Proximate and Anti-Nutritional Analyses of Three Varieties (TGX1987-10F, TGX2018-1E, TGX2024-3E) of Soybeans (*Glycine Max* (L.) Merrill.)

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Abstract

Soybean is an important legume crop and a major source of nutrients in Nigeria. However, there is a need to compare some breeding lines for their nutritional qualities. This study evaluated the nutritional qualities of three soybean varieties (TGX1987-10F, TGX2018-1E, TGX2024-3E) as part of breeding lines undergoing genetic improvement at the Joseph Sarwuan Tarka University, Makurdi, Nigeria. The composition of soybeans was found to be dominated by carbohydrates (34.4%), followed by protein (24.44%), lipid (27.5%), moisture (6.2%), ash (4.5%), and fiber (3.3%). Among the varieties, TGX1987-10F exhibited the highest levels of carbohydrate, protein, and fiber. Conversely, TGX2024-3E displayed the highest moisture, ash, and lipid contents. TGX2018-1E occupied an intermediate position between the two varieties in terms of proximate values. There were no significant differences in the levels of anti-nutrients (cyanide and oxalate) among the varieties. However, phytic acid content varied significantly, with TGX2024-3E having the lowest amount and TGX1987-10F having the highest. Phytic acid showed a negative correlation with all nutrients except carbohydrate. These findings suggest that TGX1987-10F is the variety with the highest overall nutritional value, but it also has the highest level of phytic acid. Breeders should aim to improve the nutritional quality of soybean while also reducing anti-nutrients. This information is important for breeders and farmers who are working to ensure food abundance and quality.

Keywords: anti-nutrition; breeding; food security; nutrition; soybean

Type: Original Article

Received: 07 September 2023; Revised: 21 February 2024; Accepted for publication: 16 March 2024; Published online: 18 March 2024

1. Introduction

Soybean (*Glycine max*), also known as soya bean, is a species of legume native to East Asia. It is widely grown for its edible bean, which has numerous uses [1]. Soybeans have long been recognized as a plant food that is relatively high in protein compared to other plants [2]. While many leguminous crops provide some protein, soybean is the only readily available crop that provides an inexpensive and high-quality source of protein comparable to that found in poultry and swine diets [3,4]. As an important and inexpensive food crop, soybeans contain about 40% protein, 30% carbohydrates, excellent amounts of dietary fiber, vitamins, minerals, and 20% oil. This oil content makes soybeans second only to peanuts in terms of oil content among food legumes.

Like most plants, soybeans grow through distinct morphological stages as they develop from seeds into mature plants. They share a characteristic of many legumes: the ability to fix atmospheric nitrogen [1]. This annual leguminous crop is grown to provide food for humans, animal feed, and raw materials for various industries. The soybean seed itself is the richest in food value of all plant foods consumed worldwide. It is used in bread production as a component flour [5]. Leading infant food manufacturers in the country utilize soybeans due to their high nutritional value. In Nigeria, soybeans are consumed as soy milk, the leftover cake is used for livestock feed, and the flour is added to pap, a food for infants and children [6].

Soybeans are also processed into flour, and their oil finds use in local paint, cosmetics, and soap-making industries. Oil extracted from soybeans is very rich in essential fatty acids, such as linoleic and linolenic acids. Both are crucial for human health, as they help regulate blood pressure and facilitate the absorption of vital nutrients [7].

Soy protein has the potential to lower LDL (bad cholesterol) levels and decrease the risk of coronary heart disease (CHD). Even people with diabetes can receive significant health benefits from consuming soybeans [8].

However, despite the documented health benefits of soybean consumption, recent studies have raised concerns about some potential negative effects on animal and human health. Soybeans contain several naturally occurring compounds that may be toxic to humans and animals, including trypsin inhibitors (serine proteases found in the digestive system), phytic acid, lectins, hemagglutinins,

certain metalloproteins like soyatoxin, and other biological components. Some studies report high levels of protease inhibitors, particularly trypsin inhibitors, in legume seeds such as soybeans, with concentrations ranging from 1 to 5% of the total protein content [9].

This study aims to determine the nutritional values of three soybean varieties to address malnutrition in Nigeria. Soybeans are a documented staple food for weaned babies and nursing mothers. By identifying the variety with the most favorable nutritional profile, this study can guide consumer choices and inform recommendations for farmers. This will ultimately contribute to the country's food security by ensuring both quality and safety. The growing interest in plant protein as a food system ingredient globally highlights the importance of these proteins' functional characteristics [10].

The three new soybean varieties being investigated have unknown nutritional compositions. Therefore, it is crucial to determine their nutrient and anti-nutrient content to assess their suitability for consumption. This study specifically focused on the proximate contents (moisture, ash, fiber, lipid, protein, and carbohydrate) and anti-nutritional factors (cyanide, phytic acid, and oxalate) present in three soybean varieties (TGX1987-10F, TGX2018-1E, and TGX2024-3E). It also explored the relationships between these nutrients and anti-nutrients.

2. Methodology

2.1 Study Area

This study was conducted at the General Biology Laboratory, College of Biological Sciences, Joseph Sarwuan Tarkaa University, Makurdi, Benue State, Nigeria.

2.2 Sample Collection, Identification and Preparation

Seeds of the three soybean varieties were obtained from the Department of Plant Breeding and Seed Science, College of Agronomy, Joseph Sarwuan Tarka University, Makurdi. These varieties were part of the genetic resources used in the ongoing molecular breeding work conducted by the department. Approval and release for use were granted by the Management of the department's Molecular Biology Laboratory.

2.3 Proximate Analysis

2.3.1 Moisture Content Determination

Moisture content was determined using the oven drying method [11]. Three moisture cans were dried in an oven and cooled in desiccators before being weighed. Exactly 5 g of each sample was placed in a separate moisture can, then placed in an oven and dried at 105°C for 2 h. The cans were then removed, placed in a desiccator to cool, and weighed again. This cycle of heating, cooling, and weighing was repeated until a constant weight was obtained. The moisture content was determined by the weight difference and expressed as a percentage of the sample weight. The formula used was:

$$\% \text{ Moisture} = \frac{w2-w3}{w2-w1}\ x\ 100/1$$

where:
w1=weight of the empty moisture can
w2=weight of can and sample before drying
w3=weight of can and sample after drying

2.3.2 Crude Protein Determination

The micro-Kjeldahl titration method was used to determine the protein content of the soybean samples. This method involves mixing 2 g of each sample with 10 mL of concentrated sulfuric acid (tetraoxosulfate (VI) acid) in a Kjeldahl digestion flask. A selenium catalyst tablet was added, and the mixture was heated under a fume hood. The digest was then transferred to a 100 mL volumetric flask and made up to volume with distilled water. Exactly 10 mL of the digest was mixed with an equal volume of 45% sodium hydroxide (NaOH) solution and poured into a Kjeldahl distillation apparatus. The mixture was distilled, and the distillate was collected in a solution containing 4% boric acid and 3 drops of a mixed indicator (methyl red and bromocresol green) until a total of 50 mL of distillate was obtained. This indicator changes color from green to a deep red or pink endpoint during titration. The collected distillate was then titrated with 0.02 N sulfuric acid (H_2SO_4) solution. The total nitrogen content was calculated and multiplied by a factor of 6.25 to obtain the crude protein content [12]:

$$\% \text{ Crude protein} = \%\boldsymbol{N6.25}$$

$$\% \text{ N2} = \frac{(100x)Nx14xVfxT}{w\ x\ 100\ x\ VA}$$

where:
W=weight of the sample
N = normality of filtrate (H_2SO_4) = 0.02 N
V_F = total volume of the digest = 100 mL
V_A = volume of the digest distilled

2.3.3 Fat Determination

The fat content of the samples was determined by the solvent extraction method using a Soxhlet apparatus. Five grams of each sample were wrapped in porous filter paper (Whatman number one filter paper). The wrapped sample was placed in a Soxhlet thimble and positioned in the Soxhlet flask of the reflux condenser. The solvent was heated in a flask by an electrothermal heater, causing it to vaporize and condense in the reflux condenser. The condensed solvent continuously siphoned through the thimble, completely immersing the wrapped sample and extracting the fat. This process continued repeatedly for about 4 h, until the fat extraction was complete. The extracted samples were then removed and reserved for crude fiber analysis. The solvent was recovered, and the extraction flask with its oil content was dried to remove residual solvent. After cooling in a desiccator, the flask was reweighed. The fat (oil) content was then calculated as a percentage of the sample weight using the following formula [13]:

$$\% \text{ of fat} = \frac{w2-w1}{w1}\boldsymbol{x}\frac{100}{1}$$

where:
w1 = weight of empty extraction flask
w2 = weight of flask and oil extract

2.3.4 Ash Determination

The ash content was determined using the furnace incineration gravimetric method, as recommended [14]. Crucibles were dried in an oven and cooled in desiccators before being weighed. Approximately 5 g of each sample was weighed and placed in a pre-weighed crucible. The covered crucible was then placed in a muffle furnace at a temperature of 70°C. The temperature was maintained for 2 h, or until a whitish ash remained. After 2 h, the muffle furnace was switched off. The crucibles were removed and placed in a desiccator to cool. Once cool, the crucibles containing the ash were

weighed again. The percentage ash content was then determined using the formula:

$$\% \text{ Ash} = \frac{w2-w3}{w2-w1} x \frac{100}{1}$$

where:
w1 = weight of the crucible
w2 = weight of sample crucible
w3 = weight of crucible + ash

2.3.5 Crude Fiber Determination

Crude fiber content was determined by the Weende method [13]. Approximately 5 g of each sample, previously defatted during fat analysis, was used. The defatted sample was treated with 200 mL of 1.25% H_2SO_4 solution and boiled under reflux for 30 min. The resulting mixture was then filtered using a two-fold muslin cloth to trap particles, with the residue washed with several portions of hot water. The washed samples were carefully transferred to a beaker and boiled for 30 min with 200 mL of 1.25 M NaOH solution. The digested sample was then washed several times with hot water. The washed sample was carefully scraped into a pre-weighed porcelain crucible and dried in an oven at 150°C for 3 h. After drying, the crucible was cooled in a desiccator and weighed. The cooled sample was then ashed in a muffle furnace at 550°C for 2 h. Finally, the crucible was cooled in a desiccator and reweighed. The crude fiber content was calculated using the formula:

$$\% \text{ Crude fiber} = \frac{loss\ in\ weight\ incinertion}{weight\ of\ sample} x \frac{100}{1} = \frac{w2-w3}{weight\ of\ sample}$$

where:
w2 = weight of crucible sample after washing and drying in oven
w3 = weight of crucible + sample ash

2.3.6 Carbohydrate Determination

Carbohydrate content was determined by difference, also known as nitrogen-free extract (NFE). The NFE was calculated using the following formula:

$$\% \text{ NFE} = \mathbf{100} - \% (a + b + c + d + e)$$

where:
a = protein
b= fibre
c= ash
d= moisture

2.4 Determination of Anti-Nutritional Factors

For oxalate determination, approximately 0.5 g of each sample was weighed into a 100 mL conical flask. Then, 15 mL of 3 M H_2SO_4 was added, and the mixture was stirred for 1 h with a magnetic stirrer. The mixture was then filtered using Whatman No. 1 filter paper. Five mL of the hot filtrate was titrated with 0.05 M $KMnO_4$ solution until a faint pink color persisted for at least 30 s. The oxalate content was calculated based on the equivalence of 1 mL of 0.05 M $KMnO_4$ to 2.2 mg oxalate [15].

Titrimetric method was used for phytic acid determination [16]. Approximately 2 g of sample was soaked in 100 mL of 2% HCl for 3 h and then filtered. Twenty-five mL of the filtrate was placed in a 100 mL conical flask. Five mL of KSCN solution (5 M) was added as an indicator, followed by 50 mL of distilled water to adjust the acidity (pH = 4.5). The solution was then titrated with $FeCl_3$ solution containing 0.005 ml of Fe^{3+} per mL of solution until a brownish-yellow color persisted for 5 min. Phytic phosphorus (Pp) was determined, and the phytic acid content was calculated by multiplying the Pp value by 3.55. Since each mg of iron equals 1.19 mg of Pp, the Fe equivalent can be calculated as 1.15 x titer value. Pp is then determined by multiplying the titer value by 1.19 and 1.95. Therefore, the phytic acid content is calculated as 1.95 x 1.19 x 3.55 x titer value.

For cyanide determination, approximately 2.5 g of sample was ground into a paste and dissolved in 50 mL of distilled water in a conical flask. The mixture was left overnight for cyanide extraction. The extract was then filtered. Four mL of alkaline picrate solution was added to 1 mL of the sample filtrate, and the mixture was incubated in a water bath for 5 min. After color development (reddish-brown), the absorbance was read at 450 nm against a blank.

2.5 Data Analysis

Data were analyzed using Minitab 16.0. The following statistical tools were employed: descriptive statistics (mean, standard error), chi-square test, one-way ANOVA, and Pearson's correlation. Turkey's multiple comparison test was used to separate means at the 95% confidence level (α = 0.05).

3. Results and Discussion

Table 1 presents the proximate composition of three soybean varieties: TGX1987-10F, TGX2018-1E, and TGX2024-3E. Among these varieties, TGX1987-10F boasted the highest levels of carbohydrates (37.03%), protein (24.44%), and fiber (3.67%). Conversely, TGX2024-3E exhibited the highest content of lipids (29.07%), ash (5.67%), and moisture (6.33%). As depicted in Figure 1, the grand mean nutritional composition of soybeans revealed carbohydrates as the predominant class (34.39%), followed by lipids (27.5%), protein (24.16%), moisture (6.17%), ash (4.5%), and fiber (3.28%).

The findings of this study align with previous observations. Rex [17] highlights the significance of soybean as a legume due to its high protein content (35-48%) with a well-balanced amino acid profile. This translates to soybean products being widely used globally as a source of vegetable protein and a significant source of high-quality oil (15-22%). Similarly, Deshpande et al. [18] confirms that soymilk is rich in water-soluble protein, carbohydrates, and oil nutrients, including polyunsaturated fatty acids like linoleic acid.

The observed protein content in the studied soybean varieties (24.44%) surpasses the amounts reported in Nwoke et al. (4.5-4.8%) and Khatib et al. (4.9 to 5.5%), suggesting potential improvement in protein content of these soybean breeds. However, the current study's protein value falls short of the 35.6% found in Useh [2], the 37.69% reported by Ogbemudia et al. [21], and the 39.24% reported by Bayero et al. [22]. This variation in reported soybean protein content across studies could be partially attributed to the cultivation environment and the type of nutrients applied.

The research by Useh [2] reinforces the established notion of soybean as a plant food with a relatively high protein content compared to other plants. Ogbemudia et al. [21] suggests its potential application in managing protein deficiency conditions like Kwashiorkor and marasmus. Additionally, Prestamo et al. [23] emphasizes the importance of incorporating soybean foods into diets to potentially prevent and treat chronic diseases such as cancer and cardiovascular diseases.

Table 1: Proximate composition in three varieties of soybean.

Varieties	Moisture (%)	Ash (%)	Fiber (%)	Lipid (%)	Protein (%)	Carbohydrate (%)
TGX1987-10F	6.00 ± 0.29	4.17 ± 0.73	3.67 ± 0.33	24.70 ± 0.62	24.44 ± 0.51	37.03 ± 2.00
TGX2018-1E	6.17 ± 0.17	3.67 ± 0.17	3.00 ± 0.29	28.73 ± 0.15	24.02 ± 0.24	34.42 ± 0.38
TGX 2024-3E	6.33 ± 0.17	5.67 ± 0.17	3.17 ± 0.17	29.07 ± 0.83	24.03 ± 0.42	31.73 ± 1.16
Grand mean	6.17 ± 0.12	4.50 ± 0.37	3.28 ± 0.17	27.50 ± 0.76	24.16 ± 0.21	34.39 ± 1.02

Note: Moisture: $\chi 2$ (Variety Vs Moisture content) = 0.009, P=0.996 (P>0.05); Ash: $\chi 2$ (Variety Vs Ash content) = 0.481, P=0.786 (P>0.05); Fiber: $\chi 2$ (Variety Vs Fiber content) = 0.074, P=0.964 (P>0.05); Lipid: $\chi 2$ (Variety Vs Lipid content) = 0.430, P=0.807 (P>0.05)

Table 2: Anti-nutritional factors report in three varieties of soybean.

Varieties	Cyanide (mg/100g)	Oxalate (mg/100g)	Phytic acid (mg/100g)
TGX1987-10F	0.84 ± 0.0^{a}	0.69 ± 0.58^{a}	34.74 ± 0.72^{a}
TGX2018-1E	0.55 ± 0.17^{a}	0.91 ± 0.47^{a}	28.66 ± 0.67^{b}
TGX 2024-3E	0.44 ± 0.09^{a}	0.88 ± 0.43^{a}	25.52 ± 0.57^{c}
FAO/WHO limit	20	<100	100-400

Note: F (Cyanide content) = 3.20, P= 0.113 (P>0.05); F (Oxalate content) = 0.06, P=0.944(P>0.05); F (Phytic acid content) = 50.83, P=0.000 (P<0.05); *Means that do not share a letter are significantly different.

Table 3: Pearson's correlation matrix.

	Moisture	Ash	Fiber	Lipid	Protein	Carbohydrate	Cyanide	Oxalate	Phytic acid
Moisture	1								
Ash	0.553	1							
Fiber	-0.465	0.110	1						
Lipid	0.309	0.329	-0.350	1					
Protein	0.556	0.298	0.092	-0.142	1				
Carbohydrate	-0.588	-0.756	0.090	-0.816	-0.292	1			
Cyanide	-0.085	-0.270	0.162	-0.543	0.486	0.386	1		
Oxalate	0.103	0.001	-0.346	-0.202	-0.230	0.244	-0.527	1	
Phytic acid	-0.340	-0.343	0.549	-0.825	0.395	0.607	0.653	-0.088	1

Many leguminous crops offer some protein, but soybean stands out as the sole readily available crop providing an inexpensive, high-quality protein source comparable to poultry and swine diets [3,4]. The average lipid content observed in this study (29.07%) exceeded the values reported in previous works: 19%, 9.14%, and 28.2% [21,24]. However, it fell short of the 30.31% value obtained by Bayero et al. [22]. This high lipid content (29.07%) suggests soybean as a promising oil source, aligning with its classification as an oilseed by the Food and Agriculture Organization [25] rather than a pulse. Notably, Balasubramaniyan and Palaniappan highlighted that soybean oil comprises 85% unsaturated fatty acids, including two essential fatty acids (linoleic and linolenic acid) that the human body cannot synthesize [26]. This makes them highly desirable in the human diet.

The low moisture content (6.33%) observed indicates the potential for long-term storage of these varieties. Microorganism multiplication requires moisture, and the low levels here suggest extended shelf life. This result aligns with the findings of Edema et al. (6.11% moisture) [27]. However, higher moisture contents were reported by Ogbemudia et al. (8.07%) and Bayero et al. (8.13%) [21,22]. According to Nwoke et al. [19], low moisture content can positively impact food stability and safety by limiting microbial growth. The ash content observed in this study (5.67%) agrees with the findings of Lokuruka (around 5% ash) [28]. It differs from the report by Ogbemudia et al. (4.29% ash) [21]. The fiber content (3.67%) aligns with the findings of Dickson et al. (3.75% to 6.00% range) [29]. Dietary fiber offers established benefits, exerting various physiological effects within the gastrointestinal tract. These effects include changes in fecal water content, bulk, and transit time, along with the elimination of bile acids and neutral steroids, which contribute to lowering body cholesterol levels [29].

The high carbohydrate content of soybeans suggests the potential use of the flour sample in managing protein-energy malnutrition. The sufficient carbohydrate quantity provides a readily available energy source, sparing protein for its primary functions of building and repairing body tissues rather than using it for energy (reference not provided). The carbohydrate content (37.03%) in this study surpassed the values obtained by Ogbemudia et al. (6.11%) and Bayero et al. (5.08%) [21,22]. Notably, TGX1987-10F exhibited the highest amount of both carbohydrates and protein. This characteristic further strengthens its position as a high-quality seed, performing best in physical evaluation and sensory assessment. Consequently, it could be selected as a rich supplement source for humans and livestock. Conversely, the high lipid content of TGX 2024-3E suggests its potential for oil extraction.

Table 2 shows the content of three anti-nutritional factors (cyanide, oxalate, and phytic acid) in the three soybean varieties. Both cyanide and oxalate levels were low and statistically similar ($P > 0.05$) across the varieties. TGX1987-10F had the highest cyanide content (0.8 mg/100 g) and TGX 2024-3E had the lowest (0.44 mg/100 g). Similarly, TGX1987-10F had the highest oxalate content (0.91 mg/100 g), while TGX 2024-3E had the least (0.69 mg/100 g). Phytic acid, however, showed the highest concentration among the three anti-nutrients and exhibited significant variation between the varieties ($P < 0.05$). TGX1987-10F contained the most phytic acid (34.74 mg/100 g), while TGX 2024-3E contained the least (25.52 mg/100 g). Figure 2 visually demonstrates this, with the overall mean phytic acid content (34.74 mg/100 g) being 36 times higher than oxalate and 49 times higher than cyanide in soybeans.

The presence of various non-nutritive compounds in soybeans can decrease their nutritional value. These compounds, known as

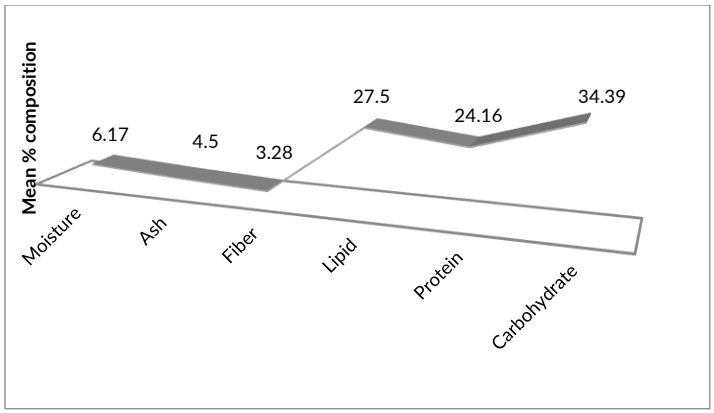

Figure 1: Grand mean of proximate composition in soybean seeds.

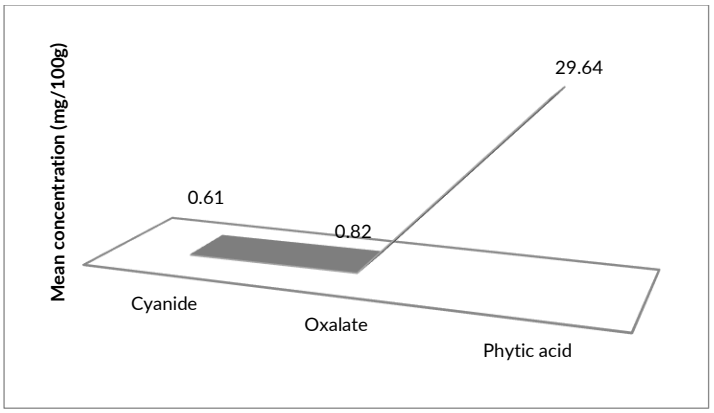

Figure 2: Comparative analysis of anti-nutritional factors in three varieties of soybean.

anti-nutritional factors, can hinder nutrient uptake and cause adverse physiological and biochemical effects in humans and animals [30,31]. In some cases, they can even be toxic. Fortunately, all the anti-nutrients observed in the three varieties were below the WHO/FAO permissible limit of 100-400 mg/100 g, making them safe for consumption.

Both cyanide and oxalate contents were low in the samples, with minimal variation between the varieties. Phytic acid, the anti-nutrient with the highest concentration, showed significant variation among the varieties. The phytic acid values reported here were higher than the range of 5.45 to 8.05 mg/100 g found by Pele et al. [32] in some soybean samples. This suggests potential for breeding soybeans with lower phytic acid content, further improving their overall quality.

Phytic acid, a potent anti-nutritional factor, is widely present in legumes and seeds [33]. It can inhibit important digestive enzymes like dietary tyrosinase, trypsin, pepsin, and lipases [34, 35]. This inhibition hinders protein degradation in the stomach and small intestine. Interestingly, TGX1987-10F, the variety with the highest phytic acid content, also exhibited good seed quality with the best carbohydrate and protein content. Therefore, reducing phytic acid levels would further enhance the overall quality of these varieties.

Research suggests that phytic acid can be toxic to body organs [2,36,37]. Ideally, it should be completely removed. Additionally, Ologhobo et al. [38] reported that phytic acid can bind to minerals like iron, calcium, and zinc, reducing their absorption and potentially leading to mineral deficiencies, particularly in populations relying heavily on soybeans for protein.

The study revealed several correlations between the components of the three soybean varieties. Ash content showed strong positive correlations with fiber (0.958), protein (0.995), and oxalate (0.697). In contrast, moisture content exhibited a negative correlation with all other variables except ash. This suggests that drier seeds tend to have higher concentrations of carbohydrates. Fiber content displayed positive correlations with ash (0.958), protein (0.981), and oxalate (0.873). Interestingly, phytic acid exhibited a negative correlation with all components except carbohydrates (0.840), indicating that higher carbohydrate levels are associated with increased phytic acid content.

Further analysis (Table 3) revealed a moderate negative correlation between moisture and carbohydrates (-0.588), suggesting that a decrease in moisture content leads to an increase in carbohydrate content. While ash content showed a weak negative correlation with other variables, fiber displayed a moderate positive correlation with phytic acid (0.549). This suggests that higher fiber content coincides with increased phytic acid levels. Notably, the variety with the highest phytic acid content also had the highest fiber content, supporting a positive influence between the two. Conversely, lipid content demonstrated a negative correlation with all variables, including phytic acid (-0.825). This implies that an increase in lipid content reduces the amount of phytic acid. This negative correlation is further confirmed by the variety containing the highest lipid content also having the lowest phytic acid level. Similarly, phytic acid displayed a moderate positive correlation with carbohydrates (0.607), suggesting that higher carbohydrate content leads to increased phytic acid. The variety with the highest carbohydrate content also had the highest phytic acid content. These findings suggest that increasing lipid content might be a strategy to reduce phytic acid levels in the three soybean varieties.

Among the studied varieties, TGX 2024-3E stood out with the lowest phytic acid and cyanide content. Interestingly, it also had the highest levels of lipid, ash, and moisture, along with considerable amounts of protein and fiber compared to other varieties.

The study was limited to only three soybean varieties, potentially affecting the generalizability of the results. Additionally, the proximate analysis did not encompass mineral components and other anti-nutrients commonly found in legumes. Expanding the study to include a wider variety selection and a more comprehensive analysis of anti-nutrients is recommended for future research.

Table 4. Comparative analysis of proximate factors in soybean from different sources.

Varieties	Moisture (%)	Ash (%)	Fiber (%)	Lipid (%)	Protein (%)	Carbohydrate (%)	Source
TGX1987-10F	6.00	4.17	3.67	24.70	24.44	37.03	Present study
TGX2018-1E	6.17	3.67	3.00	28.73	24.02	34.42	Present study
TGX 2024-3E	6.33	5.67	3.17	29.07	24.03	31.73	Present study
TGX1019-2EB	3.55	3.97	5.32	26.07	22.39	38.55	[29]
TGX1019-2EN	2.75	4.57	4.28	23.40	18.24	46.60	[29]
TGX1485-1D	3.82	4.11	5.11	23.54	18.24	36.40	[29]

4. Conclusion

This study compared the nutritional values of three soybean varieties, empowering consumers to make informed choices based on quality, safety, and anti-nutritional factors. The results suggest that breeding programs should prioritize improving protein and lipid content while reducing phytic acid levels. Among the examined varieties, TGX1987-10F emerged as the superior choice, boasting the highest levels of carbohydrates, protein, fiber, and moisture, alongside lower levels of anti-nutrients. This variety's superior nutritional profile makes it the most recommended for consumption among the three. This information is valuable for breeders, farmers, consumers, and all stakeholders in the soybean industry.

Acknowledgement

Gratitude is directed to the two anonymous reviewers for the valuable suggestions that greatly improved this manuscript.

Conflict of Interest Statement

The authors declare no conflict of interest.

Author Contributions

All authors have contributed equally. They have read and agreed to the published version of the manuscript.

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