Original Research Article

Evaluation of Physicochemical, Functional, and Anti-Nutritional Properties of Soya Bean Varieties in Two Research Centers

ABSTRACT

Background: Soybean (Glycine max) is a vital leguminous crop known for its high nutritional value and economic significance. Its cultivation is expanding globally, especially in developing countries like Ethiopia, where it is recognized as a potential solution to malnutrition and food insecurity. This study aims to evaluate the physicochemical, functional, and anti-nutritional properties of different soybean varieties grown at two research centers in Ethiopia.
Methodology: Mature soybean seeds were collected from the Kelafo and Dolo-Ado Research Centers, alongside two local varieties purchased from markets in Gode and Jigjiga cities. The seeds were cleaned, sun-dried, and milled into flour for analysis. Physical properties, including seed weight and bulk density, were measured. Functional properties, such as water absorption capacity (WAC) and oil absorption capacity (OAC), were assessed using standardized methods. Anti-nutritional factors, specifically tannins and phytates, were quantified using appropriate biochemical techniques. Statistical analyses were performed using GenStat version 18.
Results: The evaluation revealed significant seed weight and bulk density variations among the soybean varieties. D-Pawa 2 exhibited the highest seed weight, while L-Gode had the lowest. K-Gizo demonstrated the highest WAC (2.532 g/g) and OAC, suggesting its suitability for various food applications. The anti-nutritional analysis indicated that local varieties had higher tannin and phytate concentrations than adopted varieties, particularly with D-Pawa 2 exhibiting elevated levels of anti-nutritional compounds.
Conclusion: The findings of this study highlight the importance of selecting soybean varieties based on their physicochemical and functional properties for food processing applications. Although local varieties may possess high nutritional content, their elevated anti-nutritional factors necessitate proper processing techniques to enhance their utilization. These insights contribute to promoting soybean cultivation and improving nutritional 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 (Hartman et al., 2011).

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 (Engelbrecht, 2017). In Ethiopia, the promotion of soybean production supported food security initiatives, enhanced the nutritional status of the population, and contributed to the agricultural economy (Achamyelh et al., 2020).

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 (Karr-Lilienthal et al., 2020). Additionally, functional properties like water absorption capacity and oil retention were essential for industrial and food applications (Godswill et al., 2019).

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 (Liener et al., 1994).

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. METHOD 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.

$$\text{Seed Weigh} = \frac{Total\ weight\ of\ seed\ (g)}{Number\ of\ Seed} x100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ eq.1$$

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).

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

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. (2015). WAC was calculated using the following formula:

$$WAC\ (\%) = \frac{weight\ oF\ water\ bound}{weight\ of\ sample\ (dry\ basis)} x100 \ldots \ldots \ldots \ldots \ldots \ldots \ldots eq.3$$

2.3.2. Oil Absorption Capacity

The water absorption capacity (WAC) was determined according to the method outlined by Guzmán et al. (2015). The WAC was calculated using the following formula:

$$OAC\ (\%) = \frac{weight\ oF\ water\ bound}{weight\ of\ sample\ (dry\ basis)} x100 \ldots \ldots \ldots \ldots \ldots \ldots \ldots eq.4$$

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 $FeCl_3$ 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 HNO_3. A standard curve of $Fe(NO_3)_2$ concentrations was plotted to calculate the ferric ion concentration.

$$\text{Phytic acid}(\%) = \frac{X * 1.19}{2} x100 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . \ldots \ldots eq.5$$

Where$X$=Titrevalue x0.00195

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.

$$\text{CE}(\%) = \frac{C * 10}{200} x100 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . \ldots \ldots eq.6$$

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 $p < 0.05$.

C) RESULTS AND DISCUSSION

3.1.Physical Properties of Soya bean

The 100-seed weight and bulk density of the soybean varieties showed considerable variation. D-Pawa 2 had the highest seed weight, suggesting it may be more suitable for food processing applications where a larger seed size is preferred. In contrast, L-Gode had the lowest seed weight, which might influence its use in certain applications. The bulk density ranged from 0.766 to 0.683 g/ml, with L-Gode showing the highest value and D-Pawa 1 the lowest. Bulk density is a crucial factor in determining the storage, packaging, and transport of grains. Higher bulk density generally implies better-handling properties for food processing industries (Karr-Lilienthal et al., 2020). Variations in seed weight and bulk density are influenced by both genetic factors and environmental conditions, such as soil fertility and water availability (Faéet al., 2020).

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.

3.2.Functional Properties of Soya bean

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 (Jideani, 2020). Functional properties are influenced by factors such as protein content, particle size, and processing methods (Guzmán et al., 2015).

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.

3.3.Anti-Nutritional Factors of soya bean

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 (Liener et al., 1994). 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 (Singh,2023)). 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 (Haug &Lantzsch, 1983).

Table 1. 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
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.

D) 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.

E) REFERENCES

Achamyelh, K., & Hailemariam, M. (2020). Challenges and Opportunities of Soybean Marketing in Chewaka District, Ethiopia. Asian Journal of Economics, Business and Accounting, 13–22. https://doi.org/10.9734/ajeba/2020/v17i130250

Engelbrecht, G., Claassens, S., Mienie, C. M. S., &Fourie, H. (2020). South Africa: An Important Soybean Producer in Sub-Saharan Africa and the Quest for Managing Nematode Pests of the Crop. Agriculture, 10(6), 242. https://doi.org/10.3390/agriculture10060242

Godswill, A. C. (2019). Proximate composition and functional properties of different grain flour composites for industrial applications. International Journal of Food Sciences, 2(1), 43–64. https://doi.org/10.47604/ijf.1010

Hartman, G. L., West, E. D., & Herman, T. K. (2011). Crops that feed the World 2. Soybean—worldwide production, use, and constraints caused by pathogens and pests. Food Security, 3(1), 5–17. https://doi.org/10.1007/s12571-010-0108-x

Karr-Lilienthal, L. K., Grieshop, C. M., Merchen, N. R., Mahan, D. C., & Fahey, G. C. (2004). Chemical Composition and Protein Quality Comparisons of Soybeans and Soybean Meals from Five Leading Soybean-Producing Countries. Journal of Agricultural and Food Chemistry, 52(20), 6193–6199. https://doi.org/10.1021/jf049795+

Liener, I. E. (1994). Implications of antinutritional components in soybean foods. Critical Reviews in Food Science and Nutrition, 34(1), 31–67. https://doi.org/10.1080/10408399409527649

Jideani, V. A.. (2011). Functional Properties of Soybean Food Ingredients in Food Systems. Soybean - Biochemistry, Chemistry and Physiology. https://doi.org/10.5772/14668

Guzmán, C., Posadas-Romano, G., Hernández-Espinosa, N., Morales-Dorantes, A., &Peña, R. J. (2015). A new standard water absorption criteria based on solvent retention capacity (SRC) to determine dough mixing properties, viscoelasticity, and bread-making quality. Journal of Cereal Science, 66, 59–65. https://doi.org/10.1016/j.jcs.2015.10.009

Haug, W., &Lantzsch, H. (1983). Sensitive method for the rapid determination of phytate in cereals and cereal products. Journal of the Science of Food and Agriculture, 34(12), 1423–1426. Portico. https://doi.org/10.1002/jsfa.2740341217

Faé, G. S., Kemanian, A. R., Roth, G. W., White, C., & Watson, J. E. (2020). Soybean yield in relation to environmental and soil properties. European Journal of Agronomy, 118, 126070. https://doi.org/10.1016/j.eja.2020.126070

Singh, A. P. (2023). Nutritional Composition, Bioactive Compounds, and Phytochemicals of Wheat Grains. Wheat Science, 125–181. https://doi.org/10.1201/9781003307938-5