Mean ± std dev [a]	85.96 ± 1.16	8.72 ± 3.05	218.05 ± 14.13
Grobogan	87.03 ± 0.12 abcde	18.09 ± 0.62 a	208.45 ± 0.15 cdef
Tanggamus	86.37 ± 0.06 defg	9.13 ± 0.09 hi	207.14 ± 12.47 def
Anjasmoro	86.63 ± 0.21 bcdef	10.54 ± 0.06 ef	210.30 ± 4.83 bcdef
Wilis	84.13 ± 0.45 mn	8.36 ± 0.65 ijk	199.02 ± 15.39 ef
Mean ± std dev [b]	86.04 ± 1.20	11.53 ± 4.06	206.22 ± 8.98
Mean ± std dev [c]	85.97 ± 1.15	9.19 ± 3.37	216.08 ± 14.05

Note: Figures within a column followed with the same letter are not significantly different (P>0.05). L* : lightness level, ranging from 0 (dark/black) to 100 (light/white). [a b c] is obtained from 20 lines, 4 check varieties and total of 24 lines and check varieties, respectively

In general, a white or light yellow (creamy white) color of tofu is favored. Even though most of the soybean seeds used in this study were yellow-seeded, the levels of lightness/brightness of the seed coat varied from dull to bright, depending on genetic factors, as well as post-harvest handling (harvesting, drying, and storage), as natural pigment is profoundly affected by moisture, temperature, and humidity. Long storage periods of soybean seeds under warm, moist, and humid conditions would also cause color degradation of the tofu produced from these seeds (Liu and Chang 2012; Kamizake et al. 2016; Kamikaze et al. 2018). The L* values in this study were slightly greater than those of tofu made from five Indonesian soybean varieties *c.a.* 83.13-85.10 (Yulifianti and Ginting 2013). Meanwhile, a wide range of L* values (53.05 to 86.16) was observed in tofu prepared from 14 Korean soybean cultivars (Kim et al. 2010).

Table 2 shows that the tofu hardness considerably varied among the 24 soybean lines/varieties. Tofu derived from Grobogan variety had the highest hardness value (18.09 N), reflecting the firmest texture, followed by Tgm/Anj-995 (13.55 N). Meanwhile, Tgm/Anj-910 and Tgm/Anj-919 lines showed the lowest hardness values (soft texture). Three other check varieties (Wilis, Tanggamus, and Anjasmoro) had hardness values between 8 to 10 N. Among the 20 soybean lines, four lines had hardness values higher than those of the three checks (firmer texture), 10 lines were similar and six lines were lower, or had a softer texture (2.75–7.56 N). Ginting et al. (2009), James and Yang (2016) and Yasin et al. (2019) reported that a high soybean seed protein content is essential for tofu ingredients as it affects the physical and sensorial attributes (firmness) of the tofu. However, the correlation between protein content and tofu hardness was not significant in the present study (r = 0.299). Thus, differences in protein fraction (globulin and the ratio of 11S and 7S) may contribute to such differences in tofu hardness (Yang and James 2013; James and Yang 2014; Wang et al. 2018). A positive correlation (r = 0.99) has been noted between tofu hardness and the ratio of 11S protein (glycinin) and 7S protein (β-conglycinin) of the soybean seed (Stanojevic et al. 2011) as well as by Wang et al. (2020) with r = 0.343.

In addition to protein content of the seed, the texture of tofu is also affected by the type of coagulant (Zhang et al. 2018; Wang et al. 2018; Shi et al. 2020). Acetic acid, as used in the present study, produces typically medium firm tofu, whereas calcium sulfate and magnesium chloride produce relatively soft tofu and very soft tofu (silken tofu) is obtained when GDL (glucono delta lactone) is applied as a coagulant (Syah et al. 2015; Zheng et al. 2020). Using a similar coagulant as used in this study, Yulifianti and Ginting (2013) measured a wide variation of tofu hardness derived from six soybean varieties, ranging from 9.91 N to 29.69 N. This may also due to a lower moisture contents measured in the latter study (75.13-77.23%) relative to present study (Table 3). Wang et al. (1983) revealed a negative correlation (r = -0.65) between the hardness of tofu with its moisture content.

Table 3. Chemical composition of tofu derived from 24 soybean lines/varieties

Soybean variety/line	Moisture (%)	Ash (%)	Protein (%)
Tgm/Anj-784	80.55 ± 0.44 abc	2.85 ± 0.04 fg	53.17 ± 1.41 efgh
Tgm/Anj-832	79.29 ± 0.62 cdef	3.03 ± 0.06 defg	53.22 ± 1.83 efgh
Tgm/Anj-844	79.44 ± 0.43 cde	2.83 ± 0.12 fg	54.17 ± 1.51 defg
Tgm/Anj-847	79.45 ± 0.12 cde	3.13 ± 0.27 cdef	55.32 ± 1.01 cde
Tgm/Anj-856	79.16 ± 1.64 def	2.73 ± 0.23 g	58.87 ± 0.88 a
Tgm/Anj-857	79.71 ± 0.53 bcde	3.70 ± 0.36 a	52.65 ± 1.07 fgh
Tgm/Anj-858	80.24 ± 0.26 abcd	3.06 ± 0.28 defg	56.01 ± 1.30 bcd
Tgm/Anj-862	81.49 ± 0.34 a	3.21 ± 0.17 bcde	54.76 ± 0.63 def
Tgm/Anj-888	81.26 ± 0.19 a	3.04 ± 0.11 defg	59.54 ± 1.53 a
Tgm/Anj-889	80.85 ± 0.41 ab	3.41 ± 0.08 abc	55.43 ± 2.46 cde
Tgm/Anj-908	79.67 ± 0.38 bcde	3.53 ± 0.11 ab	52.70 ± 0.77 fgh
Tgm/Anj-909	80.83 ± 0.22 ab	3.32 ± 0.43 bcd	52.58 ± 1.08 fgh
Tgm/Anj-910	77.95 ± 2.30 f	3.11 ± 0.43 cdef	50.68 ± 1.60 hi
Tgm/Anj-919	81.34 ± 0.34 a	3.48 ± 0.11 ab	58.45 ± 1.36 ab
Tgm/Anj-931	79.29 ± 1.26 cde	2.97 ± 0.18 efg	56.19 ± 2.02 bcd
Tgm/Anj-932	79.57 ± 0.39 bcde	3.03 ± 0.08 defg	49.65 ± 1.97 i
Tgm/Anj-933	79.29 ± 0.09 cde	2.74 ± 0.11 g	57.42 ± 1.22 abc
Tgm/Anj-957	81.41 ± 0.34 a	3.30 ± 0.31 bcde	53.26 ± 0.94 efg
Tgm/Anj-991	78.99 ± 0.17 def	3.33 ± 0.19 bcd	50.67 ± 1.88 hi
Tgm/Anj-995	78.40 ± 0.36 ef	3.11 ± 0.14 cdef	54.56 ± 0.60 def
Mean ± std dev [a]	79.91 ± 1.19	3.15 ± 0.32	54.47 ± 2.95
Grobogan	80.22 ± 1.13 abcd	3.26 ± 0.16 bcde	54.60 ± 0.78 def
Tanggamus	79.88 ± 0.42 bcd	2.97 ± 0.22 efg	54.40 ± 2.28 defg
Anjasmoro	81.43 ± 1.27 a	3.11 ± 0.33 cdef	55.65 ± 2.15 cde
Wilis	79.02 ± 0.85 def	2.99 ± 0.06 defg	51.93 ± 1.91 ghi
Mean ± std dev [b]	80.14 ± 1.23	3.08 ± 0.22	54.14 ± 2.14
Mean ± std dev [c]	79.95 ± 1.19	3.13 ± 0.30	54.41 ± 2.82

Note: Figures within a column followed with the same letter are not significantly different (P>0.05). [a b c] is obtained from 20 lines, 4 check varieties and total of 24 lines and check varieties, respectively

Significant yield recoveries of fresh tofu were obtained from 24 soybean lines/varieties, with an average two-fold increase of their initial seed weight (Table 2). The Tgm/Anj-888 and Tgm/Anj-909, together with 11 other lines, showed the highest yield recoveries, which were relatively higher than those of four check varieties, while seven lines were similar. These differences may be due to differences in the moisture content of the tofu, which was associated with the protein content and fraction of protein (gel-forming properties) and would ultimately affect the yield recovery (Min et al. 2005). The protein content of soybean seeds positively correlates with tofu yield recovery (Min et al. 2005; Ginting et al. 2009), however this phenomenon was not seen in this study, nor the studies by Yulifianti and Ginting (2013) and Wang et al. (1983), suggesting that the protein fraction is more prominent in dictating the yield recovery of tofu. Ginting et al. (2009) revealed that soybeans with a higher globulin fraction would provide a higher yield of tofu. In particular, the ratio of 11S/7S globulin positively correlates (r = 0.91) with the tofu yield (Stanojevic et al. 2011), as 11S gel has a higher water holding capacity relative to 7S gel (Yang and James 2013).

In addition to protein, tofu yield is also determined by the bean to water ratio. In the present study, the tofu yields were higher than those of a previous study using six soybean varieties, which ranged from 156 to 183% (Yulifianti and Ginting 2013) due to a higher ratio used (1:12 w/v vs. 1:8 w/v). The increased yield is primarily the result of increased water retention in the tofu gel (Wang et al. 1983). Tofu with a higher yield recovery is desirable as it would be more profitable for the processor. Korean tofu derived from 14 cultivars with a moisture content of 74.42–80.01% gave lower yield recoveries c.a.137.77–201.91% (Kim et al. 2010), relative to the present study. A lower finding of tofu yield (169.7-192.7%) was also investigated by Wang et al. (1983) using 10 US and Japanese soybean varieties as well as in Ethiopian tofu c.a. 123.35-134.03% (Yasin et al. 2019). The type of coagulant may also affect the yield recovery of tofu (Stanojevic et al. 2011; Li et al. 2015). Tofu prepared using GDL as a coagulant provides an approximately three-fold higher yield recovery compared to that of calcium sulfate tofu (Poysa and Woodrow 2002).

Chemical composition of tofu

The tofu moisture content was significantly different between lines, which ranged from 77.95 to 81.49% (Table 3). Eight lines had high moisture contents, which were similar to those of the Anjasmoro and Grobogan varieties, while five lines with low moisture contents were identical to that of Wilis variety, and the remaining lines were similar to the Tanggamus variety. The seed's capacity to absorb water during soaking (Wang et al. 1983) and the protein gel's capacity to hold water, which is dictated by the bean to water ratio and the fraction of seed protein, may contribute to such differences in tofu moisture contents, which would affect its yield recovery and hardness (Min et al. 2005). Yulifianti and Ginting (2013), who used a lower ratio of bean to water (1:8 w/v) for extraction, reported a lower tofu moisture content (75.13–77.23%) from six soybean varieties that were approximately similar to those of Korean tofu (74.42-80.01%) prepared from 14 cultivars (Kim et al. 2010) and tofu resulted from eight Ethiopian cultivars (72.45-74.95%) (Yasin et al. 2019). Also, soaking time, extraction method, coagulant as well as pressing load and time may be attributed to tofu moisture content. Kim and Wicker (2005) recorded a slightly lower moisture content of tofu (76.9-77.5%) relative to present study when used $MgCl_2$ as a coagulant, while higher moisture contents (84.20-85.68%) were obtained in the tofu coagulated with CaSO4 (Wang et al. 1983). Moisture together with hardness would affect the mouth feel, texture and taste (Wang et al. 2019).

Slight differences in the ash content of tofu from the 24 soybean varieties/lines were observed, which ranged from 2.73 to 3.70% dw (Table 3). This is primarily due to the ash contents of the soybean seeds, including phytic acid, which contains principally phosphorus (Raboy 2009; Nissar et al. 2017), as the same preparation method was applied for all tofu, particularly the amounts of water and coagulant added. A slightly higher ash content (3.35-4.34% dw) was noted in tofu prepared from six soybean varieties (Yulifianti and Ginting 2013), while lower values (1.81-2.225 dw) were noticed in tofu prepared from eight Ethiopian varieties (Yasin et al. 2019).

The Tgm/Anj-888, Tgm/Anj-856, Tgm/Anj-919, and Tgm/Anj-933 lines showed the highest tofu protein contents (57.42–59.54% dw), which were higher than those of four check varieties (51.93–55.65% dw) as seen in Table 3. Meanwhile, the Tgm/Anj-932, Tgm/Anj-991, and Tgm/Anj-910 lines, which had the lowest protein contents, were similar to that of Wilis variety. This disparity in tofu protein content may be due to differences in soybean protein content, protein fraction and extracted or soluble protein into the filtrate/soymilk. Min et al. (2005) revealed a significant correlation between the protein contents of soybean seed and soymilk. However, only the coagulated or gel of soluble protein fraction in the soymilk would dictate the final protein content in the tofu, thus it may not always positively correlate with the initial protein content of soybean seed (Wang et al. 1983). This phenomenon was also seen in the present study as among the five soybean lines with a protein content >40% (dw), only Tgm/Anj-856 line showed a high protein content in its respective tofu. The protein contents obtained at present study were slightly higher than those of tofu (50.96-56.36% dw) previously investigated by Yulifianti and Ginting 2013 as well as tofu made from 10 US and Japanese soybean varieties (47.49% to 53.29% dw) and eight Ethiopian varieties (53.04-56.73% dw) as recorded by Wang et al. (1983) and Yasin et al. (2019), respectively. The protein contents of tofu in this study had met the requirement (> 9% fw or about > 45% dw) set by the national standard quality (Indonesian Agency for National Standardization 1998).

Sensorial attributes of tofu

Table 4 presents data demonstrating that the colors of raw tofu prepared from the 19 soybean lines were fairly liked, which were similar to those of the four check varieties, whereas the Tgm/Anj-844 line was slightly liked. These slight differences in visual color acceptance were in agreement with the slight differences in lightness values (L*) as presented in Table 2, as most of the soybeans used were yellow-seeded.

The aroma of tofu prepared from three soybean lines was slightly liked, while those derived from the remaining lines and the four check varieties were fairly liked. This may due to the beany off-flavor that commonly occurs during the processing of soybeans, due to the oxidation of fatty acids by lipoxygenase enzyme, even though it expectedly has been eliminated/minimized through heat treatment during boiling (Chong et al. 2019). Differences in the original amounts of lipoxygenase enzyme existing in the soybean lines/varieties (Yuan and Chang 2007; Tian and Hua 2021) can contribute to any detectable beany flavor in the produced tofu.

Three lines had a reasonably soft tofu texture, namely Tgm/Anj-888, Tgm/Anj-933, and Tgm/Anj-844, which were similar to that of Tanggamus variety. Meanwhile, seven lines had a firm texture, which was identical to that of Wilis variety, and the remaining lines had a slightly firm texture, as also seen in the Grobogan and Anjasmoro varieties. These texture scores, which were manually observed by panelists, did not correlate with the hardness levels measured using the texture analyzer (Table 2). This might be due to differences in personal perceptions or preferences of tofu texture.

The colors of most deep-fried tofu were fairly liked by panelists, except for Tgm/Anj-957, which was slightly liked. This was in agreement with the colors of raw tofu that were also mostly liked by panelists. Deep-frying is a standard method for the preparation of tofu in Indonesia. Hence color is one of the essential attributes of consumer acceptance. A similar phenomenon was also observed for the aroma of tofu, which was entirely liked by panelists. A lower approval of the smell of raw tofu was detected in three lines (Table 4), but this was no longer exhibited once the tofu was fried. This suggests that the beany off-flavor had been eliminated during the deep-frying process through the denaturation of the lipoxygenase enzyme and evaporation of the beany flavor compounds (Yuan and Chang 2007).

Taste is the most important criteria for deep-fried tofu. Table 4 shows that the taste of tofu prepared from 14 lines was fairly liked, which was similar to those of the Grobogan and Anjasmoro varieties. Meanwhile, six lines had tofu taste scores similar to that of the Tanggamus variety (slightly liked), and panelists disliked the tofu prepared from Wilis variety. Variation in the chemical components of soybean lines/varieties, such as protein, fat, lipoxygenase, saponin, and flavonoids (Roland et al. 2011; Ma et al. 2015) that are associated with the palatability, and beany, chalky and bitter flavors of tofu, may contribute to such differences in taste acceptances. Yoo (2011) also noted differences in the texture, taste and overall acceptability of tofu due to soybean varieties.

Total scores for the color, aroma, and taste of deep-fried tofu prepared from Grobogan, Tanggamus and Anjasmoro ranged from 11.1 to 11.5, while they were lower for Wilis variety (9.7) as presented in Table 4. Nine lines had scores higher than those of three check varieties (11.6–12.3), four lines had similar scores (11.2–11.5), and seven lines had slightly lower scores (10.3–10.9). However, no single line had a total score more moderate than that of the Wilis variety. This demonstrates that about 13 soybean lines had similar or better color, aroma, and taste, compared to three check varieties.

Tanggamus, Anjasmoro, and Wilis varieties had a soft tofu texture, while Grobogan was slightly firm (Table 4). Among the 20 lines, tofu prepared from six lines had a smooth texture, while 14 lines were somewhat firm, which were similar to the Grobogan variety, no single line produced tofu with a firm texture. Tofu with a soft touch is usually preferred by the consumer, particularly in East Java.

Based on all criteria for both raw and deep-fried tofu, particularly color, texture and taste, no single check variety was fairly liked. Even though Tanggamus variety produced tofu with a fairly desired color and texture for both raw and deep-fried tofu, its taste was slightly disliked. Meanwhile, the color, flavor and texture of deep-fried tofu from Anjasmoro was fairly liked. Therefore, tofu prepared from Anjasmoro variety gave the most current sensorial scores in this study and was used as a reference for the 20 studied lines. Both the Tgm/Anj-908 and Tgm/Anj-991 lines had the highest total scores for color, aroma, and taste (Figure 2.A-B), however the texture of their raw and deep-fried tofu was slightly firm. This can be improved by increasing the bean to water ratio. Tgm/Anj-932, Tgm/Anj-995, Tgm/Anj-862, and Tgm/Anj-888 lines showed slightly lower taste scores, but the texture was softer. Tgm/Anj-888 line had similar total sensorial attribute scores to those of Anjasmoro variety, even higher than another five lines, suggesting its suitability for tofu ingredients (Figure 2.C). The Tgm/Anj-888, Tgm/Anj-862, Tgm/Anj-908, and Tgm/Anj-932 lines also produced tofu with a high yield recovery (217.79–234.49%) and in particular, the highest protein content was seen in Tgm/Anj-888 tofu (59.54% dw) as listed in Tables 2 and 3.

In conclusion, twenty promising soybean lines tolerant to acid soil varied in their physical and chemical characteristics, as well as their own tofu. One line, namely Tgm/Anj-995 belonged to large-seeded and comparable in size to that of Grobogan and Anjasmoro (check varieties). The Tgm/Anj-862, Tgm/Anj-856, Tgm/Anj-858, Tgm/Anj-909, and Tgm/Anj-888 lines showed higher protein contents (>40% dw) than those of four check varieties. However, there was no correlation between soybean seed protein content and yield recovery or tofu hardness in this study. Six lines, namely Tgm/Anj-908, Tgm/Anj-991, Tgm/Anj-932, Tgm/Anj-995, Tgm/Anj-862, and Tgm/Anj-888, were tailored for tofu ingredients with respect to their color, aroma, taste, and texture attributes, which were similar, and even more significant than those of Anjasmoro's tofu. This higher performance of soybean lines than their check varieties is essential for the selection and release of new varieties adapted to acid soil as supportive data for their superior agronomic performances.

Table 4. Sensorial attributes of raw and deep-fried tofu prepared from 24 soybean lines/varieties

Variety/line	Raw tofu [a]			Deep-fried tofu [a]				
	Color	Aroma	Texture [b]	Color	Aroma	Taste	Total scores	Texture [b]
Tgm/Anj-784	4.1 ± 0.3	3.6 ± 0.5	2.7 ± 0.5	3.7 ± 0.5	3.8 ± 0.4	3.7 ± 0.5	11.2 ± 0.5	2.9 ± 0.7
Tgm/Anj-832	3.7 ± 0.5	3.7 ± 0.7	3.1 ± 0.6	3.5 ± 0.5	3.5 ± 0.5	3.4 ± 0.5	10.5 ± 0.2	3.3 ± 0.5
Tgm/Anj-844	3.3 ± 0.7	3.5 ± 0.5	3.6 ± 0.5	3.9 ± 0.7	3.8 ± 0.6	3.8 ± 0.8	11.5 ± 0.2	2.8 ± 0.6
Tgm/Anj-847	4.0 ± 0.7	3.4 ± 0.5	2.9 ± 0.7	3.7 ± 0.7	3.8 ± 0.6	3.4 ± 0.7	10.9 ± 0.4	3.5 ± 0.5
Tgm/Anj-856	3.6 ± 0.7	3.3 ± 0.7	2.2 ± 0.6	3.5 ± 0.5	3.6 ± 0.5	3.3 ± 0.9	10.4 ± 0.5	3.3 ± 0.8
Tgm/Anj-857	3.7 ± 0.5	3.6 ± 0.5	2.9 ± 0.6	4.1 ± 0.6	3.9 ± 0.7	3.9 ± 0.7	11.9 ± 0.4	3.4 ± 0.7
Tgm/Anj-858	3.6 ± 0.5	3.6 ± 0.7	2.4 ± 0.7	3.9 ± 0.7	3.9 ± 0.7	3.8 ± 0.8	11.6 ± 0.6	3.2 ± 0.6
Tgm/Anj-862	3.5 ± 0.5	3.5 ± 0.5	2.9 ± 0.6	4.0 ± 0.7	4.1 ± 0.7	3.5 ± 0.5	11.6 ± 0.4	3.5 ± 0.5
Tgm/Anj-888	3.8 ± 0.6	3.5 ± 0.5	4.3 ± 0.7	3.8 ± 0.6	4.0 ± 0.5	3.7 ± 0.7	11.5 ± 0.3	3.5 ± 0.5
Tgm/Anj-889	3.7 ± 0.5	3.7 ± 0.7	1.7 ± 0.5	3.9 ± 0.6	4.0 ± 0.8	3.9 ± 0.7	11.8 ± 0.9	3.2 ± 0.8
Tgm/Anj-908	4.0 ± 0.7	3.8 ± 0.6	2.6 ± 0.5	4.1 ± 0.7	4.2 ± 0.8	4.0 ± 0.8	12.3 ± 0.6	3.2 ± 0.6
Tgm/Anj-909	3.9 ± 0.7	3.3 ± 0.5	2.4 ± 0.5	4.0 ± 0.7	4.0 ± 0.5	3.7 ± 0.7	11.7 ± 0.6	3.2 ± 0.8
Tgm/Anj-910	3.6 ± 0.5	3.5 ± 0.5	2.2 ± 0.6	3.6 ± 0.5	3.5 ± 0.5	3.2 ± 0.8	10.3 ± 0.5	3.3 ± 0.7
Tgm/Anj-919	3.5 ± 0.5	3.8 ± 0.6	2.0 ± 0.8	3.6 ± 0.5	3.8 ± 0.8	3.3 ± 0.7	10.7 ± 0.7	3.1 ± 0.3
Tgm/Anj-931	4.1 ± 0.6	3.8 ± 0.8	3.2 ± 0.6	3.9 ± 0.7	3.9 ± 0.7	3.6 ± 0.5	11.4 ± 0.3	3.4 ± 0.8
Tgm/Anj-932	4.2 ± 0.6	3.7 ± 0.7	2.5 ± 0.7	4.1 ± 0.6	4.2 ± 0.6	3.7 ± 0.7	12.0 ± 0.6	3.5 ± 0.5
Tgm/Anj-933	3.6 ± 0.5	3.8 ± 0.4	3.7 ± 0.7	3.5 ± 0.5	3.5 ± 0.5	3.6 ± 0.5	10.6 ± 0.1	3.8 ± 0.6
Tgm/Anj-957	3.9 ± 0.6	3.6 ± 0.5	2.0 ± 0.7	3.4 ± 0.5	3.7 ± 0.7	3.2 ± 0.8	10.3 ± 0.7	2.6 ± 0.8
Tgm/Anj-991	4.0 ± 0.7	3.8 ± 0.6	2.7 ± 0.9	4.0 ± 0.7	4.1 ± 0.6	4.1 ± 0.6	12.2 ± 0.5	2.8 ± 0.6
Tgm/Anj-995	3.8 ± 0.4	3.6 ± 0.5	3.4 ± 0.7	4.0 ± 0.7	4.1 ± 0.3	3.7 ± 0.5	11.8 ± 0.3	3.7 ± 0.5
Grobogan	3.9 ± 0.6	3.8 ± 0.6	2.7 ± 0.5	3.6 ± 0.7	3.9 ± 0.6	3.6 ± 0.5	11.1 ± 0.5	3.1 ± 0.7
Tanggamus	4.0 ± 0.5	4.0 ± 0.7	3.6 ± 0.5	4.0 ± 0.8	4.1 ± 0.6	3.3 ± 0.7	11.4 ± 0.3	3.7 ± 0.7
Anjasmoro	3.9 ± 0.6	3.9 ± 0.7	2.7 ± 0.8	4.0 ± 0.7	4.0 ± 0.7	3.5 ± 0.5	11.5 ± 0.5	3.6 ± 0.8
Wilis	3.8 ± 0.6	3.9 ± 0.7	2.4 ± 0.8	3.6 ± 0.5	3.8 ± 0.8	2.3 ± 0.5	9.7 ± 0.7	3.5 ± 0.5

Note: Score: [a] Acceptance toward color, aroma, and taste: 1: Dislike very much, 2: Dislike moderately, 3: Like slightly, 4: Like moderately, 5: Like very much. [b] Texture: 1: Very firm, 2: Firm, 3 = Slightly firm, 4: Soft, 5: Very soft

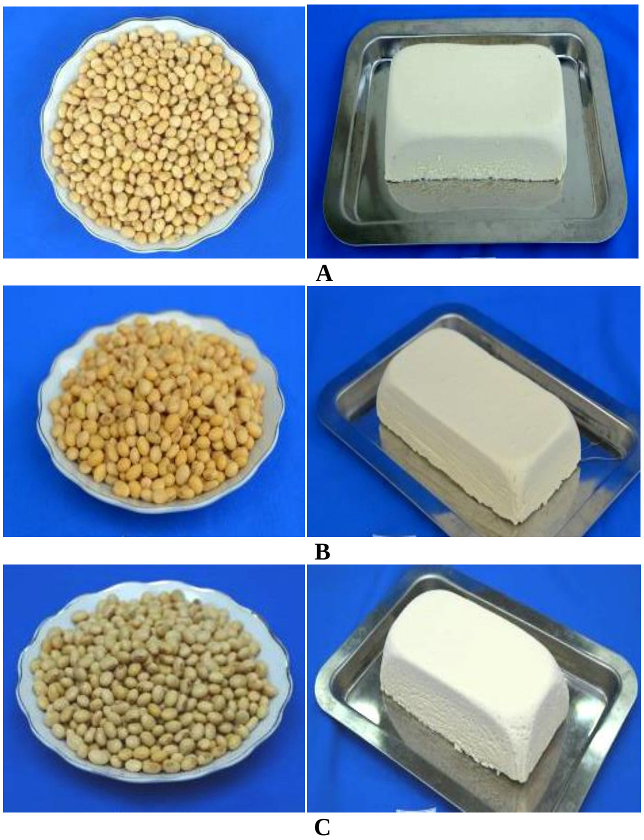

Figure 2. Soybean seed and its respective tofu: A. Tgm/Anj-908, B. Tgm/Anj-991, C. Tgm/Anj-888

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