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Physicochemical and sensory properties of tofu prepared from eight popular soybean [*Glycine max* (L.) Merrill] varieties in Ethiopia

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ABSTRACT

Variety is one of the major factors that influence food product making potential of soybeans. The present study was aimed to investigate the qualities of tofu prepared from eight popular soybean varieties in Ethiopia by analyzing the physicochemical properties and sensory qualities using the standard procedures. The result revealed that tofu yield was in the range of 123.35–134.03% with a significant difference among soybean varieties. The moisture, protein, fat, fiber and ash contents of tofu samples were ranged from 72.45–74.93%, 53.04–56.73%, 27.92–33.88%, 0.36–1.13% and 1.81–2.22%, respectively. Clark 63k, AFGAT, Awassa-95 and Wagayen varieties have gotten the highest overall acceptability by sensory evaluation. However, generally all the tofu samples have a good nutritional composition and fell within acceptable limits, indicating that the eight soybean varieties used in this study can be potentially used for cheese processing and substitute dairy products.

Introduction

Soybean (*Glycine max* (L.) Merrill) is one of the most important and multipurpose legume crops in the world. It is rich in protein and oil content with approximate value of 40% and 20%, respectively [23]. The crop has enormous uses; including nutritional and medicinal uses [15]. It has been used as food for a long in many Asian countries. In addition to nutrition, chemical components like isoflavones, lecithin, biopeptides and others have reported to provide protective effect against cardiovascular diseases, chronic cancer, type-2 diabetes and reduced menopausal discomfort in women [5].

Today, soybean foods such as tofu, soymilk, soymilk powder, bean sprouts, dried tofu, soy sauce, soy flour, tempeh and soybean oil have been prepared and used through traditional ways and using modern processing techniques in the world. Although soybean foods are well adapted in Asia, its consumption in other regions was insignificant. In Europe and North

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America, the soybean products have gradually gained popularity due to increased consumer awareness of their health benefits [11]. Recently, the value of soybean as a high-protein food source has been recognized in Sab-Saharan Africa as well. Consequently, the utilization and consumption of soybean-based foods are becoming popular essentially to solve the redundant malnutrition and stunting which is affecting around half of all the children in the area [13]. Although its use in Ethiopia is by far lower, it is considerably increasing [1].

Tofu is coagulated soymilk and consumed on a wet or dry basis. Dry tofu has high protein content (50%) and fat content (27%), and also contains sufficient amount of carbohydrates and minerals [18]. It is cholesterol free, lactose free, and lower in saturated fat. Tofu can be served as meat or cheese substitute in more economical, nutritious, and versatile way [16].

Texture and yield of tofu are important determinants of product acceptance by consumers and producers, respectively. Factors such as variety of soybean, processing method and type and concentration of coagulant have been reported to influence the yield, quality, and texture of tofu [21,24,25]. Bhardwaj et al. [2] and his colleagues have reported that the varietal differences in seed protein content, seed size and soymilk solids were a significant determinants of tofu yield.

In Ethiopia, 25 improved soybean varieties have been released at national level so far mainly with their yield and pest resistance merits [26]. Alongside, much effort has been made to improve their agronomic practices [12]. As a result, the area coverage and production of soybean have increased 10 fold (19,397 ha) and 21 fold (35,880 ton) in the past 10 years [9]. However, since there is a very limited value addition activities in the country, majority of soybean grain (1.4 million kg) are exported. On the other hand, Ethiopia imports soybean products that are by far higher than the volume of domestic production. This remarks the need for value addition activities and utilization of domestic production. To this regard, evaluating the product making quality of released soybean variety is prior attention. Therefore, the current study was aimed to investigate the physicochemical and sensory properties of tofu prepared from popular soybean varieties in Ethiopia.

Materials and methods

Materials

Eight popular soybean varieties (Gishama, Awassa-95, AFGAT, Tgx-13.3-2644, Nova, Belessa-95, Wegayen, and Clark 63k) were collected from Pawe Agricultural Research Center. Lemon fruits that used as a coagulant were obtained from Melkasa Agricultural Research Center. The experiment was conducted in food science and nutrition research laboratories of Ethiopian Institute of Agricultural Research.

Tofu preparation

Tofu is prepared as described by Shokunbi et al. [22]. Firstly, 200 g of soybean was taken for each variety and sorted out of debris and damaged seeds. The cleaned soybeans were washed, blanched for 10 min in boiling water, and soaked in 600 ml of tap water (soybean: water ratio 1:3, w/v) overnight at room temperature. Hydrated beans were drained, rinsed, and dehulled manually, then wet-milled using Philips blender (Model HR2094, China) with 1600 ml of hot water (soybean: water ratio 1:8, w/v). Then, the slurry was cooked with continuous stirring for 15 min and filtered using double layer cheese cloth to separate soymilk from insoluble residue called *okara*. The temperature of soymilk was lowered to 75 °C and then 100 ml of filtered lemon juice was added for 1000 ml of soymilk as a coagulant. Once stirred the mixture was kept until coagulated. Finally, the mixtures were poured over muslin cloth and the liquid pressed out. Tofu yield, moisture content, and pH were determined on wet basis and the rest of the tofu samples were freeze dried and kept under refrigerated temperature for further analysis.

Determination of tofu yield

Tofu yield was calculated as the weight of fresh tofu obtained from the amount of the soybean used for its preparation.

$$\text{Yield of fresh tofu} = \frac{\text{weight of fresh tofu (g)}}{\text{weight of soybean (g)}} \times 100$$

Physicochemical analysis

The tofu samples were analyzed for moisture, total nitrogen, fat, fiber and total ash in triplicate using standard methods (AOAC (2010), as cited in [22]. The moisture content was determined by oven-drying at 105 °C (AOAC, 967.08). The total nitrogen content was determined by the Kjeldahl method and the conversion factor 6.25 was used to convert into percent crude protein. The crude fat content was determined by continuous extraction in a Soxhlet apparatus using hexane as solvent (AOAC, 2003.06). To determine dietary fiber, defatted tofu samples were digested in diluted (1.25%) sulphuric acid solution for 30 min at boiling point followed by digestion with 1.25% sodium hydroxide solution for the same duration (AOAC, 958.06). The total ash content was evaluated by the gravimetric method of incineration in a muffle furnace at 550 °C (AOAC, 942.05). The pH of the tofu was determined with a calibrated digital pH meter (Model3020, Jenway). About 10 g of fresh tofu sample was taken and mixed with 10 ml of distilled water in the ratio of 1:1, and then pH value was measured.

Table 1
The yield and physicochemical compositions of tofu resulted from popular soybean varieties in Ethiopia.

Treatments	Tofu yield (%)	Moisture content (%wb)	Crude protein (%db)	Crude fat (%db)	Crude fiber (%db)	Total ash (%db)	pH
Gishama	127.25 ± 1.65^{b}	73.57 ± 0.52^{bc}	55.43 ± 1.92^{abcd}	31.47 ± 1.50^{bc}	0.98 ± 0.03^{b}	2.02 ± 0.13^{abc}	3.93 ± 0.04^{c}
Awassa-95	125.08 ± 0.54^{b}	72.79 ± 0.92^{bc}	56.25 ± 1.03^{ab}	30.47 ± 0.86^{c}	0.77 ± 0.01^{cd}	2.06 ± 0.11^{abc}	4.11 ± 0.02^{b}
AFGAT	128.73 ± 1.83^{ab}	73.83 ± 0.04^{ab}	56.73 ± 2.93^{a}	27.92 ± 0.39^{d}	0.54 ± 0.01^{f}	2.06 ± 0.03^{abc}	4.04 ± 0.02^{bc}
Tgx-13.3-2644	123.79 ± 2.80^{b}	74.93 ± 0.12^{a}	53.49 ± 0.80^{cd}	31.81 ± 0.71^{bc}	0.58 ± 0.01^{e}	1.93 ± 0.11^{bc}	4.14 ± 0.02^{b}
Nova	134.03 ± 4.16^{a}	72.97 ± 0.17^{bc}	53.04 ± 0.77^{d}	33.88 ± 0.24^{a}	0.74 ± 0.01^{d}	1.91 ± 0.03^{bc}	4.11 ± 0.11^{b}
Belessa-95	123.35 ± 2.79^{b}	73.77 ± 0.58^{ab}	54.27 ± 0.85^{bcd}	32.68 ± 0.75^{ab}	1.13 ± 0.01^{a}	1.81 ± 0.04^{c}	4.07 ± 0.05^{b}
Wegayen	127.05 ± 1.28^{b}	73.20 ± 0.56^{bc}	55.28 ± 0.13^{abcd}	31.06 ± 0.23^{c}	0.36 ± 0.01^{g}	2.14 ± 0.11^{ab}	4.13 ± 0.06^{b}
Clark-63k	127.16 ± 4.05^{b}	72.45 ± 0.70^{c}	55.77 ± 0.14^{abc}	31.23 ± 0.89^{c}	0.78 ± 0.01^{c}	2.22 ± 0.19^{a}	4.27 ± 0.02^{a}
Mean	127.05	73.44	55.03	31.32	0.73	2.02	4.10
CV (%)	2.08	0.74	2.51	2.55	2.10	5.29	1.29
LSD (α 0.05)	6.08	1.25	2.39	1.38	0.04	0.25	0.12

Data (mean + SD); means with the same letter in a column are not significantly different.

Sensory evaluation

The sensory analysis of tofu sample was conducted using five-point hedonic scale, where 5 stands for like very much and 1 for dislike too much. Thirty untrained panelists composed of males and females who were familiar with tofu were evaluated the samples in terms of color, flavor, taste, texture, and overall acceptability [14].

Experimental design and analysis

The experiment was carried out in triplicates for all the measured parameters. Complete randomized design and randomized complete block design were employed to study the physicochemical compositions and the sensory acceptability of tofu samples, respectively. Data were statistically analyzed using SAS software version 9.2, GLM procedure and the result was expressed as means ± standard deviation. Statistical differences between means ($p < 0.05$) were tested by Fischer's least significant differences (LSD).

Results and discussion

The result revealed that there were statistically significant differences ($p = 0.05$) among soybean varieties in tofu yield, moisture content, crude protein, crude fat, crude fiber, total ash and pH (Table 1). The tofu yield was ranged from 123.35% to 134.03% with the highest from Nova (134.04%) followed by AFGAT (128.73%) and the lowest from Belessa-95 (123.35%). This result is in line with the report of Gartaula et al. [8] which was 126.61 ± 4.055% for calcium chloride coagulated tofu, 146.661 ± 3.775% for calcium sulphate coagulated tofu, and 147.30 ± 6.34% for lemon juice coagulated tofu. Dzikunoo et al. [6] also reported a yield of 104.95% for citric acid coagulated tofu. This indicates that the average tofu yield (127.055%) obtained in this study was comparable with tofu yields reported by other scholars. On the other hand, the significant difference observed in the tofu yield is perhaps partly related to the difference of soybean varieties in seed size. Nova has a higher seed size than the seven soybean varieties used in this study (PARC, unpublished).

The moisture content of tofu sample was varied from 72.45% (Tgx-13.3-264) to 74.93% (Clark 63k) with the average of 73.44%. The result agrees with Gartaula et al. [8] who reported the moisture content of 71.88 ± 0.96% for lemon juice coagulated tofu. Reyhaneh et al. [21] also demonstrated a moisture content of 86.75 ± 0.16% and 85.98 ± 0.33% for calcium sulfate and *Withania coagulans* extract coagulated tofu's, respectively. Many investigations have proved that the moisture content of tofu could be affected by various factors off which the type of coagulant and concentration used are the major [4,20–22,24].

The highest value of crude protein content was recorded from AFGAT (56.73 ± 2.93%) followed by Clark-63k (55.77 ± 0.14), Wegayen (55.28 ± 0.13) and Awassa-95 (55.26 ± 1.03), while the lowest value was recorded from Nova (53.04 ± 0.77%). The result of the current investigation was in accordance with the findings of Reyhaneh et al. [21] which were 52.70 ± 1.41% for calcium sulfate coagulated tofu and 52.25 ± 1.53% for *Withania coagulans* extract coagulated tofu. Similarly, Gartaula et al. [8] have reported 51.58 ± 0.69% crude protein value for lemon juice coagulated tofu.

The crude fat content was ranged from 33.88% (Nova) to 27.92% (AFGAT). The crude fat content reported in this finding was higher than 28.73 ± 0.63% (calcium sulfate coagulated tofu), 28.44 ± 0.81% (*Withania coagulans* extract coagulated tofu) and 13.45 ± 0.02% (lemon juice coagulated tofu) reported by Reyhaneh et al. [21] and Gartaula et al. [8], respectively.

The tofu resulted from Belessa-95 had the highest crude fiber value (1.13%) and tofu prepared from Wegayen had the least crude fiber value (0.36%). The value is argued by the report of Ifesan and Oguntoyinbo [10] for tofu obtained from blends of soybean and sesame seed (1.03 ± 0.11).

Like other physicochemical parameters, the total ash value of tofu was significantly different among soybean varieties with the range from 1.81% (Belessa-95)–2.22% (Clark 63k). The remaining varieties were statistically not different from Clark

Table 2
Correlation analysis of yield and physicochemical compositions of tofu prepared from popular soybean varieties in Ethiopia.

	Tofu yield (%)	Moisture content (%wb)	Crude protein (%db)	Crude fat (%db)	Crude fiber (%db)	Total Ash (%db)
Tofu yield (%)	1					
Moisture content (%wb)	−0.411048971	1				
Crude protein (%db)	−0.175506845	−0.349458815	1			
Crude fat (%db)	0.17633193	−0.066875538	−0.86492786[a]	1		
Crude fiber (%db)	−0.21780786	−0.093712591	−0.143057161	0.415463977	1	
Total ash (%db)	0.100380922	−0.544918541[a]	0.669735302[a]	−0.518836582[a]	−0.493614931	1

[a] Significant correlation.

Table 3
Correlation analysis of sensory evaluation.

	Color	Flavor	Taste	Texture	Overall acceptability
Color	1				
Flavor	0.7462[a]	1			
Taste	0.4716	0.5917[a]	1		
Texture	−0.0069	0.0819	0.6713[a]	1	
Overall acceptability	0.3137	0.0504	0.5133[a]	0.4911	1

[a] Significant correlation.

Table 4
Characteristics and ecological adaptation of soybean varieties in Ethiopia.

Variety	Maturity	Yield (kg ha^{-1})	Seed size[a]	Oil content (%)	Altitude (m.a.s.l)	Year of release
Gishama	Medium	1765.9	Medium	22.1	520–1800	2010
Awassa-95	Early	1688.2	Small	20.6	520–1800	2005
AFGAT	Medium	1893.1	Medium	21.7	750–1800	2007
Tgx–13.3–2644	Late	1582.1	Medium	21.9	1200–1900	2007
Nova	Early	1058.1	Large	21.7	1200–1700	2012
Belessa-95	Late	1677.5	Medium	23.4	520–1800	2003
Wegayen	Late	1411.1	Large	22.2	520–1800	2010
Clark-63k	Medium	2102.6	Medium	22.7	1300–1800	1981

Source: Modified from Tesfaye et al. [26].
[a] PARC.

63k by total ash except Belessa-95. However, the value was lower compared to the one reported by Gartaula et al. [8] and [19] which was 3.15 ± 0.05% and 3.52 ± 0.17%, respectively.

Correlation analysis of the yield and physicochemical properties of tofu showed a positive correlation between crude protein and total ash content. However, both crude protein and total ash content were negatively correlated to crude fat content indicating that the protein and total ash content increases as fat content decreases and vice versa (Table 2). Accordingly, the higher in crude protein and total ash content is the lower in crude fat content, and vice versa (Table 1). Similarly, Filho et al. [7] had reported the negative correlation between protein and oil content of soybean. In fact, the released soybean varieties in Ethiopia have been showed increasing trend in protein content and declining trend in oil content [26]. Pawe 03 – the most recently released soybean variety with superiority both in protein content (42%) and oil content (23.6%) is exceptional and the best compromising variety [17].

The sensory result of tofu shows statistically significant difference among soybean varieties in taste, texture, and overall acceptability and non-significant difference in color and flavor ($P = 0.05$) (Fig. 1). The Combined effect of tofu sensory parameter scores was recorded as overall acceptability. Accordingly, Clark-63k has gotten the highest overall acceptability score (4.17) followed by AFGAT (3.93), Wegayen (3.90), and Awassa-95 (3.87). On the other hand, the lowest overall acceptability score was given for Balassa-95 (3.60) and it was statistically similar to the remaining test varieties. A significant positive correlation was observed between overall acceptability and taste as well as between texture and taste (Table 3).

In summary, the resulted tofu from all tested soybean varieties in the current study falls within acceptable limits, indicating cheese making potential. The difference in yield and physicochemical properties is resulted from the varietal differences; they vary in maturity, oil content and others (Table 4). As Bhardwaj et al. [3] had reported earlier, soybean seed size is the most determinant of tofu yield: the larger seed size the larger will be tofu yield. However, tofu quality is more relevant than quantity for consumers and it often contrasts each other. In this study, for instance, the variety that gave the highest tofu yield (Nova) has gotten the lowest overall acceptability by sensory evaluation. On the other hand, Clark-63k, AFGAT, Awassa-95, and Wegayen – those having a higher protein and total ash content have gotten the highest overall acceptability by sensory evaluation. The overall acceptability is highly related to texture and taste of the tofu. More specifically, both

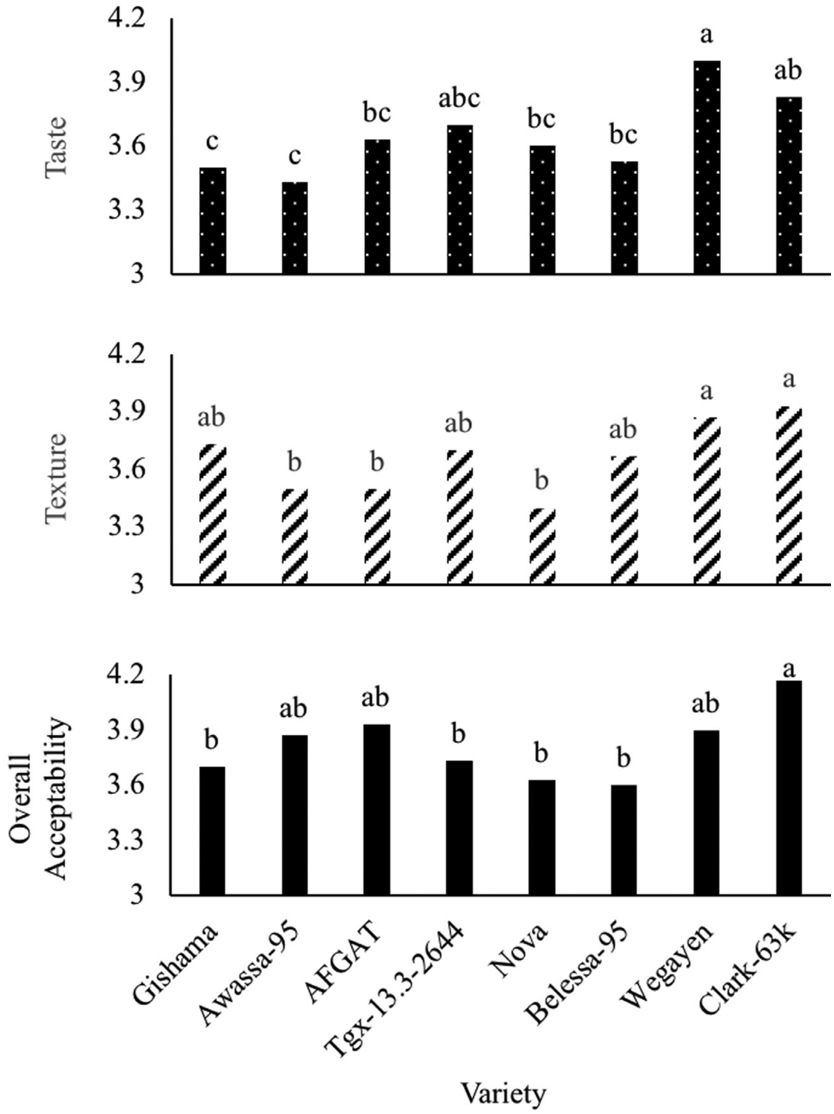

Fig. 1. Sensory result of tofu prepared from popular soybean varieties in Ethiopia. The letters on the bars indicate mean separation among soybean varieties at $p < 0.05$.

Clark-63k and Wegayen have gotten the highest score for tofu texture and taste. Indeed, the firmer tofu texture is achieved by a high protein content of the varieties [27]. Fortunately, except Awassa-95, all these varieties possess medium-to-larger seed size which is one of the preferred traits by processing industries.

Conclusions

The present study investigated the physicochemical properties and sensory qualities of tofu samples prepared from eight popular soybean varieties in Ethiopia. Physicochemical properties and sensory quality of tofu was significantly ($p < 0.05$) varied among soybean varieties. In general, all the tofu samples had good nutritional composition and fell within acceptable limits, indicating that the eight soybean varieties used in this study can potentially be used for cheese processing and, thus, substitution of dairy products.

Declaration of Competing Interest

We, the authors would like to declare that there is no conflict of interest regarding the publication of this article.

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