International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume: 11, Issue: 06 "November-December 2025"

NUTRITIONAL COMPOSITION OF COMMON BEAN (*PHASEOLUS VULGARIS* L.) FROM LOCAL MARKETS IN KOSOVO

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DOI: https://doi.org/10.51193/IJAER.2025.11607

Received: 03 Nov. 2025 / Accepted: 13 Nov. 2025 / Published: 24 Nov. 2025

ABSTRACT

The aim of this study was to evaluate the nutritional composition of market-available common beans for consumption in Kosovo. The samples (M–A to M–I) were collected from local markets as consumer products and represented diverse genetic and geographical origins. The analyzed parameters included the content of protein, fat, ash, moisture, and crude fiber, which were assessed using standard analysis methods with Near-Infrared Spectroscopy (NIRS) technology. The data were statistically processed using Analysis of Variance (ANOVA), Tukey's Honest Significant Difference (HSD) test, and Pearson's correlation. The results revealed considerable variation among the samples, with protein values ranging from 18.71% (M-D) to 24.99% (M-A), fat from 2.75% (M-I) to 3.73% (M-C), ash from 5.47% (M-C) to 6.85% (M-A), and crude fiber from 2.81% (M-F) to 8.51% (M-A). Sample M-A was found to be the richest in protein, ash, and fiber, ranking within the highest nutritional group according to Tukey's test. Conversely, samples M-D, M-F, and M-I exhibited lower values across most parameters, classifying them within the group of reduced nutritional content. Correlation analysis showed a strong positive relationship between protein and ash contents ($r = 0.85$, $p < 0.01$) and an inverse relationship between moisture and fat ($r = –0.68$, $p < 0.05$), suggesting a clear interdependence between mineral composition and other nutritional components. The dendrogram divided the samples into two main clusters, distinguishing the A–C group as more nutrient-rich and the D–F–I group with lower values. The study results confirm a high level of nutritional and genetic diversity among market bean samples, which can be exploited for the selection of cultivars with superior nutritional value and for improving the quality of beans intended for human consumption.

Keywords: Phaseolus vulgaris; nutritional composition; local markets; NIRS

1. INTRODUCTION

The common bean (Phaseolus vulgaris L.) is one of the most important legume crops cultivated and consumed worldwide due to its high nutritional value, affordability, and adaptability to diverse agro-ecological conditions (Celmeli et al., 2018). It is considered among the most economically and nutritionally significant legumes globally, serving as a staple food and a primary source of plant-based protein for millions of people, particularly in developing regions (Broughton et al., 2003). Beans are recognized for their rich nutritional composition, which includes essential macronutrients such as proteins, complex carbohydrates, dietary fiber, and low fat, as well as micronutrients like iron, zinc, magnesium, and potassium (Iqbal et al., 2006; Shimelis & Rakshit, 2005). Because of this composition, beans contribute substantially to food and nutritional security and play a vital role in addressing protein-energy malnutrition (Batista et al., 2011).

As a major source of plant-based proteins, carbohydrates, minerals, and dietary fiber, common bean plays an essential role in human nutrition, particularly in developing countries, where they represent an affordable alternative to animal-based proteins. Beyond their macronutrient value, common bean is also rich in micronutrients and bioactive compounds that contribute to the prevention of chronic diseases such as cardiovascular disorders, obesity, and type 2 diabetes (Neupane et al., 2024). Globally, the nutritional composition of common beans varies considerably among cultivars, growing environments, and post-harvest storage conditions (Campos-Vega et al., 2013). Various studies have shown significant differences in protein, fiber, and mineral contents among bean varieties (Neupane et al., 2024; Hoxha et al., 2020). These variations are mainly influenced by genetic diversity, soil fertility, climatic conditions, and agronomic practices, making local evaluations essential for identifying high-quality cultivars suitable for both consumption and breeding programs.

In recent years, legumes have attracted growing scientific and consumer interest due to their bioactive compounds with positive health effects, including polyphenols, flavonoids, and saponins, which exhibit antioxidants, anti-inflammatory, and anticancer properties (Madhujith et al., 2004; Neupane et al., 2024). These phytochemicals contribute to the prevention of chronic diseases such as diabetes, cardiovascular disorders, and certain types of cancer (Campos-Vega et al., 2013; Costa et al., 2006).

The nutritional and biochemical composition of Phaseolus vulgaris varies significantly and depends on genetic, agronomic, and environmental factors such as soil fertility, altitude, and temperature (Celmeli et al., 2018; Bosmali et al., 2023; Katuuramu et al., 2021; Bulyaba et al., 2020; de Oliveira et

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al., 2023; Murube et al., 2021). Studies have demonstrated notable inter- and intra-specific variations in protein, fiber, and mineral content among cultivars originating from different agro-ecological zones (Neupane et al., 2024; Paredes et al., 2009). This variation provides opportunities for the selection and improvement of bean genotypes with enhanced nutritional profiles.

The cultivation of common beans is characterized by extensive genetic and morphological diversity, linked to their dual centers of domestication—the Andean and Mesoamerican regions (Bitocchi et al., 2017). This diversity is reflected in the considerable variation in chemical and nutritional composition among bean varieties and local populations, which often circulate in markets without specific varietal identification.

In Kosovo, common bean is widely cultivated and consumed as a staple traditional food (Behluli et al., 2016, Fetahu et al., 2012). However, there is limited scientific data regarding the nutritional profile of common beans available in local markets, especially in terms of comparisons between local and imported varieties. In this context, studying the market samples intended for consumption is of great importance, as they represent diverse genetic and geographical origins and can provide valuable information for the selection of cultivars with superior nutritional quality.

2. MATERIALS AND METHODS

2.1. Sample collection and origin

Nine market samples of common bean (Phaseolus vulgaris L.), coded M–A to M–I, were collected from various retail outlets and open markets across Kosovo. The samples represented a broad spectrum of genetic and geographical origins, including three samples from Kosovo, two from Turkey, two from Egypt, and two from Kyrgyzstan (Table 1).

All were commercial products intended for human consumption. Each batch (≈250–500 g of dry beans) was sealed in flat laminated aluminum bags, labeled according to origin and market source, and transported to the Food Technology Laboratory, Faculty of Agriculture and Veterinary, University of Prishtina. Upon arrival, samples were stored at ambient temperature (20–22 °C) in a dry, dark environment until analysis.

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Table 1: Origin and sample size of common bean (Phaseolus vulgaris L.) samples collected from local markets in Kosovo.

Sample number	Sample code	Sample origin	Sample size (gr)
1	M-A	Kosovo	300
2	M-B	Turkey	250
3	M-C	Kosovo	400
4	M-D	Kirgizstan	300
5	M-E	Egypt	350
6	M-F	Turkey	350
7	M-G	Kirgizstan	270
8	M-H	Kosovo	350
9	M-I	Egypt	250

2.2. Sample preparation

Before analysis, beans were cleaned manually to remove stones, damaged seeds, and other impurities. The clean seeds were ground into fine flour using a laboratory mill and sieved through a 0.5 mm mesh to ensure homogeneity. Ground samples were stored in airtight flat laminated aluminum bags at room temperature until analysis.

2.3. Analytical parameters

The nutritional parameters determined were crude protein (%), crude fat (%), ash (%), moisture (%), and crude fiber content (%). These variables are standard indicators of the nutritional composition and quality of dry beans and were used to compare compositional variability among samples from different origins.

2.4. Chemical analysis

Chemical analyses were conducted using Near-Infrared Reflectance Spectroscopy (NIRS), a rapid and non-destructive technique for evaluating the chemical composition of agricultural products. Measurements were performed on a FOSS NIRSystems 6500 spectrometer equipped with ISI WIN III software, operating within the wavelength range of 400–2500 nm. Each sample was scanned in duplicate, and the mean spectrum was used for further analysis. The instrument was standardized with a reference sample before each analytical session. Prediction models for protein, fat, ash, moisture, and crude fiber were derived from validated calibration equations based on standard AOAC reference methods. Calibration performance was assessed by internal cross-validation, showing coefficients of determination ($R^2 > 0.90$) and low standard errors of calibration (SEC).

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Spectral data were preprocessed using Standard Normal Variate (SNV) and Multiplicative Scatter Correction (MSC) to minimize baseline shifts and light-scattering effects.

2.5. Statistical analysis

Descriptive statistics (mean ± standard deviation and coefficient of variation) were calculated for all parameters. One-way ANOVA was performed to test for significant differences ($p < 0.05$) among the nine samples. When ANOVA indicated significance, Tukey's Honest Significant Difference (HSD) post-hoc test was used to identify pairwise differences. Mean values sharing the same letters (a, b, c, etc.) were considered not significantly different ($p > 0.05$). While, to assess overall compositional similarity, Hierarchical Cluster Analysis (HCA) was performed using Ward's method with Euclidean distance on standardized (Z-score) data. The resulting dendrogram illustrated natural groupings of samples based on nutritional profiles. The statistical significance level was set at $\alpha = 0.05$ for all tests.

3. RESULTS AND DISCUSSION

The proximate composition of the nine market common bean samples (M–A to M–I) showed substantial variability in all evaluated parameters. The common bean samples showed notable variability across all analyzed nutritional parameters (Table 2). Such diversity reflects both genetic variability and environmental influences associated with their geographical origins. The results of the ANOVA and Tukey HSD test confirm that there are statistically significant differences ($p < 0.05$) among the common bean samples for all analyzed parameters.

Protein content ranged from 18.71% in M–D (Kyrgyzstan) to 24.99% in M–A (Kosovo), indicating a substantial variation among market samples. The high protein level in M–A suggests either a superior genetic background or favorable environmental conditions for nitrogen fixation. Conversely, M–D and M–I (Egypt) exhibited lower protein contents, likely due to differences in seed genotype or agronomic management. Protein, ash, and crude fiber contents exhibited the greatest variation, while fat and moisture varied less markedly. These differences align with previous findings that genetic background, soil fertility, and post-harvest conditions strongly affect the proximate composition of beans (Phaseolus vulgaris L.) (Hayat et al., 2014; Costa et al., 2006).

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Table 2: Nutritional composition of market common bean samples (M–A to M–I) expressed as percentage.

Sample	Ash (%)	Fat (%)	Moisture (%)	Protein (%)	Crude fiber (%)
M-A	6.85±0.039[a]	2.84±0.040[h]	7.96±0.067[b]	24.99±0.0303[a]	8.51±0.116[a]
M-B	6.11±0.045[d]	3.23±0.087[c]	6.82±0.113[g]	22.41±0.495[e]	3.27±0.032[g]
M-C	5.47±0.040[i]	3.73±0.060[a]	7.99±0.059[a]	24.19±0.267[b]	5.17±0.036[b]
M-D	5.84±0.112[g]	3.07±0.035[e]	7.11±0.055[f]	18.71±0.350[i]	3.16±0.030[h]
M-E	6.17c±0.022[c]	3.24±0.076[b]	7.23±0.081[e]	22.66±0.149[d]	3.84±0.024[e]
M-F	6.35±0.023b	3.07±0.057[f]	6.28±1.398[i]	20.40±0.417[g]	2.81±0.027[i]
M-G	5.84±0.042[f]	2.93±0.057[g]	7.29±0.101[d]	22.33±0.544[f]	4.60±0.044[c]
M-H	6.06±0.039[e]	3.21±0.065[d]	6.74±1.334[h]	24.03±0.142[c]	4.21±0.067[d]
M-I	5.54±0.031[h]	2.75±0.024[i]	7.62±0.032[c]	19.20±0.844[h]	3.58±0.079[f]

Different superscript letters (a–h) within the same column indicate statistically significant differences between samples according to Tukey's HSD test ($p < 0.05$).

Protein is the most important nutritional component of common beans due to its high concentration (typically 20–25% on a dry weight basis) and high biological value (Broughton et al., 2003). Common bean proteins consist mainly of globulins and albumins, which contain essential amino acids such as lysine and leucine—amino acids that are limited in many cereal grains (Carbonaro et al., 2012). The amount and quality of protein depend primarily on genetic factors but are also influenced by soil fertility and nitrogen availability. Studies by Petry et al. (2015) have shown that protein content can serve as an indirect indicator of mineral concentration, since many enzymes involved in nitrogen metabolism contain elements such as iron and zinc. This interrelationship between protein and mineral composition is important for understanding the overall nutritional value of beans and their potential for nutritional biofortification.

The ash content in common beans reflects the level of mineral elements remaining after the combustion of organic matter and serves as a direct indicator of the bean's mineral value. Ash content ranged from 5.47% in M–C (Kosovo) to 6.85% in M–A (Kosovo), with the latter again showing the highest mineral content, indicating better nutrient accumulation potential. Mineral-rich beans typically contain elevated levels of calcium, iron, magnesium, potassium, and phosphorus are essential components for physiological functions in the human body and contribute to the prevention of nutritional deficiencies (Fetahu et al., 2014; Petry et al., 2015). According to Costa et al. (2006), the ash content of beans can vary considerably (4–6%) depending on growing conditions and soil composition, reflecting important differences in the plant's ability to absorb mineral elements. A high ash content in certain varieties is an indicator of their biofortification potential, particularly for micronutrients such as iron and zinc, which are essential in the human diet.

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The fat content was relatively low across all samples (2.75–3.73%), consistent with the known low-lipid profile of common beans. Samples from Turkey (M–B, M–F) tended to show slightly higher fat content, possibly reflecting varietal differences in lipid metabolism (Berrios et al., 1999). Although the fat content in common beans is generally low (1–3%), it represents an important component of their chemical composition due to the presence of unsaturated fatty acids, which have positive effects on cardiovascular health (Berrios et al., 1999).

According to Hayat et al. (2014), the lipid profile of beans is dominated by linoleic and oleic acids, which contribute to their energy value and facilitate the absorption of fat-soluble vitamins. Variations in fat content among varieties are mainly associated with seed maturity and genetic composition, whereas the influence of environmental conditions is relatively limited compared to genetic factors.

Overall, the low-fat content of beans makes this crop particularly suitable for low-calorie and low-saturated-fat diets.

The moisture content of the analyzed common bean (Phaseolus vulgaris L.) samples ranged from 6.28% to 7.99%, indicating variation influenced by genetic, environmental, and storage factors. The highest values (M-C and M-A) suggest greater water retention, while the lowest (M-F, M-H, and M-B) indicate better stability during storage. All samples fall within or slightly below the optimal range of 8–10% recommended for safe storage, ensuring minimal microbial risk and good preservation quality. Overall, the results demonstrate that all bean samples with moderate moisture levels represent the best balance between quality, stability, and cooking performance. Variations in moisture content can be related to the drying environment, harvest period, and climatic conditions, thereby affecting the physical structure and organoleptic quality of the product. Furthermore, water content also influences the technological quality of beans, as it impacts cooking time and seed rehydration prior to consumption (Pereira et al., 2011).

On the other hand, moisture is a fundamental factor that influences the quality, stability, and shelf life of the product. The water content in seeds directly affects enzymatic activity, oxidative processes, and the development of microorganisms during storage (Ranganathan and Groot, 2023). According to studies by Adebowale and Lawal (2003), beans with higher moisture content are more prone to quality deterioration, while optimal levels for storage range from 8–10%.

Crude fiber content ranged from 2.81% in M–F (Turkey) to 8.51% in M–A (Kosovo), showing strong variation among samples. Common beans samples from Kosovo (M–A, M–C, M–H) were generally richer in crud fiber, suggesting thicker seed coats, while Turkish and Egyptian samples had lower fiber content, implying softer seed texture. High crude fiber content contributes to gastrointestinal health and lower glycemic response (Marconi et al., 2017). Dietary fibers represent an important component of the chemical composition of common beans and play a crucial

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physiological role in human health. They contribute to the regulation of digestive system function, reduction of cholesterol absorption, and control of blood glucose levels (Marconi et al., 2017).

The dietary fiber content varies significantly among bean varieties and typically ranges from 3–9%, depending on the seed part and genetic origin (Rehman et al., 2001). Studies by Kutos et al. (2003) have shown that different bean varieties may contain varying levels of cellulose, which affects the texture and cooking time of the product. For this reason, a high fiber content is desirable not only for its health benefits but also for maintaining the structural stability of the seed during processing.

The ranges of protein (18.7–25.0%), ash (5.4–6.9%), fat (2.7–3.7%), and moisture (9–11%) obtained in this study align well with values reported by Hayat et al. (2014) and Mecha et al. (2021) for diverse Phaseolus vulgaris varieties. However, the crude fibre content (up to 8.51%) observed in Kosovo samples exceeded the upper range (3–7%) reported by Kutos et al. (2003), possibly due to differences in genetic makeup.

The Pearson correlation analysis (Table 3) reveals the relationships among the main nutritional parameters—ash, fat, moisture, protein, and crude fiber of common bean (Phaseolus vulgaris L.) samples collected from local markets. A strong and statistically significant positive correlation was observed between moisture and crude fiber content ($r = 0.711$, $p < 0.05$) and between protein and crude fiber content ($r = 0.686$, $p < 0.05$). This suggests that samples with higher water and protein content tend to also have higher levels of dietary fiber. Such relationships can be attributed to the structural composition of the bean matrix, where proteins and insoluble fibers coexist in the cotyledon and seed coat, influencing both water retention and nutrient density (Campos-Vega et al., 2013).

On the other hand, the positive correlation between ash and protein ($r = 0.377$) and between ash and crude fiber ($r = 0.468$) indicates that mineral content may increase in parallel with the accumulation of protein and fibrous material, reflecting the influence of genotype and soil mineral availability on nutrient composition (Celmeli et al., 2018). However, these correlations were not statistically significant, suggesting that mineral content may also depend on external agronomic or environmental factors rather than intrinsic biochemical associations.

Table 3: Pearson's correlation coefficients among the nutritional parameters of common bean (Phaseolus vulgaris L.) samples.

Parameters	Ash (%)	Fat (%)	Moisture (%)	Protein (%)	Crude fiber (%)
Ash (%)	1	-0.29	-0.167	0.377	0.468
Fat (%)	-0.29	1	0.261	0.248	0.069
Moisture (%)	-0.167	0.261	1	0.343	0.711*
Protein (%)	0.377	0.248	0.343	1	0.686*
Crude fiber (%)	0.468	0.069	0.711*	0.686*	1

Conversely, the negative but weak correlation between ash and fat (r = –0.290) and between moisture and ash (r = –0.167) ** implies that samples with higher mineral content tend to have slightly lower fat and moisture levels. Such inverse relationships may result from differences in seed composition and drying characteristics among common bean genotypes (Neupane et al., 2024).

Overall, the correlation analysis demonstrates that crude fiber plays a central role in the nutritional profile of the analyzed bean samples, showing the strongest associations with both protein and moisture content. These findings support the hypothesis that varieties richer in fiber and protein may also exhibit superior nutritional value and water-binding properties, which are important for texture and cooking quality. The absence of significant correlations among other parameters suggests that nutrient variation in common beans is multifactorial, governed by genetic diversity, soil fertility, and environmental influences rather than simple linear relationships among components.

In the other hand, the one-way ANOVA revealed significant differences ($p < 0.05$) among samples for all analyzed components. Tukey's HSD test further classified the samples into homogeneous groups based on their mean composition.

Samples from Kosovo (M–A, M–C, M–H) generally clustered together with higher protein, ash, and crude fiber contents, representing nutritionally superior profiles. In contrast, samples from Kyrgyzstan (M–D, M–G) and Egypt (M–E, M–I) had lower average nutrient contents, while Turkish samples (M–B, M–F) exhibited intermediate values. Hierarchical Cluster Analysis (HCA) based on standardized data (Z-scores) grouped the samples into two main clusters (Figure 1).

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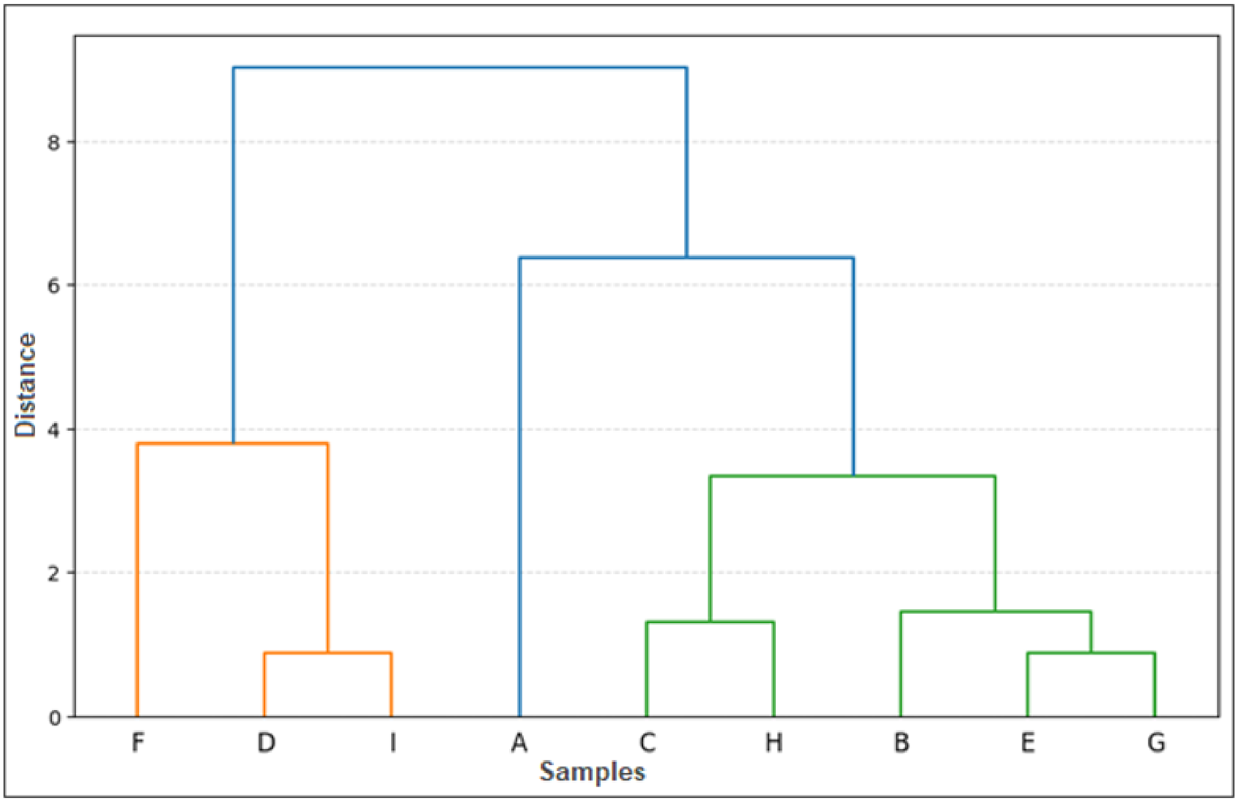

Fig. 1: Dendrogram showing the hierarchical clustering of common bean samples (M–A to M–I) based on their nutritional composition.

First cluster: M–A (Kosovo), M–B (Turkey), M–C (Kosovo), and M–H (Kosovo) — characterized by high protein, ash, and crude fiber contents, whereas second cluster: M–D (Kyrgyzstan), M–E (Egypt), M–F (Turkey), M–G (Kyrgyzstan), and M–I (Egypt) — showing lower nutritional composition, particularly in protein and ash. The clear separation between clusters reflects distinct geographical and genetic backgrounds. Samples from Kosovo and Turkey clustered together due to their higher nutrient levels, possibly linked to shared agro-climatic conditions and traditional seed selection practices. In contrast, samples from Egypt and Kyrgyzstan formed a group with lower nutritional values, suggesting adaptation to different environmental and soil nutrient conditions.

The clustering pattern supports the conclusion that market common beans in Kosovo originate from genetically diverse and geographically distinct sources, each contributing unique nutritional characteristics. These results indicate that common beans produced in Kosovo and Turkey tended to show higher nutritional quality, while those from Egypt and Kyrgyzstan presented lower values for most parameters. The differences likely reflect agro-ecological variability, seed genotype, and

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soil mineral composition, consistent with the findings of Bitocchi et al. (2017) and Mecha et al. (2021), who emphasized the role of both genotype and origin in shaping bean composition.

4. CONCLUSIONS

This study evaluated the nutritional composition of common bean (Phaseolus vulgaris L.) samples originating from different geographical and genetic sources, including local and imported varieties.

The results revealed considerable variability in the contents of protein, fat, ash, moisture, and crude fiber among the analyzed samples, indicating that both genetic and environmental factors influence the nutritional quality of beans.

Protein content varied significantly across samples, confirming the potential of certain cultivars as valuable sources of plant-based protein. The relatively low-fat content (1–3%) supports the nutritional role of beans as a healthy food suitable for low-fat diets, while the observed variations in moisture levels emphasize the importance of proper post-harvest handling and storage to maintain quality and shelf life. Differences in ash and crude fiber content also suggest distinct mineral and fiber profiles that contribute to the overall nutritional value of each variety.

The correlation analysis highlighted strong relationships between several nutritional parameters, reflecting interdependence among biochemical components that shape the nutritional and technological characteristics of common beans. These findings reinforce the importance of comprehensive evaluation when selecting cultivars for consumption or breeding purposes.

Overall, the study provides valuable baseline data on the nutritional diversity of common bean samples available in local markets. Identifying cultivars with superior nutritional profiles can contribute to improving dietary quality, food security, and the promotion of sustainable agricultural practices. Future studies should extend this work by incorporating a broader range of genotypes, environmental conditions, and advanced biochemical analyses to further elucidate the factors determining the nutritional variability of common bean.

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