Investigation of Quality and Cooking Traits Diversity in a Global Common Bean Germplasm

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Abstract: Common bean is a nutrient-dense food legume serving a source of food for millions of people all over the world. Quality and cooking traits are considered important criteria for the success and appealability of any crop cultivars to the end-users. In this study, we aimed to explore the cooking and quality-related traits diversity in a world common bean germplasm originated from 10 countries of world. A good range of variations were observed for all studied traits and mean fat, starch and fiber contents were 1.65 %, 42.96% and 9.23%, respectively. Genotype-140 reflected higher swelling capacity, swelling index, hydration capacity, hydration index, seed density and lesser cooking time. Correlation analysis was performed and hydration capacity showed highly significant and positive correlation with hydration index, swelling capacity and swelling index. Principal component analysis (PCA) was performed and 1st five PCs accounted a total of 78.14% variations. Biplot analysis resulted a total of 51.01% variations and studied germplasm was divided on the basis of cooking and quality traits. Constellation plot divided the studied germplasm into two main clustered A and B on the basis of moisture, swelling capacity, seed density and cooking time. Genotype-39 and genotype-20 were found distant for fat contents, while genotype-24 and genotype-120 for starch contents. Therefore, these genotypes are recommended as parents for common bean breeding regarding fat and starch contents. Moreover, genotype-140 showed minimum cooking time, it should be also used as a candidate parent to develop common bean cultivars requiring lesser cooking time to save time and energy. We believe that results presented herein will be very helpful for common bean breeding community interested in quality and cooking traits.

Keywords: *Phaseolus vulgaris*, Starch, Hydration capacity, Swelling capacity, Cooking time.

1. INTRODUCTION

The world is facing with the threat of food insecurity mainly due to global climate change. Along with climate change, uncontrolled increase in world population has also made difficult to produce enough food. About 80 million people from developing countries has not enough to eat due to these uncertainties [1]. World population is estimated to reach 10 billion by 2050. Therefore, it is the dire need to enhance world crop production by 60 to 110% to feed the world in 2050 [2]. Food and Agriculture Organization (FAO) stated that the available daily average per capita calories to the world population were 2789 kcal in 2000 and is expected to be 3130 kcal in 2050. Thus, legume crops play an important role to provide cheap and balanced food in terms of nutrients and calories and minimized the food gaps [3].

Human select food on the basis of cost, convenience, accessibility, quality, taste and nutrition [4]. Common bean (*Phaseolus vulgaris* L.) is an important source of food and feed more than 300 million people throughout the world [5]. Common bean is serving a dietary staple in parts of Africa and Latin America where moderate to high consumption (16–34 kg per capita annually) is common [6]. Common bean remained an underrated crop, still the presence of good amount of proteins, carbohydrates, vitamins and minerals make this crop a suitable food choice worldwide, especially in developing societies [7]. A steady increase in common bean production has been observed as its production was 23 million tons in 2010 and reached 26 million tons in 2016 [8]. Common bean is considered a dietary staple in most parts of the world especially Eastern and Southern Africa and provide protein, iron, zinc and folate [9-10].

Wise use of plant genetic diversity is important in order to fulfill world food demands in an efficient manner [11]. The strategy to explore genetic and phenotypic variation through characterization of crop

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genetic resources is very helpful and the identified variation could be effectively used by the scientific community for various breeding purposes [11-12]. Quality and cooking parameters that impact consumer's preference to some foods should be focused by conducting various breeding activities for these traits. Very limited information is available on the common bean quality and cooking parameters and there is a need to pay more attention on common bean cooking and quality-related traits. It is also believed that variation among the common bean genotypes grown under same soil conditions, fertilizer doze and agronomic practices might be due to their genetic make-up. Identification of bean germplasm containing better cooking qualities along with other nutritional outcomes is very important in the quest [13].

Quality of any food crop is main criteria towards its success to end-users and remained an important aspect of plant breeding. Common bean is considered a good source of protein, fat, carbohydrates, dietary fiber, minerals and antioxidants [7-12-13]. A good numbers of studies has been conducted to characterize the soaking and cooking characteristics of common bean [14-15]. Beside the existence of higher nutritional contents, common bean requires a long time for cooking. Adkins *et al.* [16] revealed that 7–11 kg of fuel wood is required to cook one kg of beans, while less than one kg of fuel wood requires to cook one kg of maize flour. Therefore, common bean genotypes withbetter nutritional quality and reduced cooking time are desirable to save time and energy. Diversity regarding cooking time in common bean is less explored as compared to environmental influences on it. Elia *et al.* [17] found high level of variations for various cooking traits beside the usage of lesser number of common bean genotypes in their study. Review literature suggested that cooking time in common bean is oligo-genic trait with narrow sense heritability ranged from 0.74 to 0.90 [18]. The presence of sufficient amount of genetic variability has been observed for cooking time in common bean. Cooking time of Andean common bean panel comprised 200 genotypes was evaluated that ranged from 16 to 90 min under optimal growing, storage and cooking conditions [13-19]. There is a need to conduct more studies to explore quality and cooking variations potential of common bean. Regarding to this perspective, present study aimed to elucidate quality and cooking traits diversity in a global common bean germplasm of 150 genotypes originated from 10 countries.

2. MATERIALS AND METHODS

2.1. Plant Material and Field Experimentation

A total of 150 common bean genotypes originated from 10 countries were used as plant material to explore the diversity in cooking and quality traits. A total of 98 genotypes originated from nine countries were provided by The United States Department of Agriculture (USDA). A total of 49 landraces were collected from six provinces of Turkey and three commercial cultivars were also included as plant material in this study. Experiment was conducted during 2019 at the Research and Application Area of Sivas Vocational School, Cumhuriyet University (39º 42'31.39' K, 37º 01'13.15' D and 1271 m above the sea level) using augmented block design with three check cultivars. Seeds were sown on 15th May 2019 by hand in elementary plots, each consisting of 2 m-long rows, with a 50 cm inter- and 10 cm intra-row spacing. The experimental site was mainly silt (48.3%) and clay (37.1%) with pH of 7.28 and low in organic matter content (1.7%). A total of 10 plants were maintained in each row after thinning. Ammonium sulfate (51 kg/ha) and Di-ammonium phosphate (DAP: 130 kg/ha) were used as fertilizer source. Three irrigations and hoeings were performed and all other agronomic practices were followed regarding to local conditions.

2.2. Evaluation of Quality and Cooking Traits

2.2.1. Determination of Fat and Starch Contents

Seed fat content of each common bean genotype was determined by following the methodology suggested by Uzun *et al.* [20]. Starch contents were investigated by following the methodology suggested by Ovando-Martínez *et al.* [21]. Fiber content in studied germplasm was calculated according to methodology of Horwitz and Latimer [22].

2.2.2. Determination of Moisture and Ash Contents

Moisture content in world common bean germplasm was investigated by oven drying at 105 °C to constant weight according to methodology suggested by AOAC (Association of Official Analytical Chemists, 2005) [23]. To investigate the ash content, calcination in a furnace at 550 °C was maintained accordingly to protocol suggested by AOAC (Association of Official Analytical Chemists, 2005) [23].

2.2.3. Determination of Hydration Capacity and Hydration Index

A total of 100 g seeds from each genotype was taken and soaked in 100 ml of distilled water in a measuring cylinder. The measuring cylinder was covered with an aluminum foil and left to soak 24 h at room temperature. After 24 hours, seeds were drained and tissue paper was used to remove excessive water. Hydration capacity and hydration index were calculated by following the methodology suggested and followed by Wani*et al.* [14] and Adebowale *et al.* [24].

2.2.4. Determination of Swelling Capacity and Swelling Index

A total of 100 g seeds from each genotype was taken and their volume was predetermined using a graduated cylinder. Seeds were then soaked for 24 h in distilled water. After 24 h, seed volume after soaking was measured and swelling capacity and the swelling index were calculated by following methodology suggested by Wani *et al.* [14] and Adebowale *et al.* [24].

2.2.5. Determination of Seed Density

A total of 100 g seeds from each genotype was taken and transferred to a measuring cylinder and 100 ml distilled water was added. To obtain seed volume (ml/100 g seeds), 100 ml was subtracted from the total volume (ml). Increase in the seed volume was recorded immediately, so that swelling character not a problem. Seed density for each common bean genotype was calculated and recorded as g/ ml [25].

2.2.6. Determination of Cooking Time

Cooking time was recorded by following the methodology reported by] Wani *et al.* [14]. A total of 20 g seeds from each genotype was taken and transferred in to a 500 mL beaker and filled it with distilled water. Boiling process continued and seeds samples (3-5) were withdrawn using a spatula at 5 min intervals upto 30 min and thereafter after every 2 min and tested for softness by pressing between finger and thumb. Total time from the start of boiling process to achieve desirable softness was recorded as the cooking time.

2.3. Statistical Analysis

Various parameters like minimum, maximum, mean, and standard deviation were calculated through statistical software XLSTAT (www.xlstat.com). Same software was used to calculate the Pearson correlation coefficient, principal component analysis (PCA) and bi-plot analysis. The cluster constellation plot for world common bean germplasm was constructed through JMP 14.1.0 statistical software (2018, SAS Institute Inc., Cary, NC, USA).

3. RESULTS

Quality traits like fat, starch, fiber, moisture, and ash contents ranged from 1.131% to 2.178%, 38.170% to 47.814%, 7.180% to 11.767%, 10.0% to 19.0%, and 1.0% to 4.50% with a mean of 1.658%, 42.96%, 9.233%, 10.895%, and 3.025% respectively (Table **1**). Similarly, cooking traits like SC, SI, HC, HI, seed density and cooking time ranged from 0.10 ml/seed to 1.445 ml/seed, 0.090 to 0.533, 0.117g/seed to 1.877 g/seed, 0.161 to 5.469, 0.105g/ml to 3.175 g/ml, and 46.46 minutes to 218.22 minutes with a mean value of 0.279, 0.219, 0.452, 1.288, 0.622 and 114.410 respectively. Maximum and minimum starch contents were observed with genotype-39 and genotype-20, respectively. Genotype-24 and genotype-120 showed maximum and minimum starch contents. Genotype-140

Table 1: Minimum, Maximum, Mean and Standard Deviation of Studied Traits for World Common bean Panel

Traits	Minimum	Maximum	Mean	Std. deviation
Fat (%)	1.131	2.178	1.658	0.256
Starch (%)	38.170	47.814	42.967	1.905
Fiber (%)	7.180	11.767	9.233	0.899
Moisture (%)	10.0	19.0	10.895	1.244
Ash (%)	1.0	4.50	3.025	0.552
Swelling capacity (ml/seed)	0.10	1.445	0.279	0.176
Swelling index	0.090	0.533	0.219	0.078
Hydration capacity (g/seed)	0.117	1.877	0.452	0.261
Hydration index	0.161	5.469	1.288	0.827
Seed density (g/ml)	0.105	3.175	0.622	0.379
Cooking time (Minutes)	46.469	218.222	114.410	34.332

reflected higher swelling capacity, swelling index, hydration capacity, hydration index, seed density and lesser cooking time than the other genotypes.

Correlation coefficients among the various important quality and cooking traits of 150 common bean genotypes are presented in Table **2**. Starch observed significant and positive correlation with fat content. SC, SI, HC, HI, and seed density revealed significant and positive correlations among each other. Principal component analysis was computed for important quality and cooking traits in common bean panel of 150 genotypes. We selected the first five components that accounted 78.419% of the total variation (Table **3**). The first component accounted 36.412% of the variation with highest contribution from SC. The second component observed 14.655% of the variation with highest contribution from fiber. The third component showed 10.466% variation and ash was the highest variation contributing trait. Similarly, the fourth and fifth components revealed 8.901 and 7.984% of the variation with highest contribution from fat and moisture respectively. Bi-plot analysis explained nearly 51% of the total trait variation considering the first two PCs

Table 2: Pearson's Correlation Analysis for Cooking and Quality Traits in World Common Bean Germplasm

Variables	Fat	Starch	Fiber	Moisture	Ash	SC	SI	HC	HI	Seed Density	Cooking Time
Fat	1										
Starch	0.60**	1									
Fiber	0.19	0.13	1								
Moisture	0.33**	0.22	0.12	1							
Ash	0.24	-0.06	-0.33	-0.06	1						
SC	-0.04	-0.12	-0.14	-0.05	0.12	1					
SI	-0.05	-0.13	-0.11	-0.04	0.13	0.82**	1				
HC	-0.09	0.06	0.02	-0.04	0.07	0.77**	0.58**	1			
HI	-0.07	0.03	0.04	-0.09	0.13	0.70**	0.55**	0.86**	1		
Seed Density	-0.10	-0.15	-0.23	-0.10	0.19	0.90**	0.62	0.80**	0.68**	1	
Cooking Time	-0.11	-0.20	-0.18	-0.15	0.02	0.11	0.10	0.02	0.03	0.09	1

**Statistically significant at P ≤ 0.01.

Table 3: Principal Component Analysis for World Common Bean Germplasm

	F1	F2	F3	F4	F5
Fat (%)	-0.057	0.169	0.304	0.870	0.215
Starch (%)	-0.061	0.467	0.292	-0.332	-0.102
Fiber (%)	-0.087	0.504	-0.438	0.162	-0.112
Moisture (%)	-0.062	0.382	0.289	-0.289	0.725
Ash (%)	0.106	-0.302	0.658	-0.057	-0.200
Swelling capacity (ml/seed)	0.471	0.027	-0.015	0.069	0.145
Swelling index	0.400	-0.001	-0.021	0.083	0.191
Hydration capacity (g/seed)	0.444	0.202	-0.050	-0.055	-0.091
Hydration index	0.420	0.189	-0.036	-0.009	-0.188
Seed density (g/ml)	0.459	-0.038	0.040	-0.003	0.012
Cooking time (minutes)	0.061	-0.428	-0.328	-0.073	0.513
Eigenvalue	**4.005**	**1.612**	**1.151**	**0.979**	**0.878**
Variability (%)	**36.412**	**14.655**	**10.466**	**8.901**	**7.984**
Cumulative %	**36.412**	**51.066**	**61.533**	**70.434**	**78.419**

(Figure **1**). Bi-plot analysis distinguished the common bean genotypes based on their cooking and quality traits. Constellation plot analysis implemented in JMP software divided the evaluated common bean genotypes into two main populations on the basis of their moisture, swelling capacity, seed density and cooking time (Figure **2**). Population A covered total of two genotypes and rest of genotypes were clustered in population B.

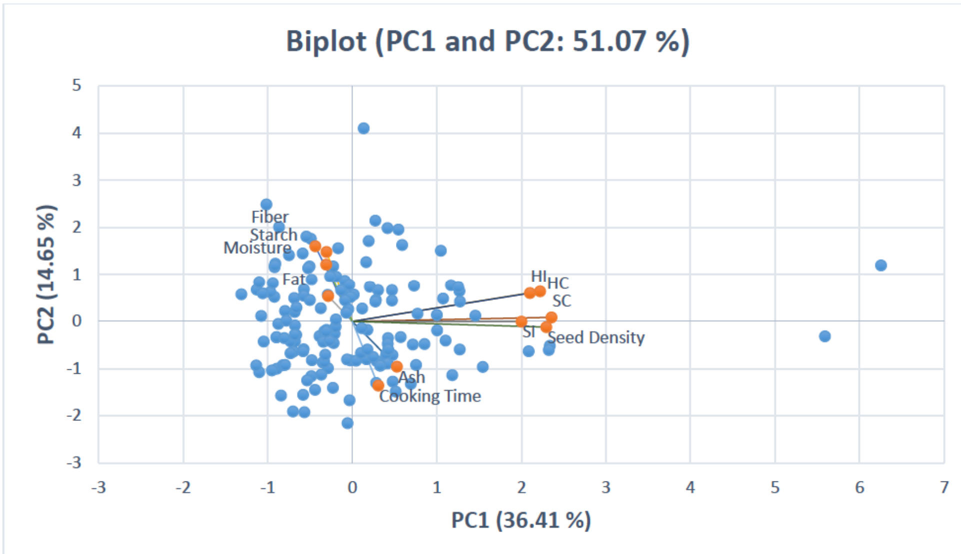

Figure 1: Bi-plot analysis for quality and cooking traits of world common bean germplasm.

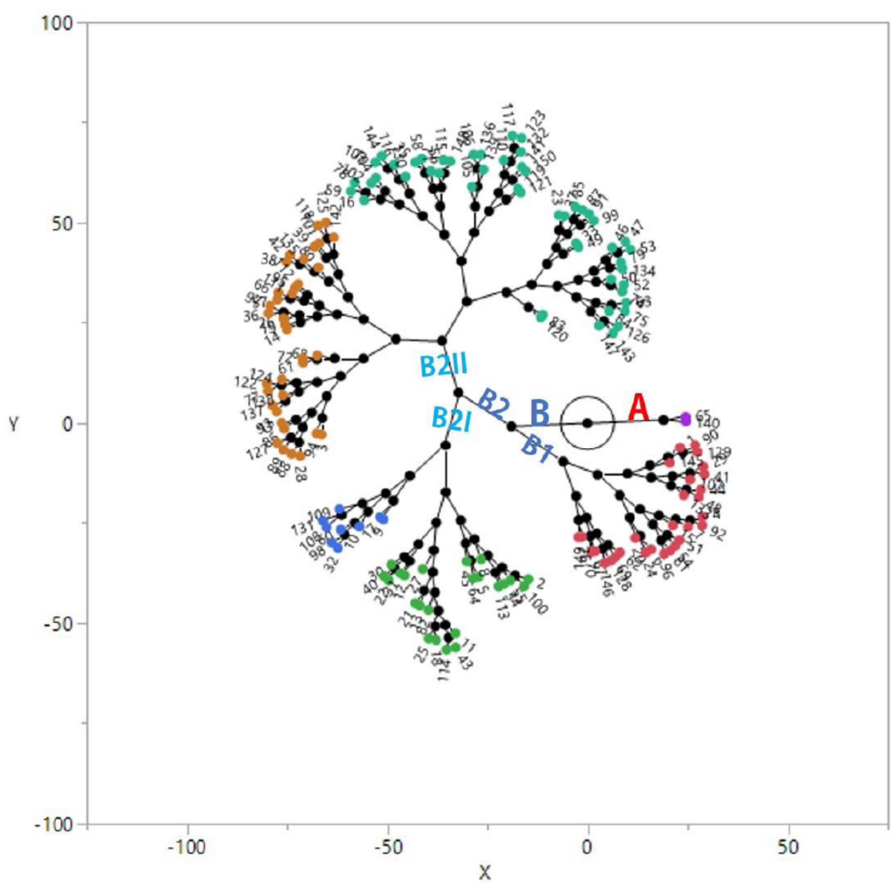

Figure 2: Constellation plot of quality and cooking traits in world common bean germplasm.

4. DISCUSSION

4.1. Diversity in Quality Traits

Quality traits are very important aspects regarding to end-users interest and appealability towards food crops. Efforts are ongoing to improve the quality and cooking traits of food legumes. Common bean contains good concentration of protein and considered as “poor man's meat”. This study aimed to explore the variations for quality and cooking traits in a world common bean germplasm. All studied traits reflected a good level of variations that will be helpful for common bean breeding activities in near future. Fat content in human diet has highly significant and direct effect on human health. Fats provide essential fatty acids called linoleic and linolenic acid and body cannot make them it self. Common bean is considered a great source of fatty acid, and range of fat contents found in this study were high than the reported byprevious studies [26-27]. Starch is an important carbohydrate in the human diet and play an important role in the exogenous supply of glucose and the total food energy intake. Marquezi *et al*. [28] found starch contents in range of 39.68 to 43.78% while we found starch contents in a range of 38.17-47.81%. Similarly starch contents found in this study were higher than reported by earlier studies [29-30]. Dietary fiber is considered rich food products as they are associated with various physiological actions in the small and large intestine. Dietary fiber promotes various beneficial physiological effects like laxation, and or blood cholesterol attenuation. Similar to protein, starch and fat, common bean is considered a good source of dietary fiber as well. Range and mean fiber contents resulted in this study were found low than the previous studies [26-31].

Range and mean moisture contents observed in this study were found higher than earlier studies [26]. Wani *et al.* [14] found 10.0% to 10.2% moisture contents, while we found 10.0%-19.0% moisture contents. Range of ash contents observed in this study was found higher compared to previous studies [14]. Ash contents found in this study were much similar to the reported by Brigide *et al.* [26]. All of quality traits observed in this study showed higher values than the reported by previous studies. This might be due to differences in germplasm, number of samples and climatic conditions. As all of studied traits reflected good level of variation, it is a time to conduct multi-year/environment field trials of common bean to evaluate stable and superior genotypes for traits of interest. As some genotypes were found distinct for fat (Genotype-39 and genotype-20) and starch(Genotype-24 and genotype-120), these genotypes should be used as candidate parents for common bean breeding regarding fat and starch contents.

4.2. Cooking Traits Diversity

During this study, a total of six cooking traits were studied and all studied traits reflected a good level of variations in world common bean germplasm. Ranges of swelling capacity and swelling index were higher than the reported by previous studies [14-32]. Higher values of swelling index revealed the higher swelling ability of genotype-140. The higher swelling capacity in any genotype is considered ideal in the preparation of soups, puddings, and sauces [33]. The swelling ability of any seed depends upon its water retention capacity or hydration capacity. Hydration capacity explains the extent to which seeds absorb water on soaking. Hydration capacity depends on chemical composition of seed coat and cotyledons [34]. Ranges and mean hydration capacity and hydration index resulted in this study were higher than the previous studies [14-32-]. Genotypes having higher hydration capacity result in better cooking quality (less cooking time and texture). Genotype-140 resulted maximum hydration capacity and can be used as candidate parent for common bean breeding. According to Nciri *et al.* [33], genotypes having higher swelling capacities can be ideal in the preparation of soups, puddings, and sauces, therefore genotype-140 will be ideal for these perspectives as well. Mean and range of seed density observed in this study were found higher than the previous studies [33-35].

Cooking time is one of the important factor used for evaluating cooking quality in pulse crops. Moreover, cooking time is important in view of the energy requirements associated with cooking and energy being a major issue in developing nations where beans are largely consumed. Result of this study showed higher variations for cooking time compared to previous studies [14-35]. Maximum hydration and swelling coefficients were resulted by genotype-140. It was reported that the legumes having the higher hydration and swelling coefficients require less cooking time. Therefore, these genotypes will be very helpful to develop common bean genotypes with lower cooking time. As is obvious from above results, there were good variations in studied germplasm for various cooking traits. These variation might be due to seed size, seed coat thickness, protein contents and water absorption characteristics of seeds.

4.3. Correlation, PCoA and Constellation Plot Analysis

During this study, fat content reflected highly significant and positive correlations with starch, moisture and ash content. Hydration capacity showed highly significant and positive correlations with hydration index, swelling capacity and swelling index. Previous studies [36-37] also reported a positive and significant correlation of hydration capacity and swelling capacity. First five principal component analysis (PCA) accounted a total of 78.14% variation. First two PCs accounted a total of 51.07% variations and maximum variation were contributed by swelling capacity and fiber. Correlation analysis and PCA have been used earlier as a selection criteria to evaluate the best performing genotypes [38]. To select common bean genotypes having lesser cooking time, swelling capacity and hydration capacity should be used as selection criteria. Biplot analysis resulted a total of 51.01% variations and studied germplasm was divided on the basis of cooking and quality traits. Constellation plot divided the studied germplasm into two main clustered A and B on the basis of moisture, swelling capacity, seed density and cooking time (Figure **2**). Only two genotype clustered in population A. A total of 148 genotypes were clustered in population B. Population B was further divided into B1 and B2. B1 was found smaller compared to B2 and clustered genotypes having higher cooking time. Subpopulation B2 was further clustered and B2I and B2II on the basis of their swelling capacity and cooking time.

Germplasm characterization facilitate the scientific community to investigate novel phenotypic and genotypic variations that can be helpful for the breeding perspectives [39-42]. Common bean is an important legume crop and source of food for millions of people [43-45]. Therefore, more studies should be conducted to explore the nutritional potential of this crop. As is obvious from above discussed results, we observed a good range of variations for quality and cooking traits. Genotype-39 and genotype-20 were found distant for fat content, while genotype-24 and genotype-120 for starch content. Therefore, these genotypes are recommended as parents for common bean breeding regarding fat and starch contents. Moreover, genotype-140 showed minimum cooking time, it should be also used as a candidate parent to develop common bean cultivars requiring lesser cooking time to save time and energy. We believe that results presented herein will be very effective to develop common bean genotypes having higher nutritional value and take lesser cooking time.

REFERENCES

[1] Khush GS, Lee S, Cho JI, Jeon JS. Biofortification of crops for reducing malnutrition. Plant Biotechnol Rep. 2012; 6(3): 195-202. https://doi.org/10.1007/s11816-012-0216-5

[2] Tilman D, Balzer C, Hill J, Befort BL. Global food demand and the sustainable intensification of agriculture. PNAS. 2011. 108(50): 20260-4. https://doi.org/10.1073/pnas.1116437108

[3] Jensen ES, Peoples MB, Boddey RM, Gresshoff PM, Hauggaard-Nielsen H, Alves BJ, Morrison MJ. Legumes for mitigation of climate change and the provision of feedstock for biofuels and biorefineries. A review. Agron Sustain Dev. 2012; 32(2): 329-64. https://doi.org/10.1007/s13593-011-0056-7

[4] Furst T, Connors M, Bisogni CA, Sobal J, Falk LW. Food choice: a conceptual model of the process. Appetite. 1996; 26(3): 247-66. https://doi.org/10.1006/appe.1996.0019

[5] Petry, N.; Boy, E.; Wirth, J.; Hurrell, R. The potential of the common bean (Phaseolus vulgaris) as a vehicle for iron biofortification. Nutrients. 2015; 7: 1144-1173. https://doi.org/10.3390/nu7021144

[6] Akibode CS, Maredia MK. Global and regional trends in production, trade and consumption of food legume crops. 2012.

[7] Celmeli T, Sari H, Canci H, Sari D, Adak A, Eker T, Toker C. The nutritional content of common bean (Phaseolus vulgaris L.) landraces in comparison to modern varieties. Agronomy 2018; 8: 166. https://doi.org/10.3390/agronomy8090166

[8] Food and Agriculture Organization. FAO Statistical Yearbook. 2016. Available online: http://www.fao.org/docrep/017/i3138e/i3138e.pdf

[9] Joshi PK, Rao PP. Global pulses scenario: status and outlook. Annals of the New York Academy of Sciences. 2017; 1392(1): 6-17. https://doi.org/10.1111/nyas.13298

[10] Sparvoli F, Laureati M, Pilu R, Pagliarini E, Toschi I, Giuberti G, Fortunati P, Daminati MG, Cominelli E, Bollini R. Exploitation of common bean flours with low antinutrient content for making nutritionally enhanced biscuits. Frontiers in Plant Science. 2016; 27(7): 928. https://doi.org/10.3389/fpls.2016.00928

[11] Nadeem MA, Karaköy T, Yeken MZ, Habyarimana E, Hatipoğlu R, Çiftçi V, Nawaz MA, Sönmez F, Shahid MQ, Yang SH, Chung G. Phenotypic characterization of 183 Turkish common bean accessions for agronomic, trading, and consumer-preferred plant characteristics for breeding purposes. Agronomy. 2020; 10(2): 272. https://doi.org/10.3390/agronomy10020272

[12] Nadeem MA, Gündoğdu M, Ercişli S, Karaköy T, Saracoğlu O, Habyarimana E, Lin X, Hatipoğlu R, Nawaz MA, Sameeullah M, *et al*. Uncovering Phenotypic Diversity and DArTseq Marker Loci Associated with Antioxidant Activity in Common Bean. Genes 2020; 11: 36. https://doi.org/10.3390/genes11010036

[13] Cichy KA, Wiesinger JA, Mendoza FA. Genetic diversity and genome-wide association analysis of cooking time in dry bean (Phaseolus vulgaris L.). Theoretical and applied genetics. 2015; 128(8): 1555-67. https://doi.org/10.1007/s00122-015-2531-z

[14] Wani IA, Sogi DS, Wani AA, Gill BS. Physical and cooking characteristics of some Indian kidney bean (Phaseolus vulgaris L.) cultivars. Journal of the Saudi Society of Agricultural Sciences. 2017; 16(1): 7-15. https://doi.org/10.1016/j.jssas.2014.12.002

[15] Wani IA, Sogi DS, Gill BS. Physical and cooking characteristics of black gram (P haseolusmungoo L.) cultivars grown in I ndia. International journal of food science

& technology. 2013; 48(12): 2557-63. https://doi.org/10.1111/ijfs.12249

[16] Adkins E, Tyler E, Wang J, Siriri D, Modi V. Field testing and survey evaluation of household biomass cookstoves in rural sub-Saharan Africa. Energy for sustainable development. 2010; 14(3): 172-85. https://doi.org/10.1016/j.esd.2010.07.003

[17] Elia FM, Hosfield GL, Kelly JD, Uebersax MA. Genetic analysis and interrelationships between traits for cooking time, water absorption, and protein and tannin content of Andean dry beans. Journal of the American Society for Horticultural Science. 1997; 122(4): 512-8. https://doi.org/10.21273/JASHS.122.4.512

[18] Jacinto-Hernandez C, Azpiroz-Rivero S, Acosta-Gallegos JA, Hernandez-Sanchez H, Bernal-Lugo I. Genetic analysis and random amplified polymorphic DNA markers associated with cooking time in common bean. Crop science. 2003; 43(1): 329-32. https://doi.org/10.2135/cropsci2003.3290

[19] Wiesinger JA, Cichy KA, Glahn RP, Grusak MA, Brick MA, Thompson HJ, Tako E. Demonstrating a nutritional advantage to the fast-cooking dry bean (Phaseolus vulgaris L.). Journal of agricultural and food chemistry. 2016; 64(45): 8592-603. https://doi.org/10.1021/acs.jafc.6b03100

[20] Uzun B, Arslan C, Karhan M, Toker C. Fat and fatty acids of white lupin (Lupinusalbus L.) in comparison to sesame (SesamumindicumL.). Food Chemistry. 2007; 102(1): 45-9. https://doi.org/10.1016/j.foodchem.2006.03.059

[21] Ovando-Martínez M, Bello-Pérez LA, Whitney K, Osorio-Díaz P, Simsek S. Starch characteristics of bean (Phaseolus vulgaris L.) grown in different localities. Carbohydrate polymers. 2011; 85(1): 54-64. https://doi.org/10.1016/j.carbpol.2011.01.043

[22] Horwitz W. Official methods of analysis of AOAC International. Volume I, agricultural chemicals, contaminants, drugs/edited by William Horwitz. Gaithersburg (Maryland): AOAC International, 1997; 2010.

[23] Association of Official Analytical Chemists - AOAC. (2005). Official methods of analysis of the Association Analytical Chemists (18th ed.). Maryland: AOAC.

[24] [24]Adebowale YA, Adeyemi A, Oshodi AA. Variability in the physicochemical, nutritional and antinutritional attributes of six Mucuna species. Food chemistry. 2005; 89(1): 37-48. https://doi.org/10.1016/j.foodchem.2004.01.084

[25] Bishnoi S, Khetarpaul N. Variability in physico-chemical properties and nutrient composition of different pea cultivars. Food chemistry. 1993; 47(4): 371-3. https://doi.org/10.1016/0308-8146(93)90179-J

[26] Brigide P, Canniatt-Brazaca SG, Silva MO. Nutritional characteristics of biofortified common beans. Food Science and Technology. 2014; 34(3): 493-500. https://doi.org/10.1590/1678-457x.6245

[27] Barampama Z, Simard RE. Nutrient composition, protein quality and antinutritional factors of some varieties of dry beans (Phaseolus vulgaris) grown in Burundi. Food Chemistry. 1993; 47(2): 159-67. https://doi.org/10.1016/0308-8146(93)90238-B

[28] Marquezi M, Gervin VM, Watanabe LB, Bassinello PZ, Amante ER. Physical and chemical properties of starch and flour from different common bean (Phaseolus vulgaris L.) cultivars. Brazilian Journal of Food Technology. 2016; 19. https://doi.org/10.1590/1981-6723.0516

[29] Pujolà M, Farreras A, Casañas F. Protein and starch content of raw, soaked and cooked beans (Phaseolus vulgaris L.). Food Chemistry. 2007; 102(4): 1034-41. https://doi.org/10.1016/j.foodchem.2006.06.039

[30] Chung HJ, Liu Q, Pauls KP, Fan MZ, Yada R. *In vitro* starch digestibility, expected glycemic index and some physicochemical properties of starch and flour from common bean (Phaseolus vulgaris L.) varieties grown in Canada. Food Research International. 2008; 41(9): 869-75. https://doi.org/10.1016/j.foodres.2008.03.013

[31] Rezende AA, PACHECO MT, SILVA VS, FERREIRA TA. Nutritional and protein quality of dry Brazilian beans (Phaseolus vulgaris L.). Food Science and Technology. 2018; 38(3): 421-7. https://doi.org/10.1590/1678-457x.05917

[32] Saha S, Singh G, Mahajan V, Gupta HS. Variability of nutritional and cooking quality in bean (Phaseolus vulgaris L) as a function of genotype. Plant foods for human nutrition. 2009; 64(2): 174-80. https://doi.org/10.1007/s11130-009-0121-4

[33] Nciri N, El-Mhamdi F, Ismail HB, Mansour AB, Fennira F. Physical properties of three white bean varieties (Phaseolus vulgaris L.) grown in Tunisia. Journal of Applied Science and Agriculture. 2014; 9: 195-200.

[34] Bewley, J.D., Black, M., Halme, P., 2006. The Encyclopedia of Seeds: Science, Technology and Uses. CABI, Wallingford, UK, pp 81.

[35] Shimelis EA, Rakshit SK. Proximate composition and physico-chemical properties of improved dry bean (Phaseolus vulgaris L.) varieties grown in Ethiopia. LWT-Food Science and Technology. 2005; 38(4): 331-8. https://doi.org/10.1016/j.lwt.2004.07.002

[36] Owusu KD, Newman CF, Gabriel AG. Evaluation of Physical and Cooking Characteristics of Five Improved Lima Beans. World. 2018; 2(2): 38-43. https://doi.org/10.11648/j.wjfst.20180202.13

[37] Saba I, Sofi PA, Baba ZA. Natural variation for seed physical, biochemical and culinary traits in common bean (Phaseolus vulgaris L.). Current Botany. 2015: 1-8. https://doi.org/10.19071/cb.2015.v6.2820

[38] Ali F, Yilmaz A, Chaudhary HJ, Nadeem MA, Rabbani MA, Arslan Y, Nawaz MA, Habyarimana E, Baloch FS. Investigation of morphoagronomic performance and selection indices in the international safflower panel for breeding perspectives. Turkish Journal of Agriculture and Forestry. 2020; 44(2): 103-20. https://doi.org/10.3906/tar-1902-49

[39] Yildiz M, Kocak M, Nadeem MA, Cavagnaro P, Barboza K, Baloch FS, Argün D, Keleş D. Genetic diversity analysis in the Turkish pepper germplasm using iPBS retrotransposonbased markers. Turkish Journal of Agriculture and Forestry. 2020; 44(1): 1-4. https://doi.org/10.3906/tar-1902-10

[40] Arystanbekkyzy M, Nadeem MA, Aktas H, Yeken MZ, Zencirci N, Nawaz MA, Ali F, Haider MS, Tunc K, Chung G, Baloch FS. Phylogenetic and taxonomic relationship of turkish wild and cultivated emmer (triticum turgidum ssp. dicoccoides) revealed by iPBSretrotransposons markers. International Journal of Agriculture and Biology. 2019; 21(1): 155-63.

[41] Ali F, Yılmaz A, Nadeem MA, Habyarimana E, Subaşı I, Nawaz MA, Chaudhary HJ, Shahid MQ, Ercişli S, Zia MA, Chung G. Mobile genomic element diversity in world collection of safflower (Carthamus tinctorius L.) panel using iPBS-retrotransposon markers. PloS one. 2019; 14(2): e0211985. https://doi.org/10.1371/journal.pone.0211985

[42] Barut M, Nadeem MA, Karaköy T, Baloch FS. DNA fingerprinting and genetic diversity analysis of world quinoa germplasm using iPBS-retrotransposon marker system. Turkish Journal of Agriculture and Forestry. 2020: 44.

[43] Nadeem MA, Habyarimana E, Çiftçi V, Nawaz MA, Karaköy T, Comertpay G, Shahid MQ, Hatipoğlu R, Yeken MZ, Ali F, Ercişli S. Characterization of genetic diversity in Turkish common bean gene pool using phenotypic and whole-genome DArTseq-generated silicoDArT marker information. PloS one. 2018; 13(10): e0205363. https://doi.org/10.1371/journal.pone.0205363

[44] Yeken MZ, Nadeem MA, Karaköy T, Baloch FS, Çiftçi V. Determination of Turkish Common Bean Germplasm for Morpho-agronomic and Mineral Variations for Breeding Perspectives in Turkey. Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi. 2019; 22: 39-51.

[45] Aydin MF, Baloch FS. Exploring the genetic diversity and population structure of Turkish common bean germplasm by the iPBS-retrotransposons markers. Legume Research-An International Journal. 2019; 42(1): 18-24. https://doi.org/10.18805/LR-423

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