



Evaluation of Physicochemical, Functional, and Anti-nutritional Properties of Soya Bean Varieties

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Authors' contributions

This work was carried out in collaboration among all authors. Author MDA conceived the study, contributed to the study design, performed the analysis, and wrote the manuscript. Authors AMA, SMH, and AGO contributed data duration and visualization. Author MDA reviewed and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Background: Soybean (*Glycine max*) is an essential leguminous crop, highly valued for its nutritional and economic benefits. In Ethiopia, it holds promise for addressing malnutrition and food insecurity. This study assesses the physicochemical, functional, and anti-nutritional properties of various soybean varieties cultivated at two research centers and local markets.

Methodology: Soybean seeds were collected from Kelafo and Dolo-Ado Research Centers, along with local varieties from markets in Gode and Jigjiga. The seeds were cleaned, sun-dried, and

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milled into flour for analysis. Physical properties, such as seed weight and bulk density, were measured, while functional properties, including water absorption capacity (WAC) and oil absorption capacity (OAC), were evaluated. Anti-nutritional factors like tannins and phytates were quantified, and statistical analyses were performed using GenStat.

Results: D-Pawa 2 showed the highest seed weight, ideal for food processing applications, while L-Gode had the lowest. Bulk density ranged from 0.766 to 0.683 g/ml, with L-Gode exhibiting the highest, which is advantageous for storage and handling. K-Gizo displayed the highest WAC (2.532 g/g), suited for products needing water retention, while K-Pawa 2 had the lowest. Both K-Gizo and K-Pawa 2 exhibited high OAC. Local varieties had higher tannin and phytate concentrations, affecting protein digestibility and mineral absorption.

Conclusion: This study emphasizes selecting soybean varieties based on physicochemical and functional properties for food processing. Local varieties, despite their nutritional potential, require proper processing methods to reduce anti-nutritional factors and enhance their utility. These findings contribute to promoting soybean use and improving nutrition and food security in Ethiopia.

Keywords: Soybean; physicochemical properties; functional properties; anti-nutritional factors.

1. INTRODUCTION

Soybean (*Glycine max*) is a leguminous crop known for its high nutritional value and economic significance. It served as a rich source of protein, essential amino acids, vitamins, and minerals, making it a vital component of both human diets and livestock feed. Globally, soybean cultivation expanded due to its versatility in food production, industrial uses, and its role in improving soil fertility through nitrogen fixation. Consequently, soybeans became one of the most important crops in the global agricultural system [1].

In developing countries, particularly in sub-Saharan Africa, soybean was increasingly recognized as a potential solution to malnutrition and food insecurity. Its ability to grow in diverse climates and soils, combined with its significant nutritional benefits, made it an appealing crop for both farmers and policymakers [2]. In Ethiopia, the promotion of soybean production supported food security initiatives, enhanced the nutritional status of the population, and contributed to the agricultural economy [3].

However, the quality of soybean products varied considerably depending on the variety and environmental conditions in which they were grown. The physicochemical properties—such as moisture content, fat, protein, and carbohydrate levels—played a critical role in determining the processing and nutritional quality of soybeans [4]. Additionally, functional properties like water absorption capacity and oil retention were essential for industrial and food applications [5].

Another significant factor affecting soybean quality was the presence of anti-nutritional

compounds, including phytates, tannins, and trypsin inhibitors, which could reduce nutrient bioavailability. These compounds, although naturally occurring, varied across soybean varieties and were influenced by environmental factors such as soil fertility and climate [6].

This study aimed to evaluate the physicochemical, functional, and anti-nutritional properties of different soybean varieties cultivated at two research centers. By examining these properties, the study provided valuable insights into the nutritional potential of selected varieties and identified those most suitable for food and industrial applications in the Somali region and Ethiopia in general. This research contributed to enhancing the use of soybeans as both a nutritional and economic resource for the country.

2. METHODS AND MATERIALS

2.1 Sample Collection and Preparation

Mature soybean seeds were obtained from the Kelafo and Dolo-Ado Research Centers, while two local varieties were purchased from markets in Gode and Jigjiga cities, located in the Somali Regional State of Ethiopia. The seeds were cleaned to remove foreign materials, damaged seeds, and those with insect infestations. Afterward, they were washed with tap water and sun-dried for 8 hours to eliminate any moisture absorbed during washing. Once dried, the seeds were milled into flour, packed in airtight polyethylene bags, and stored at 4°C for further analysis.

2.2 Determination of Physical Properties

2.2.1 Bulk density and seed weight

a) Seed Weight

One hundred soybean kernels were randomly selected and weighed individually. To analyze the length-to-breadth ratio, the cumulative measurements of the soybeans were taken in millimeters (n=10), and the L/B ratio was recorded by dividing the length by the breadth.

$$\text{Seed Weigh} = \frac{\text{Total weight of seed (g)}}{\text{Number of Seed}} \times 100 \dots \text{eq. 1}$$

b) Bulk Density

For bulk density, 50 g of soybean grains were weighed and dropped into a graduated glass measuring cylinder from a constant height of approximately 30 cm. The volume occupied by the soybean samples was recorded, and bulk density was calculated as the ratio of weight (g) to volume (ml).

$$\text{Bulk Density} = \frac{\text{Weight of soybean seeds (g)}}{\text{Volume occupied (cm}^3\text{)}} \dots \text{eq. 2}$$

2.3 Determination of Functional Properties

The water absorption capacity and oil absorption capacity were determined at 25°C using the method described by Yamazaki (1953) and modified by Medcalf and Gilles (1965).

2.3.1 Water Absorption Capacity

The water absorption capacity (WAC) was determined according to the method described by Guzmán et al. [7]. WAC was calculated using the following formula:

$$\text{WAC (\%)} = \frac{\text{weight of water bound}}{\text{weight of sample (dry basis)}} \times 100 \dots \text{eq. 3}$$

2.3.2 Oil absorption capacity

The water absorption capacity (WAC) was determined according to the method outlined by Guzmán et al. [7]. The WAC was calculated using the following formula:

$$\text{OAC (\%)} = \frac{\text{weight of water bound}}{\text{weight of sample (dry basis)}} \times 100 \dots \text{eq. 4}$$

2.4 Determination of Anti-Nutritional Factors

2.4.1 Determination of phytate

Phytic acid content was determined following the method by Wheeler and Ferrel. Two grams of milled dried sample were mixed with 50 mL of 3% trichloroacetic acid (TCA) and shaken for 3 hours. The mixture was centrifuged, and 10 mL of the supernatant was combined with 4 mL of FeCl₃ solution and heated for 45 minutes. After cooling, the precipitate was washed several times with TCA and water, then dissolved in 40 mL of hot 3.2 N HNO₃. A standard curve of Fe(NO₃)₂ concentrations was plotted to calculate the ferric ion concentration.

$$\text{Phytic acid (\%)} = \frac{X \times 1.19}{2} \times 100 \dots \text{eq. 5}$$

Where X = Titre value x 0.00195

2.4.2 Determination of tannin

Tannin quantification was conducted using the modified vanillin-HCl method. The vanillin-HCl reagent was prepared by mixing equal volumes of 8% HCl in methanol and 1% vanillin. Catechin was used to create a standard curve by dissolving 100 mg in 50 mL of 1% HCl in methanol. Absorbance was measured at 500 nm after adding 5 mL of reagent to each dilution. A 0.2 g sample in 10 mL of 1% HCl/methanol was also analyzed for tannin concentration.

$$\text{CE (\%)} = \frac{C \times 10}{200} \times 100 \dots \text{eq. 6}$$

Where: CE = Concentration corresponding to the optical density, C = Concentration, 10 = Volume of extract (ml), 200 = Sample weight (mg).

2.5 Statistical Analysis

All analyses were conducted in duplicate (unless otherwise specified) and presented as mean ± standard deviation. The statistical significance of the obtained data was analyzed and modeled using GenStat version 18, with a significance level set at a probability of p < 0.05.

3. RESULTS AND DISCUSSION

3.1 Physical Properties of Soya Bean

The 100-seed weight and bulk density of the soybean varieties exhibited significant variation.

Seed weight ranged from a minimum of 7.00% in L-Gode to a maximum of 16.50% in D-Pawa 2, indicating that D-Pawa 2, with its larger seed size, is more suitable for food processing applications that require larger seeds. In contrast, L-Gode, with the smallest seed weight, maybe less ideal for such uses.

For bulk density, L-Jigjiga had the highest value at 0.7660 g/ml, suggesting superior handling, storage, and transport potential due to its compact nature. Conversely, D-Pawa 1 had the lowest bulk density at 0.6825 g/ml, which could negatively impact its efficiency in these areas. These results highlight the role of genetic and environmental factors in shaping the physical properties of soybean varieties and their practical implications for food processing and industrial use. D-Pawa 2's higher seed weight suggests its suitability for applications requiring larger seeds, while L-Gode's lower seed weight may limit its use in specific contexts.

Bulk density ranged from 0.766 g/ml in L-Jigjiga to 0.683 g/ml in D-Pawa 1. Since bulk density is a key factor in determining grain storage, packaging, and transport, higher bulk density generally indicates better handling properties, making it favorable for food processing industries [4]. The variation in seed weight and bulk density is influenced by both genetic factors and environmental conditions, such as soil fertility and water availability [8].

3.2 Functional Properties of Soya Bean

The water absorption capacity (WAC) of the soybean varieties ranged from a minimum of 1.507% in K-Pawa 2 to a maximum of 2.675% in K-Pawa 3. This variation suggests that K-Pawa 3 is more suitable for food products requiring high water retention, while K-Pawa 2 may be less ideal for such applications. For oil absorption capacity (OAC), the values ranged from a minimum of 0.863% in K-Pawa 2 to a maximum of 1.495% in K-Gizo. This indicates that K-Gizo has the highest potential for enhancing flavor and texture in food formulations, whereas K-Pawa 2 has the lowest capacity for oil retention.

Water absorption capacity (WAC) and oil absorption capacity (OAC) are essential functional properties for determining the suitability of soybean flour in various food applications, such as bakery products and meat substitutes. K-Gizo had the highest WAC (2.532

g/g), indicating its potential for use in products requiring high water retention, such as doughs and batters. The lower WAC of K-Pawa 2 suggests limited applications in such products. K-Gizo and K-Pawa 2 also demonstrated the highest OAC, which is beneficial for enhancing flavor retention and improving texture in food formulations. However, no significant differences in OAC were observed among the varieties, which is consistent with previous studies on soybean functional properties [9]. Functional properties are influenced by factors such as protein content, particle size, and processing methods [7].

3.3 Anti-Nutritional Factors of Soya Bean

The analysis of tannins and phytates across the soybean varieties revealed significant differences. Tannin content ranged from a low of 0.121% in D-Pawa 2 to a high of 6.660% in L-Jigjiga. The substantially higher tannin levels in L-Jigjiga suggest potential challenges in protein digestibility and mineral absorption due to the binding properties of tannins, while D-Pawa 2, with its low tannin content, may pose fewer anti-nutritional concerns. Phytate content ranged from 2.317% in D-Gizo to 4.861% in D-Pawa 2. Elevated phytate levels, as observed in D-Pawa 2, can impair the absorption of minerals, particularly calcium and iron. In contrast, the lower phytate content in D-Gizo may minimize these effects, making it more suitable for nutritional purposes.

The anti-nutritional content, including tannins and phytates, varied significantly among the soybean varieties. Local varieties exhibited higher tannin concentrations, which could negatively affect protein digestibility and mineral absorption [6]. However, adopted varieties, particularly those from the SoRPARI Center, had lower tannin levels, with D-Pawa 2 showing a higher concentration of anti-nutritional compounds compared to D-Gizo. Polyphenols, like tannins, are known to bind with proteins and minerals, reducing their bioavailability [10]. Phytate content, which also affects mineral absorption, was significantly higher in the local varieties compared to the adopted varieties. These findings suggest that, although local varieties may be nutritionally dense, their high anti-nutritional factor content could limit their utilization without proper processing methods, such as soaking, fermentation, or heat treatment [11].

Table 1. Physical properties of soya bean

Varieties	Parameters	
	Seed Weight %	Bulk density %
D-Gezale	15.75 ± 0.24a	0.7635 ± 0.00a
D-Gizo	10.75 ± 0.25bc	0.7115 ± 0.00cd
D-Pawa 1	14.50 ± 0.22 a	0.6825 ± 0.03f
D-Pawa 2	16.50 ± 0.23a	0.7195 ± 0.01bcd
D-Pawa 3	11.50 ± 0.25b	0.7170 ± 0.20bcd
K-Gezale	10.50 ± 0.05bc	0.7255 ± 0.01bc
K-Gizo	11.50 ± 0.21b	0.7020 ± 0.10de
K-Pawa 1	11.00 ± 0.20b	0.7345 ± 0.00b
K-Pawa 2	11.75 ± 0.02b	0.7145 ± 0.01 cd
K-Pawa 3	8.28 ± 0.01cd	0.7170 ± 0.01bcd
L-Gode	7.00 ± 0.03d	0.763 ± 0.01a
L-Jigjiga	7.50 ± 0.03d	0.7660 ± 0.00a
G. Mean	11.38	0.719
CV (%)	5.1	0.6
LSD (%)	1.25	0.01

All values are the means expressed on a dry matter basis ± standard error. Means with the same superscripts do not differ significantly ($P < 0.05$) G=grand D=Dolo-Ado, K=Kelafo, L-local CV=Coefficient of Variation, LSD=Least Significance Difference

Table 2. Functional properties of soya bean

Varieties	Parameters	
	WAC (%)	AOC (%)
D-Gezale	1.670 ± 0.10cd	1.038 ± 0.18a
D-Gizo	2.350 ± 0.19abc	1.183 ± 0.00a
D-Pawa 1	2.077 ± 0.16abcd	1.438 ± 0.06a
D-Pawa 2	1.700 ± 0.04cd	1.093 ± 0.17a
D-Pawa 3	1.638 ± 0.06cd	1.008 ± 0.02a
K-Gezale	2.077 ± 0.00abcd	1.060 ± 0.08a
K-Gizo	2.532 ± 0.05ab	1.495 ± 0.03a
K-Pawa 1	1.998 ± 0.06abcd	1.245 ± 0.31a
K-Pawa 2	1.507 ± 0.42d	0.863 ± 0.26a
K-Pawa 3	2.675 ± 0.23a	1.085 ± 0.26a
L-Gode	1.585 ± 0.13d	0.870 ± 0.08a
L-Jigjiga	1.890 ± 0.50bcd	1.390 ± 0.31a
G. Mean	1.975	1.147
CV (%)	15.7	22.5
LSD (%)	0.68	0.26

All values are the means expressed on a dry matter basis ± standard error. Means with the same superscripts do not differ significantly ($P < 0.05$) G=grand D=Dolo-Ado, K=Kelafo, L-local CV=Coefficient of Variation, LSD=Least Significance Difference

Table 3. Anti-Nutritional Factors of soya bean

Varieties	Parameters	
	Tannins (%)	Phytates (%)
D-Gezale	0.148 ± 0.01d	3.348 ± 0.13bc
D-Gizo	0.228 ± 0.04cd	2.317 ± 0.0.23d
D-Pawa 1	0.180 ± 0.04d	3.236 ± 0.00bcd
D-Pawa 2	0.121 ± 0.03d	4.861 ± 0.22a
D-Pawa 3	0.169 ± 0.01d	4.045 ± 0.13ab
K-Gezale	0.260 ± 0.13cd	2.659 ± 0.35cd
K-Gizo	0.285 ± 0.04cd	3.463 ± 0.01bc

Varieties	Parameters	
	Tannins (%)	Phytates (%)
K-Pawa 1	0.398 ± 0.09c	3.353 ± 0.10bc
K-Pawa 2	0.164 ± 0.03d	2.777 ± 0.24cd
K-Pawa 3	0.239 ± 0.04cd	4.279 ± 0.82ab
L-Gode	4.179 ± 0.11b	3.468 ± 0.23bc
L-Jigjiga	6.660 ± 0.02a	3.931 ± 0.23ab
G. Mean	1.086	3.478
CV (%)	8.1	12.3
LSD (%)	0.19	0.93

All values are the means expressed on a dry matter basis ± standard error. Means with the same superscripts do not differ significantly ($P < 0.05$) G=grand D=Dolo-Ado, K=Kelafo, L-local CV=Coefficient of Variation, LSD=Least Significance Difference

4. CONCLUSION

This study evaluated the physical, functional, and anti-nutritional properties of various soybean varieties cultivated in two research centers. The results revealed significant differences among the varieties in terms of seed weight, bulk density, water, and oil absorption capacities, as well as anti-nutritional factors such as tannins and phytates. D-Pawa 2 exhibited the highest seed weight, while K-Gizo showed superior functional properties, particularly in water and oil absorption. Local varieties were found to have higher concentrations of anti-nutritional factors, potentially affecting their nutritional value.

These findings emphasize the importance of selecting soybean varieties with optimal physical and functional properties, while minimizing anti-nutritional factors, to enhance both food production and nutritional benefits in Ethiopia. Proper processing techniques can also mitigate the effects of anti-nutritional compounds, ensuring better utilization of these soybean varieties in food and industrial applications.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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ETHICS APPROVAL

This study was conducted following ethical standards and received approval from the

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COMPETING INTERESTS

The authors have declared that no competing interests exist.

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