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Project Report

The Nutritional Content of Common Bean (*Phaseolus vulgaris* L.) Landraces in Comparison to Modern Varieties

Tugce Celmeli, Hatice Sari, Huseyin Canci, Duygu Sari, Alper Adak, Tuba Eker and Cengiz Toker *

Department of Field Crops, Akdeniz University, Faculty of Agriculture, Antalya TR 07070, Turkey; tucee_celmeli@hotmail.com (T.C.); haticesari@akdeniz.edu.tr (H.S.); huseyincanci@akdeniz.edu.tr (H.C.); duygusari@akdeniz.edu.tr (D.S.); alperadak@akdeniz.edu.tr (A.A.); ekertuba07@gmail.com (T.E.)

* Correspondence: toker@akdeniz.edu.tr; Tel.: +90-242-3102421

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Abstract: In terms of safe food and a healthy food supply, beans (*Phaseolus* spp.) are a significant source of protein, carbohydrates, vitamins and minerals especially for poor populations throughout the world. They are also rich in unsaturated fatty acids, such as linoleic and oleic acids. From the past to the present, a large number of breeding studies to increase bean yield, especially the common bean (*P. vulgaris* L.), have resulted in the registration of many modern varieties, although quality and flavor traits in the modern varieties have been mostly ignored. The aim of the present study, therefore, was to compare protein, fat, fatty acid, and some mineral content such as selenium (Se), zinc (Zn) and iron (Fe) of landraces to modern varieties. The landrace LR05 had higher mineral contents, particularly Se and Zn, and protein than the modern varieties. The landrace LR11 had the highest linoleic acid. The landraces are grown by farmers in small holdings for dual uses, such as both dry seed and snap bean production, and are commercialized with a higher cash price. The landraces of the common bean are, not only treasures that need to be guarded for the future, but also important genetic resources that can be used in bean breeding programs. The results of this study suggest that landraces are essential sources of important nutritional components for food security and a healthy food supply.

Keywords: common bean; *Phaseolus vulgaris*; protein; fat; fatty acids; iron; zinc; selenium

1. Introduction

The genus *Phaseolus* L. consists of 76 species from the New World [1], and five species, tepary bean (*P. acutifolius* A. Gary), runner bean (*P. coccineous* L.), lima bean (*P. lunatus* L.), year-bean (*P. polyanthus* Greenman) and common bean (*P. vulgaris* L.), are under cultivation in the world [2,3]. Among the cultivated species, the common bean is dominant with a growing area ratio of 90% [4]. It is not only used as a dry grain and snap bean as vegetables but is also in the market as a canned product like industrial crops. Global production as a dry grain is 26.8 million tons, while production as a vegetable or snap bean is 23.5 million tons according to the database of the Food and Agriculture Organization (FAO) in 2016. The yields as dry grain and snap bean are 913 kg per ha and 1515 kg per ha, respectively [5]. The common bean can also fix more than 160 kg of atmospheric nitrogen per ha into soil via interactions with *Rhizobium* bacteria [6]. Because of their high protein, mineral and fiber content, beans are consumed instead of meat in underdeveloped and developing countries [7]. However, especially in the last decade, the benefits of beans have been better understood in terms of high protein, important minerals, dietary fiber and some vitamins, so consumption has also increased in developed countries [8].

Some water-soluble vitamins such as thiamin, riboflavin, niacin, vitamin B_6 and folic acid and minerals including potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu) and iron (Fe) were identified in the common bean [9]. Sangronis and Machado [10] identified phytic acid, tannins, ascorbic acids, thiamin, protein digestibility and Ca, Mg, Zn, Fe and Cu in the common bean [10]. In four genotypes of bean, Barampama and Simard [11] studied protein, ash, fat, some minerals (K, Ca, Mg, Fe, Cu, Zn and P), the essential amino acids (isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine) and some antinutritional factors (raffinose oligosaccharide, trypsin inhibitor, hemagglutinin, tannin and phytic acid) were determined. Correlations among mineral contents (Mn, Zn, Ca, Mg, K and P) in an intraspecific cross of two accessions of common beans were reported by Beebe et al. [12]. Protein and mineral contents consisting of Ca, Fe and Zn were found in both common and wild beans [13]. Protein lipids, fiber and minerals such as Ca, Fe, Mg and Zn have also been examined in the common bean [14]. The mineral composition (Sodium, K, Ca, Mg, Zn, Cu, Fe and Mn) and fatty acid profile (C14, C16, C18, C20, C24, C16:1, C18:1 and C22:1) were studied in the seeds of selected Fabaceae species including the common bean [15]. Zn contents were determined in common beans by Koehler et al. [16]. Some minerals including Zn and Fe were found in recombinant inbred lines (RILs) of the bean [17]. Common bean genotypes that were collected from various regions of India were evaluated for Fe, Zn and protein contents [18]. Furthermore, Mg, K, Fe, Zn, Mn, Cu and Se of some pulses including the common bean were determined [19].

One of the most important purposes of bean-related breeding studies is to increase the yield obtained from the unit area [4]. Many studies have reported that modern cultivars had lower levels of key micronutrients and vitamins due to focusing on high yield during domestication and post-domestication [20]. From 1961 to 2016, the mean seed yield of beans considerably increased by an average of 420 kg per ha because of new cultivars and technological applications in commercial production [5]. According to the available literature, there have been many studies to increase yield in the common bean [4] but breeding for protein, minerals, fat and fatty acids has been ignored. In addition to the increased yield of modern varieties, there is also the disadvantage of giving up the use of landraces and thereby causing them to suffer from genetic erosion [21]. Diversity was reduced by the process of domestication based on selection and environments [20]. As landraces are unique genetic resources, the potential of which has not yet been elucidated, there are some issues to be addressed in current and future breeding research. Landraces with their own flavor are produced and consumed by local producers in only a few parts of the world. In terms of food security and a healthy food supply, landraces are significant sources of protein, carbohydrates, vitamins and minerals throughout the world. Therefore, the aim of this study was to examine the protein, fat, fatty acids, Se, Fe and Zn content required for healthy and balanced nutrition, of landraces collected from the highlands of the Western Taurus Mountains, and to compare these values with modern varieties.

2. Results

2.1. Protein Content

Statistically significant differences were detected among accessions for protein content ($P < 0.05$). The protein contents of the landraces (LR) ranged from 16.54% to 25.23%, while the protein contents of the modern varieties (MV) ranged from 19.70% to 24.30%. The highest protein content was in LR05 (25.23%), while the lowest protein content was in LR10 (16.54%). The protein content of some landraces (LR07, LR10 and LR11) was lower than that of the modern varieties (Figure 1).

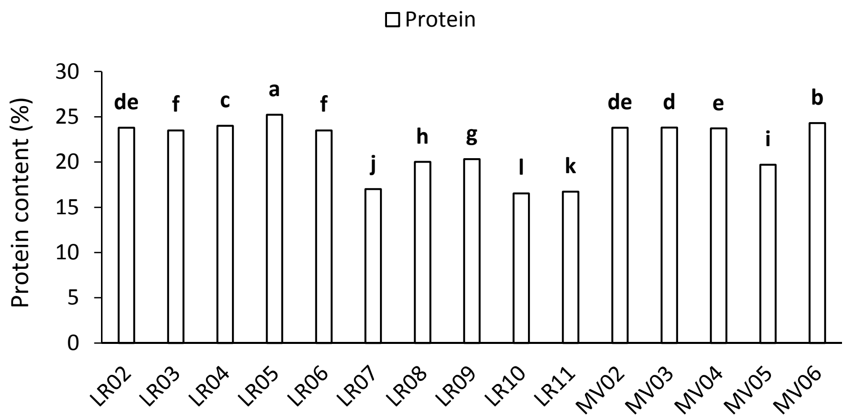

Figure 1. Crude protein of landraces (LR) and modern varieties (MV). Means followed by the same lower-case letters are not significantly different (Duncan's multiple range test (DMRT); $P < 0.05$).

2.2. Fat and Fatty Acids Composition

There were no statistically significant differences among the accessions in respect of fat content, while there were statistically significant differences among the accessions for oleic and linoleic acids ($P < 0.05$). The fat content of the accessions ranged from 0.33% to 1.33%. MV06 had the highest fat content (Figure 2). LR11 (18.60%) had the highest content of linoleic acid, one of the important fatty acids, while MV06 (7.56%) had the lowest linoleic acid content. The landraces (LR11, LR08 and LR06) had higher linoleic acid content than the modern varieties (Figure 2). MV06 (24.30%) had the highest oleic acid content, followed by MV05 (22.41%) and LR02 (22.07%) (Figure 2).

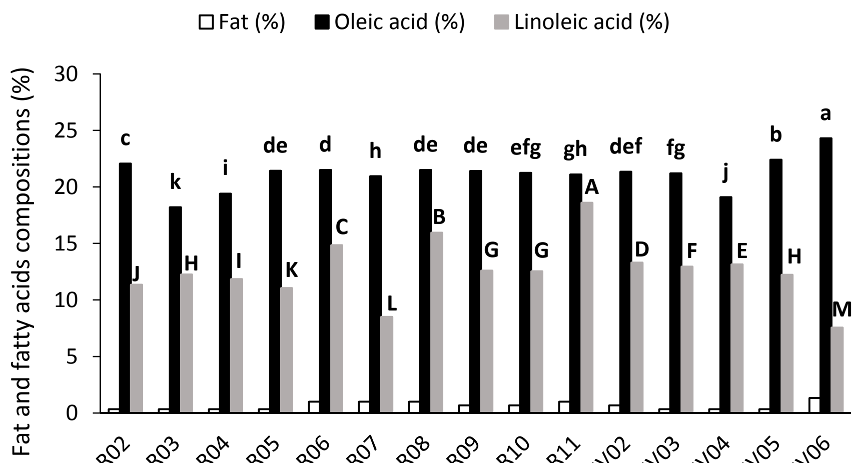

Figure 2. Fat and fatty acids compositions of landraces and modern varieties. Upper-case letters compare the beans for linoleic acid (gray bars), whereas lower-case letters for oleic acid (black bars). Means followed by the same upper- or lower-case letters are not significantly different (DMRT; $P < 0.05$).

Mono-unsaturated fatty acids (MUFA) content ranged from 19.42% to 24.26% in landraces and from 21.90% to 25.86% in modern varieties (Figure 3). The three accessions with the highest MUFA content were MV06 (25.86%), MV05 (24.78%) and LR02 (24.26%), respectively (Figure 3). The polyunsaturated fatty acid (PUFA) content of modern varieties ranged from 49.23% to 55.32%, while landraces ranged from 40.33% to 53.16% (Figure 3). In terms of MUFA and PUFA content, there was no statistically significant difference among the accessions. The majority of landraces and modern varieties had over 50% PUFA content and over 20% MUFA content (Figure 3).

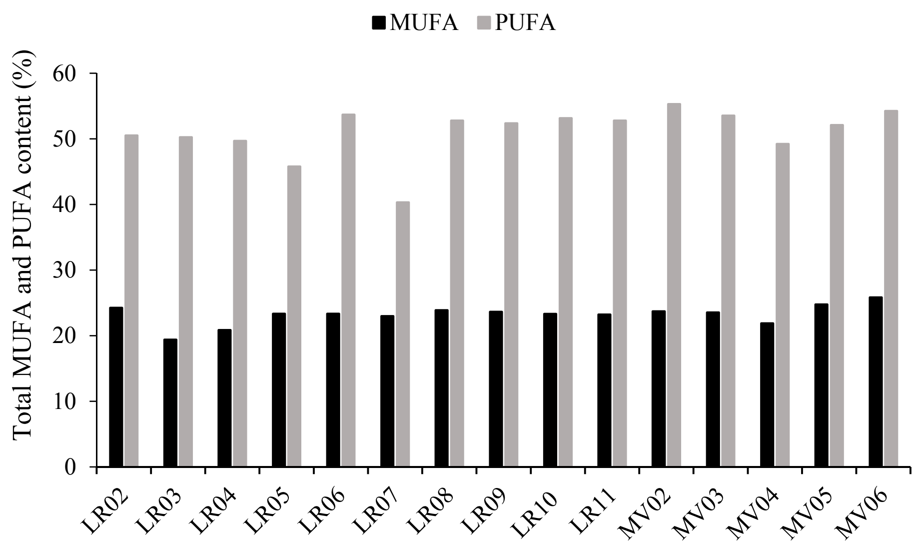

Figure 3. Total mono-unsaturated fatty acids (MUFA) and polyunsaturated fatty acid (PUFA) content of landraces and modern varieties.

2.3. Mineral Contents

Se, Zn and Fe as mineral contents of the seeds of the accessions were determined in landraces and modern varieties. There was a statistically significant difference in Se content between landraces and modern varieties. The landrace LR05 had the highest Se content of 0.48 mg/kg, followed by landrace LR11 at 0.15 mg/kg Se content landrace LR05 was found to be an approximately 2–3-fold higher level than that of the other accessions (Figure 4).

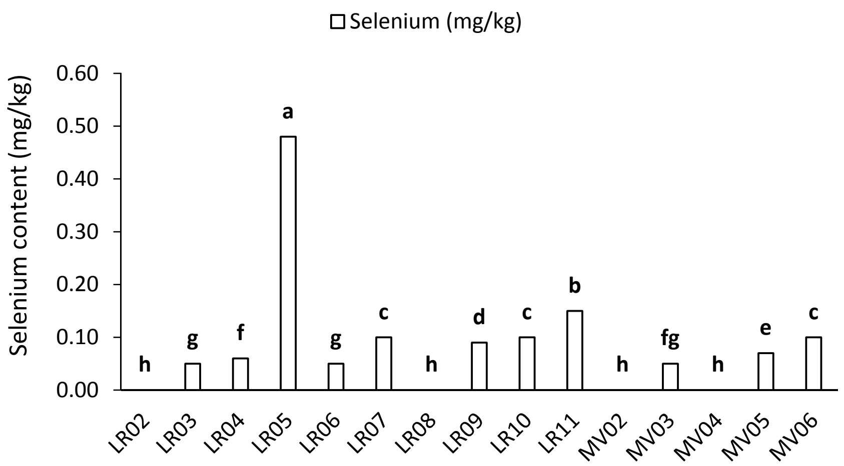

Figure 4. Se contents of landraces and modern varieties. Means followed by the same lower-case letters are not significantly different (DMRT; $P < 0.05$).

The highest Fe content was observed in MV03 (133.64 mg/kg), followed by MV04 (116.31 mg/kg) and LR10 (115.05 mg/kg) (Figure 5).

The Zn content of landraces ranged from 17.81 to 37.90 mg/kg, while it ranged from 25.03 to 35.1 mg/kg in modern varieties. LR05 had the highest Zn content at 37.88 mg/kg (Figure 5).

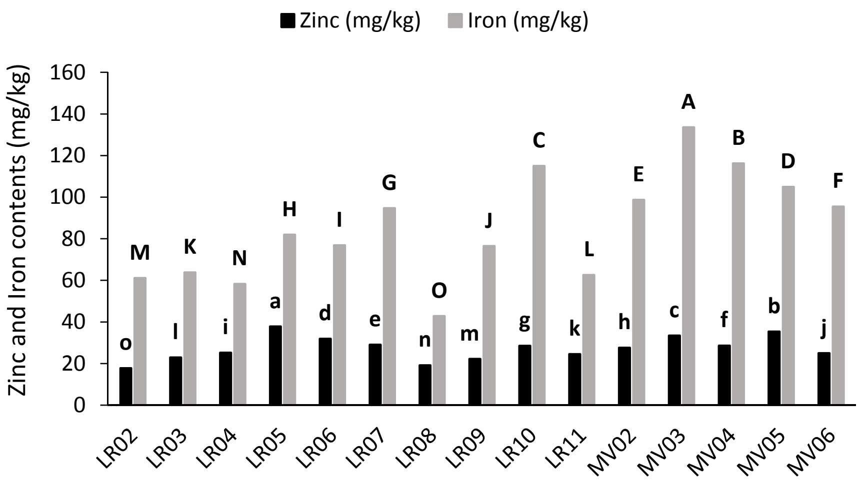

Figure 5. Zn and Fe contents of landraces and modern varieties. Upper-case letters compare the beans for Fe content (gray bars), and lower-case letters for Zn content (black bars). Means followed by the same upper- or lower-case letters are not significantly different (DMRT; $P < 0.05$).

2.4. Correlations

The fat content in the seeds of accessions was positively correlated ($P < 0.01$) with oleic acid (r = 0.531 **), and negatively correlated with protein content (r = −0.368 *). A negative correlation was found between oleic acid and linoleic acid (r = −0.304 *). Se was positively correlated ($P < 0.01$) with Zn (r = 0.541 **), and the highest correlation (r = 0.628 **) was found between Fe and Zn ($P < 0.01$). There was no significant correlation between the 100-seed weight and other traits (Table 1).

Table 1. Correlations among nutritional contents of landraces and modern varieties.

Nutritional Contents	Protein	Fat	Oleic Acid	Linoleic Acid	Selenium	Zinc	Iron
Fat	−0.368 *						
Oleic acid	−0.064	0.531 **					
Linoleic acid	−0.233	−0.091	−0.304 *				
Selenium	0.063	−0.067	0.157	−0.076			
Zinc	0.112	−0.231	0.070	0.015	0.541 **		
Iron	0.009	−0.179	0.120	−0.133	−0.006	0.628 **	
100-seed weight	−0.268	0.189	0.449	−0.338	0.201	0.204	0.303

* and ** indicate that correlation is significant at the 0.05, 0.01 level, respectively.

3. Discussion

Some landraces were determined to have more protein content in their seeds than the modern varieties. The protein content of landraces was determined as 16.54%–25.23%, while the protein content of modern varieties ranged from 19.70%–24.3% Landrace LR05 had the highest protein content at 25.23% (Figure 1). Guzman-Maldonado et al. [13] emphasized that the protein content of the cultivated bean (16.6–24.6 g/kg) was less than that of wild beans (18.8–33.3 g/kg). The protein content of *P. vulgaris* genotypes was reported as between 17.08% and 25.46% [22]. In the present study, the variation of protein content was considerably wider in landraces (16.6%–26.2%) compared to the previously mentioned reports [11,13,22]. Bean protein in the dry seeds of the common bean has been seen to vary from 17% to 35% and consist of five fractions, comprising of globulin-1 (phaseolin), globulin-2, albumin, prolamine and alkali-soluble [23]. These fractions were not examined in the present study but landraces were considered to possess important protein fractions because landraces are preferred by local consumers in the region. Protein content in common beans can be affected by different environments due to the variety of location interactions [24]. On the other hand, the protein content was slightly affected in cooked beans [25].

The fat contents of the modern varieties were between 0.33% and 1.33%, while the fat contents of landraces were between 0.33% and 1.00% (Figure 2). Fat is an important organic acid with a very important place in human nutrition. The fat content was found to be 2.20%–5.03%, linoleic acid content 33% and oleic acid content 9.5% on average [26]. LR11 (18.60%) had the highest content of linoleic acid, one of the important fatty acids, while the modern variety MV06 had the lowest linoleic acid content among the accessions (Figure 2). The oleic acid and linoleic acid content of common bean cultivars was determined as 13.9% and 12.4%, respectively [27]. Salunkhe et al. [28] reported that linoleic and linolenic fatty acids were dominant in the fat of beans. Oleic and linoleic acids in the common bean were determined as 7.8%–13.8% and 16.7%–25.8%, respectively [29]. The oleic acid content in that study was lower than the current study findings, while the linoleic acid content was higher. The content of oleic acid in landraces was found to be higher (Figure 2) than the previous studies [26–29]. Omega fatty acids consisting of linolenic acid (Omega 3), linoleic acid (Omega 6) and oleic acid (Omega 9) help to protect against obesity, strengthen the immune system and prevent cholesterol. Omega fatty acids, in addition to being physiologically and biochemically essential for body functions, also play an important role in healthy tissue development [30]. Pari and Venkateswaran [31], reported that useful fatty acids such as oleic, linoleic and arachidonic acid levels were increased when diabetic rats were fed with beans.

Essential minerals such as Se, Fe and Zn are of great importance for human health [32]. Many researchers have reported that Se has important health benefits such as strengthening the immune system and lowering the risk of cancer [32,33]. There is also evidence that Se deficiency may lead to negative consequences with disease susceptibility [34,35]. In the current study, landrace LR05 had the highest Se content at 0.48 mg/kg and this was found to be an approximately 2–3-fold higher level than that of the other accessions (Figure 4).

Zn content in the landraces ranged from 17.81 to 37.90 mg/kg, while the Zn content in the modern varieties ranged from 25.03 to 35.41 mg/kg (Figure 5). The highest Zn content was determined in landrace LR05 at 37.88 mg/kg. The Zn content of landrace LR05 was higher than the findings of Koehler et al. [16] of 24 ± 38 mg/kg, and higher than the results (17 mg/kg) reported by Guzman-Maldonado et al. [13]. Although the Zn content of landraces was higher than results reported in most previous studies, it was not higher than that of modern cultivars (Figure 4) [16,17]. However, Barampama and Simard [11] reported 7.33 mg Zn per 100 g, which was higher than that of the present study.

Anemia is generally caused by iron deficiency and there are greater numbers of anemic people in developing countries than in Europe and the USA [36,37]. The same researchers also found that 40% of Fe intake was provided by cereals and legumes. In the current study, Fe content was highest in MV03 (133.64 mg/kg), MV04 (116.31 mg/kg) and LR10 (115.05 mg/kg) (Figure 5). In the common bean, Gelin et al. [17] identified Fe content as 86.9 mg/kg among RILs, which was lower than the findings of the current study. The landrace LR10 and some modern varieties (MV03, MV04 and MV05) had a higher Fe content than the contents reported by Koehler et al. [16] and Guzman-Maldonado et al. [13]. These differences could be based on genotypes and environmental conditions. Furthermore, Zn content in the current study was significantly correlated with Se content (r = 0.541 **) and Fe content (r = 0.628 **) (Table 1).

4. Materials and Methods

4.1. Bean Accessions

The seeds of 15 common beans (*Phaseolus vulgaris* L.) comprising 10 accessions of landraces (LR02, LR03, LR04, LR05, LR06, LR07, LR08, LR09, LR10 and LR11) and 5 accessions of modern varieties (MV02, MV03, MV04, MV05, MV06) were evaluated for crude protein, fat, fatty acids, Se, Fe and Zn contents. The landraces were collected from farmers in smallholdings in the Western Taurus Mountains, while the modern varieties were obtained from international seed companies located in Antalya, Turkey. The Mountains are located at the western Mediterranean region of Turkey (at an altitude of 900–1200 m above sea level). The landraces in the target areas were preferred due to having considerable variations and are better preserved by the farmers in smallholdings. Bean accessions were grown in for two years under greenhouse conditions. The greenhouse experiment was conducted as a randomized complete block design with three replications. Plots were arranged as a single row of 2 m length with inter- and intra-row spacing of 50 and 20 cm, respectively. After harvest, air-dried 150 g seeds of each bean accession were ground using hand milling for the following analyses. The analyses were performed in two replicates, and carried out by Food Safety and Agricultural Research Center, Akdeniz University.

4.2. Crude Protein

Crude protein was determined according to the Kjeldahl method, multiplied by the 6.25 ($N \times 6.25$) conversion factor, and the results were then calculated as a percentage (%) according to AOAC [38].

4.3. Fat and Fatty Acids Analyses

The seeds of each common bean accession were subjected to oil extraction using a Dionex Accelerated Solvent Extractor (Dionex ASE 300^{TM}: Sunyvale, CA, USA). The fat content of the seed samples was determined according to the method of Uzun et al. [39]. The composition of fatty acids was determined with thermo trace GC (gas chromatography) ultra (San Jose, CA, USA) and standards were evaluated according to the method of Uzun et al. [39]. The fat and fatty acids of the accessions were reported as percentages (%).

4.4. Mineral Content

Se, Fe and Zn contents were analyzed in the ash solution, using an ICP-MS (Inductively coupled plasma-mass spectrophotometer) (Perkin Elmer ELAN DCR-e equipped with a Scott Spray Chamber 103: Norwalk, CT, USA) as previously described [40], and determined as mg/kg.

4.5. Soil Analyses

According to soil analyses in the greenhouse, organic matter (1.2%) and nitrogen (0.09%) were found to be at a low level. Soil texture, pH and $CaCO_3$ were loam, 8.0 and 17.6%, respectively. Available P, Fe, Zn, Mn and Cu were detected as 24.74, 5.11, 1, 27.74 and 1.26 mg/kg, respectively. Exchangeable K, Ca and Mg were found as 17.6 mg, 652 mg and 14.6 mg/100 g, respectively.

4.6. Statistical Analyses

Data related to the nutritional components, Se, Fe, Zn, were subjected to analysis of variance (ANOVA) with SPSS 22.0 software (SPSS: Chicago, IL, USA). The results were reported as statistics with a value of $P < 0.05$ accepted as statistically significant. Duncan's multiple range test (DMRT) was applied to compare to bean accessions. The different upper- or lower-case letters on the bars indicate significant difference, while the same upper- or lower-case letters are not significantly different ($P < 0.05$). Correlation coefficients (r) of all the nutritional contents were determined using XLTAT 2018 version 2.50918 (Addinsoft: Paris, France).

5. Conclusions

The results of the present study showed that landrace LR05 had better crude protein, Se and Zn content than modern varieties. Landrace LR11 had the highest linoleic acid. These results indicate that the landraces of the common bean are not only treasures that need to be transferred to the future but also genetic resources that can be used in bean breeding programs. The results suggest that landraces are significant sources of important nutritional components for food security and a healthy food supply.

Author Contributions: T.C. wrote a thesis in Turkish, H.S. translated the thesis from Turkish into English and H.C. collected landraces. Plants were grown by T.C., H.S., D.S., A.A. and T.E. Analyses were performed by T.C. and H.S. As the supervisor, T.C. managed the grants that funded this work. All authors read and then approved the final manuscript.

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Conflicts of Interest: We have declared that no conflict of interests.

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