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Variation in cooking quality traits in Phaseolus bean germplasm from Western Anatolia

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Abstract. Cooking quality is one of the main bean breeding objectives after yield and stress tolerance. Local bean landraces have usually superior cooking quality. An experiment was carried out in order to investigate i) the variations in the cooking quality traits in pre–breeding collection of 60 *Phaseolus sp* landraces from Western Anatolia provinces and ii) cooking time in relation with other cooking quality traits. There was a considerable variation in the variables tested within the germplasm of cooking time (26.0–100.0 min), dry weight (19.0–61.8 g), wet weight (37.00–129.15 g), hydration capacity (0.19–0.67 mL), hydration index (0.73–2.12%), dry volume (60.00–100.00 mL), wet volume (135.00–218.00 mL), swelling capacity (0.20–0.85 mL), swelling index (1.69–9.00%), cooking time (26.00–100.00 min), protein content (19.30–30.00%) and seed color. There was fourfold variation in cooking time. Cooking time was significantly correlated with protein content (r=0.732, P<0.01) and had close relationship with main seed color and dry volume. In UPGMA Cluster dendrogram, cooking time, protein content, swelling index, hydration index and main seed color formed closely related sub group. In conclusion, there was a considerable variation in the cooking quality traits investigated in the core collection of beans. There was four–fold difference within landraces for cooking time, which can be used for breeding bean cultivars with short cooking times. Cooking time in the landraces investigated was associated with protein content, main seed color and swelling index.

***Keyword**:* Heirloom, Common beans, Landraces, Cooking time.

Introduction

Common beans (*Phaseolus vulgaris* L.) are globally the most important legume species [AOAC, 1984]. Dry seeds are importance source of protein, fibre, calorie, thiamine, niacin, calcium and iron in diets. Long term storable seeds and nutritional advantages make dry beans the most consumed legume species.

Achieving high seed yields are usually primary objective in bean breeding programs in different parts of the world [SHELLIE–DESSERT and BLISS, 1991]. Cooking quality and consumer acceptability are often given a lesser importance in breeding programs. Thus, during search for higher seed yield, genetic material possessing superior cooking quality and taste traits are either underutilized or discarded at initial stages of breeding programs. High yielding advanced lines from breeding programs are commonly subjected to cooking quality tests later that are pre–requested by Seed Testing and Registration Bodies. Initial tests for coking quality at the beginning of breeding program may lead to the development of high yielding lines with good cooking quality traits. Local landraces are usually favored primarily for their taste, culinary quality and shorter cooking times [WANG et al, 2017] rather than yield potential per se. Screening local landraces for superior cooking quality may produce high yielding bean cultivars that will advertently possess also enhanced cooking quality traits.

Cooking quality is a complex characteristic affected by cooking time, impermeable seed coat, the hard–to–cook trait, seed size, seed shape, seed color, protein content, taste, palatability and storability [WANG et al, 2017; CICHY et al, 2015; KİNYANJUİ et al, 2017]. Cooking quality may also depend on cultivar properties, location, soil factors, environmental factors and storage conditions [WANG et al, 2017; CICHY et al, 2015; KİNYANJUİ Et al, 2017].

Seed Testing and Registration Body in Turkey requires during variety registration application procedures that dry weight, wet weight, hydration capacity, hydration index, dry volume, wet volume, swelling capacity, swelling index, cooking time and protein content be tested. An experiment was carried out in order to investigate i) the variations in the cooking quality traits in pre–breeding collection of *Phaseolus sp* landraces from Western Anatolia provinces and ii) cooking time in relation with other cooking quality test variables that may be used for the development of superiors cooking quality cultivars.

Material and methods

Plant Materials. A pre–breeding core collection of 54 landraces selected from a germplasm of 291 accessions collected from farmers' fields of 16 provinces of Western Anatolia in Turkey (Table 1) on the bases of phenological, morphological and agronomical observations by the cultivar evaluation criteria developed by IPGRI (International Plant Genetic Resources Institute) and EU–CPVO (European Union Community Plant Variety Office) were investigated in comparison with 6 registered cultivars in 2017 (Table 1).

Table 1.

Phaseolus sp. landraces tested for cooking quality collected from Western Anatolia provinces and commercial cultivars

Accession No.	Source
BRS–3,4,21,22,23,24/ YLV–14,28,31,32	Bursa/Yalova
BLKSR–3,4,19/ ÇNK–2,4,6,8	Balıkesir/ Çanakkale
DZC–2,3/ BLCK–7/ ISPT–3,4,6/ IZM–2,4	Düzce/ Bilecik/ Isparta/İzmir
ANT–8,22,31/ BRD–2,24,25,26	Antalya/Burdur
AYD–1,2,6,14/ DNZL–2,3,9	Aydın/Denizli
KTH–3,4,9,17,25,26,27,28	Kütahya
MNS–5,6,8/ UŞK–1/ MGL–4,30,43	Manisa/ Uşak/Muğla
Göynük, Özayşe, Kantar–05, Helda, Önceler *	Commercial cultivar

* seed from two different sources

Seeds from single plants representing each landrace were harvested after which seed samples were stored at room temperature for approximately 10 days until seeds reached around 12% moisture content, then maintained in a cold chamber at 4 ºC until use for laboratory analyses.

Following cooking quality tests were then carried out under laboratory conditions by the instructions of Turkish Variety Registration and Seed Certification Center [VRSCC, 2001].

Cooking Quality Tests

Dry weight (g). Weight of 100 seeds from each landrace were recorded.

Dry volume (mL). A sample of 100 seeds was filled to a graduated cylinder to which 50 mL distilled water was added and volume of dry seeds were measured.

Wet weight (g). Weight of 100 seeds soaked in distilled water for 16 hours were taken after rinsing water remaining.

Wet volume (mL). 100 seeds soaked in distilled water for 16 hours were transferred to a graduated cylinder to which 100 mL distilled water was added and wet volume was measured.

Swelling index (SI). Calculated as

$$SI = (\text{Wet volume} - 100) / (\text{Dry volume} - 50)$$

Swelling capacity (SC) (mL seed[1]). Calculated as following;

If there are hard seeds (non–swelling seeds);

$$SC\ (mL\ seed^{-1}) = [Y - (X - ((X/100) * N_2))] / (N_1 - N_2)$$

If there are no hard seeds;

$$SC\ (mL\ seed^{-1}) = (Y - X) / 100$$

Y= Wet volume–100, X= Dry volume–50, N_1= Number of original seeds (100 seeds), N_2= Number of hard seeds (non–swelling seeds)

Hydration index (HI) (%). Calculated using the formula as;

$$HI = Swelling\ capacity / (Dry\ volume - 50)$$

Hydration capacity (HC) (g seed⁻¹). Calculated using the formula as;

If there are hard seeds (non–swelling seeds);

$$HC\ (g\ seed^{-1}) = [Y - (X - ((X/100) * N2))] / (N1 - N2)$$

If there are no hard seeds;

$$HC\ (g\ seed^{-1}) = (Y - X) / 100$$

Y= Wet weight, X= Dry weight, N_1= Number of original seeds (100 seeds), N_2= Number of hard seeds (non–swelling seeds)

Cooking time (minute). 100 seeds soaked in water for 16 hours are put into boiling water in stainless steel cooking pot. Boiling was continued and seeds were withdrawn using a spatula at 5 minutes' intervals up to 30 minutes, and tested for softness by pressing between finger and thumb [SINGH et al, 1984].

When the desirable softness of seeds was obtained, the cooking time was recorded.

Protein (%). Protein (N) content in the ground samples was determined by using a Kjeldahl device [AOAC, 1984].

The nitrogen values were multiplied by using 6.25 coefficients to calculate crude protein ratio.

Main Seed Colour. Main seed colour was recorded by IPGRI (International Plant Genetic Resources Institute) and EU–CPVO (European Union Community Plant Variety Office).

Statistical analysis. Regression analysis of protein content and cooking time of landraces were analyzed using with SPSS 23 statistical package [SPSS, 2015]. Correlation and principal component analyses (PCAs) were performed for all data in XLSTAT 2016 statistical software (Addinsoft, New York, USA).

Components with greater than 1 Eigen value were taken into consideration. Additionally, UPGMA cluster and biplot analysis were performed using XLSTAT 2016 statistical software (Addinsoft, New York, USA) [XLSTAT, 2016].

Results and Discussion

There was a considerable variation in cooking quality variables tested within the germoplasm of 60 landraces and cultivars (Table 2).

Table 2.

Cooking quality parameters investigated of 60 *Phaseolus sp* Landraces and cultivars from Western Anatolia Provinces

Cooking Quality Parameters	Min.	Max.	Mean	Variation (%)	SE	SD
Dry Weight (g)	19.000	61.810	38.344	225.32	1.306	10.114
Wet Weight (g)	37.000	129.150	79.847	249.05	2.753	21.321
Hydration Capacity (mL)	0.194	0.673	0.431	246.91	0.014	0.107
Hydration Index (%)	0.738	2.125	1.141	187.94	0.028	0.214
Dry Volume (mL)	60.000	100.000	80.467	66.67	1.310	10.144
Wet Volume (mL)	135.000	218.000	174.767	61.48	2.607	20.193
Swelling Capacity (mL)	0.204	0.850	0.457	316.67	0.019	0.145
Swelling Index (%)	1.692	9.000	2.719	431.91	0.184	1.422
Cooking Time (min)	26.000	100.000	46.000	284.62	2.623	20.316
Protein Content (%)	19.300	30.000	23.228	55.44	0.365	2.830
Main Seed Colour *	1.000	9.000	2.000	–	0.253	1.957

*47 white, 1 grey, 1 yellow, 1 black, 5 dark yellow and 5 brown. SE= Standard Error of Mean, SD=Standard Deviation

Cooking time ranged between 26.0 min and 100.0 min with an average of 46.0 min (Table 2). Dry weight varied also from 19.0 g to 61.8 g. Other parameters significantly varied as in wet weight (37.00–129.15 g), hydration capacity (0.19–0.67 mL), hydration index (0.73–2.12%), dry volume (60.00–100.00 mL), wet volume (135.00–218.00 mL), swelling capacity (0.20–0.85 mL), swelling index (1.69–9.00%), cooking time (26.00–100.00 min) and protein content (19.30–30.00%) (Table 2).

47 of landraces and cultivars had white seed, one landrace each for grey, yellow, black, 5 had dark yellow and 5 had brown seed (Table 2).

The largest variation was recorded swelling index, swelling capacity and cooking time followed by Wet Weight, Hydration Capacity, Dry Weight, Hydration Index, Dry Volume, Wet Volume, Protein Content (Table 2).

The first 4 components with Eigen value above one explained 88.48 % of cumulative overall variance (Table 3).

Table 3.

Factor loadings for the cooking quality parameters of *Phaseolus sp* landraces and cultivars collected from western Anatolia provinces

Cooking Quality Parameters	Factor Loadings			
	PC1	PC2	PC3	PC4
Dry Weight (g)	0.977	–0.031	–0.082	–0.159
Wet Weight (g)	0.992	0.017	0.008	–0.058
Hydration Capacity (mL)	0.927	0.082	0.211	0.259
Hydration Index (%)	–0.165	0.143	0.568	0.770
Dry Volume (mL)	0.684	–0.526	0.420	–0.253
Wet Volume (mL)	0.975	0.110	0.074	–0.090
Swelling Capacity (mL)	0.796	0.535	–0.115	0.194
Swelling Index (%)	0.155	0.802	–0.472	0.224
Cooking Time (min)	0.213	–0.735	–0.464	0.276
Protein Content (%)	0.286	–0.648	–0.431	0.401
Main Seed Colour	–0.011	–0.385	0.181	0.203
Eigenvalue	5.027	2.354	1.226	1.126
Variability (%)	45.697	21.404	11.146	10.239
Cumulative %	45.697	67.101	78.247	88.486

Contributions of all characteristics in the component PC1 and PC4 were positive whereas it was varied in PC2 and PC3.Wet weight (0.992) and dry weight (0.977) had the highest Eigen values in the first component while swelling index (0.802) and cooking time (–0.735) in the second component (Table 3).

Hydration index (0.568) and swelling index (0.472) had the highest Eigen value in the third component. Hydration index (0.770) and protein content (0.401) had the highest value in the fourth component (Table 3).

Considering the strongest correlations and the contribution of each quantitative characteristic among the components, it is concluded that wet weight and dry weight and were positively correlated with the first component.

Swelling index was positively correlated in the second component, but cooking time and protein content was negatively correlated in the second component.

Considering the highest contributions to the components, PC1 could be termed as “weight axis”, PC2 “swelling axis”, PC3 “hydration axis” and PC4 “protein content axis” (Table 3).

Cooking time was highly positively correlated with protein content (r=0.732, P<0.01) (Table 4). Regression analysis of cooking time and protein content was significant (R^2=0.580, P<0.001) (Figure 1). Cooking time increased as protein content of landraces increased (Figure 1).

Although significant at P<0.05, cooking time was weakly correlated with swelling index (r=–0.273) and dry volume (r=0.267) (Table 4). Cooking time was not correlated with other variables investigated (Table 4).

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Table 4.

Pearson's correlation coefficient of cooking quality parameters of 60 Phaseolus sp. landraces and cultivars from Western Anatolia provinces

Cooking Quality Parameters	DW	WW	HC	HI	DV	WV	SC	SI	CT	PC	MSC*
Dry Weight (DW)	1	0.973**	0.852**	–0.334**	0.687**	0.943**	0.739**	0.129	0.232	0.261*	–0.046
Wet Weight (WW)		1	0.905**	–0.201	0.685**	0.979**	0.774**	0.16	0.183	0.238	–0.015
Hydration Capacity (HC)			1	0.196	0.617**	0.884**	0.799**	0.144	0.116	0.239	–0.048
Hydration Index (HI)				1	–0.13	–0.186	0.012	–0.037	–0.169	–0.062	0.047
Dry Volume (DV)					1	0.659**	0.155	–0.57**	0.267*	0.269*	0.162
Wet Volume (WV)						1	0.817**	0.202	0.064	0.129	0.015
Swelling Capacity (SC)							1	0.645**	–0.118	–0.003	–0.133
Swelling Index (SI)								1	–0.273*	–0.224	–0.177
Cooking Time (CT)									1	0.732**	0.225
Protein Content (PC)										1	0.099
Main Seed Colour											1

MSC= Main Seed Colour * $P<0.05$, ** $P<0.01$

Dry weight and wet weight were both positively correlated with dry volume, wet weight, wet volume, hydration capacity, swelling capacity and dry volume with significant Pearson's Correlation Coefficients (r= 0.687–0.973, $P<0.001$) (Table 4).

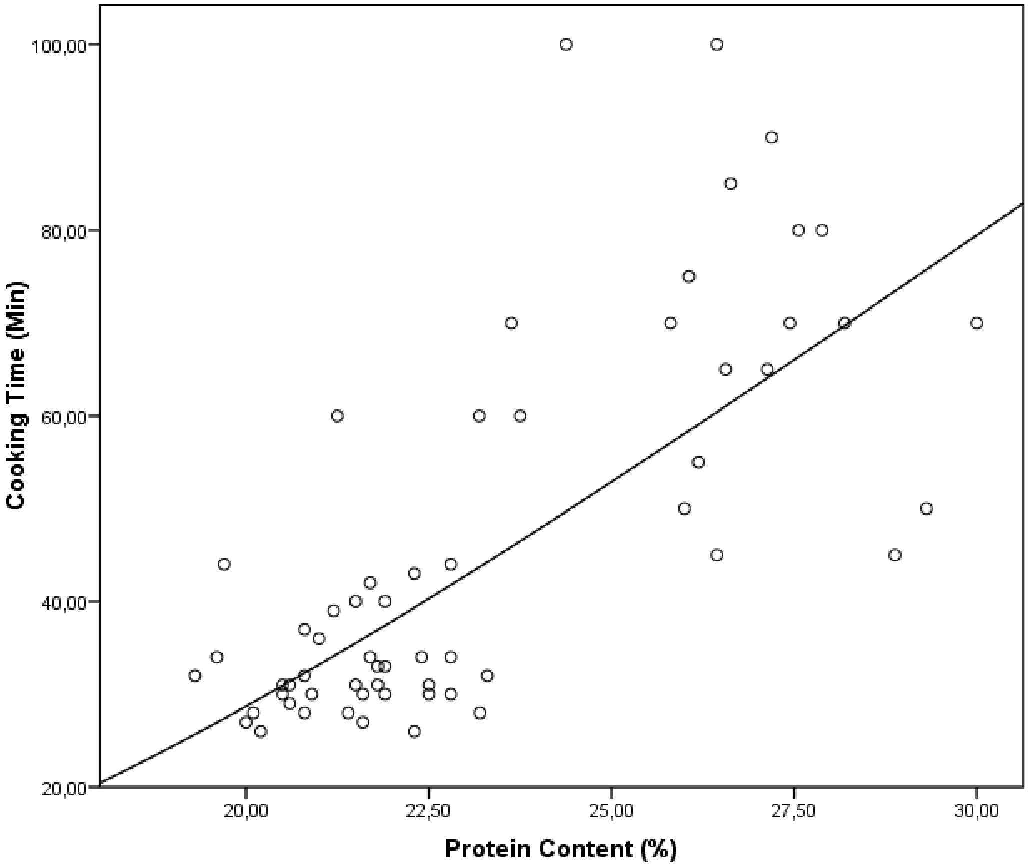

Figure 1. Regression analysis of protein content and cooking time of landraces from Western Anatolia provinces (R^2=0.580, $P<0.001$).

PCA diagram showed that protein content had the highest positive and parallel effect on cooking time followed by dry volume and main seed colour (Figure 2). Swelling index and swelling capacity had opposing and negative effect on cooking time (Figure 2). Dry weight, wet weight, hydration capacity and wet volume had also weakly negative effect on cooking time (Figure 2).

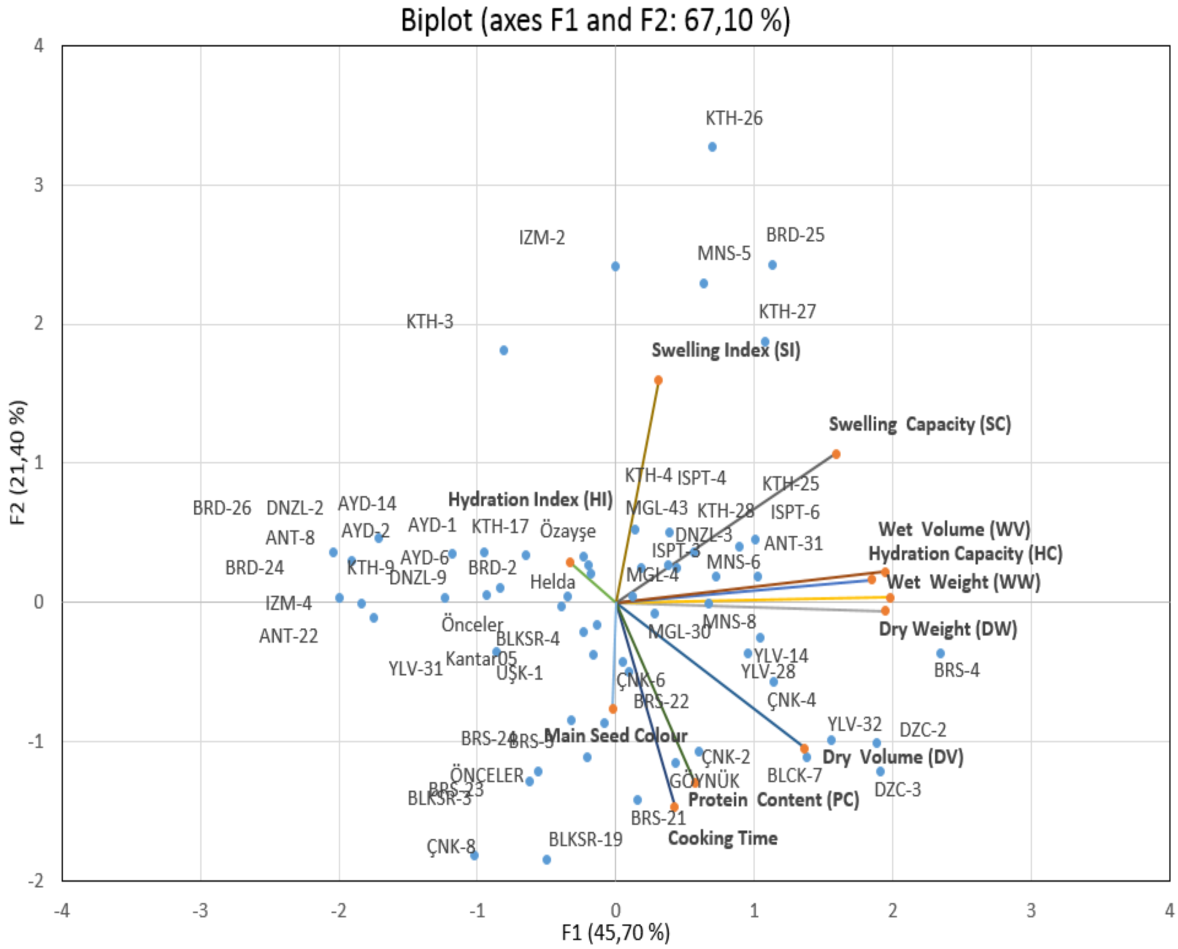

Figure 2. Principle Component Analysis and biplot of cooking quality parameters of *Phaseolus sp* landraces collected from Western Anatolia provinces

Cluster analysis of cooking quality variables produced two main groups (Figure 3). Each main group had two subgroups (Figure 3).

Cooking time, protein content, swelling index, hydration index and main seed color formed closely related sub group (Figure 3).

Dry volume, swelling capacity, hydration capacity, dry weight, wet weight and wet volume formed the most distant sub group to the sub group where coking time was placed (Figure 3). Protein content and cooking time were the most related subgroups (Figure 3).

Cooking quality is one of the important breeding objectives after yield and stress tolerance in dry beans. High yield potential and abiotic and biotic stress tolerance are traits that are important for farmers while culinary/quaking quality is important for consumers. A breeding program must meet also the expectations of consumers [SHELLIE–DESSERT and BLISS, 1991].

Cooking quality is influenced by several traits of bean seeds. Grain size, testa colour, hard seed coat, water absorption capacity, mechanical damage to seed coat, protein content and cooking time [SHELLIE–DESSERT and BLISS, 1991].

Since it is affected by several factors, cooking quality needs several methods of testing depending on the trait serving for the aim of consumer [SHELLIE–DESSERT and BLISS, 1991; WOOD, 2017]. Seed Testing and Registration Body in Turkey requires during variety registration application procedures that dry weight, wet weight, hydration capacity, hydration index, dry volume, wet volume, swelling capacity, swelling index, cooking time and protein content be tested. These tests are expected to reveal cooking quality of lines and candidate cultivars.

The data presented in the experiment revealed valuable information to compare the relationship and relative importance of the test parameters in selecting superior bean accessions for cooking quality. Of the cooking quality variables, dry weight and wet weight were both correlated with dry volume, wet volume and swelling capacity.

Seed weight and seed volume are closely related seed size attributes. Swelling capacity also indicates the relative increase in seed volume upon soaking [WOOD, 2017]. In our study, seed weight ranging from 19.0 g to 61.8 g was of normal distribution representing a wide variation. Seed size parameters of weight and volume were not significantly correlated with cooking time. In cluster dendrogram, cooking time was in the same group with protein content, swelling index, hydration index and main seed color (Figure 3).

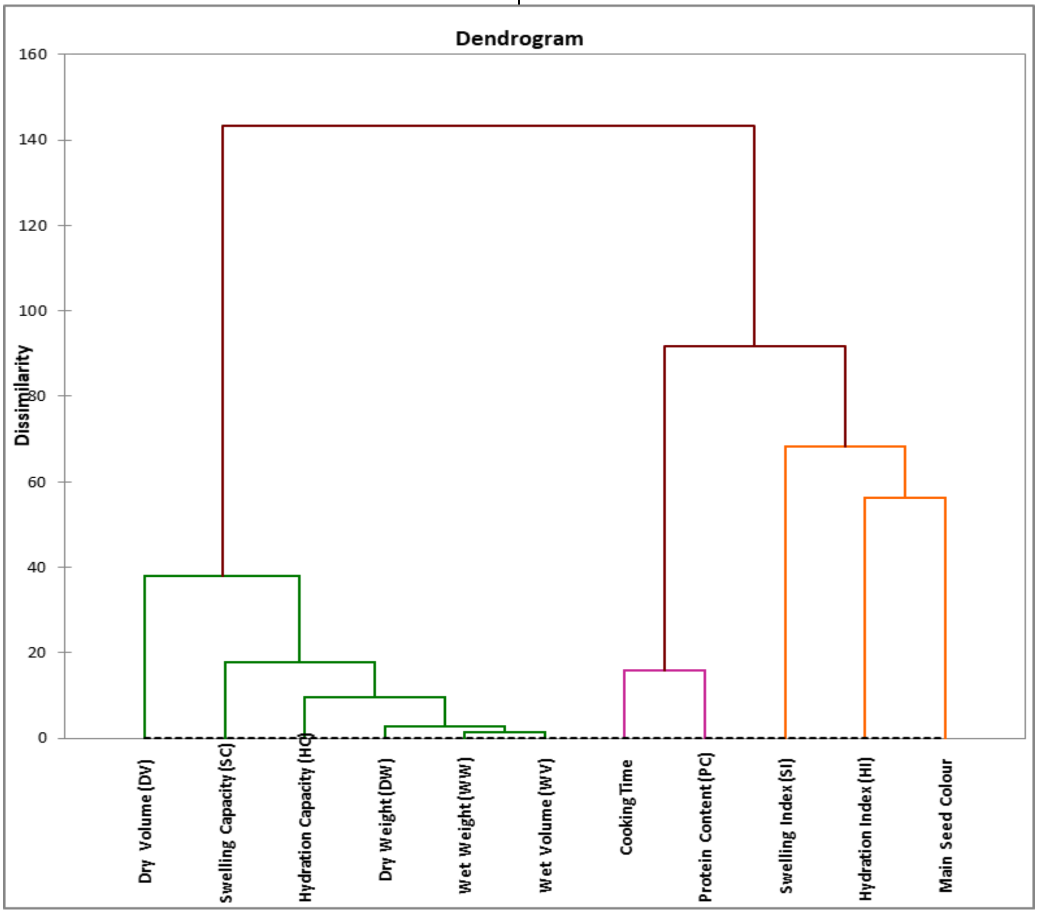

Figure 3. Cluster dendogram of cooking quality variables of 60 *Phaseolus sp* landraces from Western Anatolia provinces

In principle component analysis, dry weight, wet weight and wet volume were not positively or negatively related to cooking time (Figure 2). Swelling Capacity was however positively correlated with seed dry weight (0.739, $P<0.01$) and wet weight (0.774, $p<0.01$) although not correlated with cooking time (Table 4). In another study, seed weight and water uptake were not also correlated with cooking time [CICHY et al, 2015]. Cooking time was not correlated also with seed type as cranberry, white, yellow, mottled, speckled, kidney, cranberry etc. [CICHY et al, 2015]. Hydration capacity, an indication of the percent increase in seed weight on soaking, and hydration index were the variables closely related with seed water absorption capacity [WOOD, 2017].

In our tests, hydration index was not correlated with other cooking quality parameters. Hydration capacity was correlated with wet volume, swelling capacity and dry volume (r=0.884, r=0.799 and r=0.617 P<0.01 respectively). Hydration capacity and swelling capacity closely related formed subgroup consisting both characteristics in cluster dendrogram.

PCA analysis however showed that swelling index and swelling capacity had opposing effect on cooking time. Garcia and collab. investigating QTL mapping for the cooking time of common beans reported that there was no correlation between water absorption and cooking time [GARCIA et al, 2012]. Cooking time is the most important factor affecting the consumption of beans. Consumers prefer cultivars with shorter cooking times [SHELLIE–DESSERT and BLISS, 1991]. Recent studies focused on the genetic diversity and QTL mapping of cooking time in dry beans [CICHY et al, 2015; GARCIA et al, 2012]. Cooking time was a polygenic character Jacinto–hernandeez and collab. [JACINTO–HERNANDEZ et al, 2003] with a high heritability coefficient (0.739) [GARCIA et al, 2012; BRESSANI, 1983]. Cichy and collab. reported a fivefold diversity in cooking time in 206 *Phaseolus vulgaris* accessions and determined SNPs associated with cooking time [CICHY et al, 2015]. In another study, minimum cooking time was 22 min [GARCIA et al, 2012].

In our tests, cooking time varied between 26.0 min and 100.0 min with an average of 46.0 min representing a fourfold difference that may be exploited in a breeding program. In this experiment with 60 landraces of Phaseolus beans, cooking time was positively correlated with protein content (r=0.732, P<0.01) although in other studies cooking time was negatively correlated with protein content [WANG et al, 2017].

Cooking time was most closely related characteristic to protein content and seed color in cluster dendogram. In principle component analysis, protein content, main seed color and dry volume were however most closely related variables with cooking time.

Conclusions

In conclusion, there was a considerable variation in the cooking quality traits investigated in the core collection of beans. There was four–fold difference within landraces for cooking time, which can be used for breeding bean cultivars with short cooking times.

Cooking time in the landraces investigated was associated with protein content, main seed color and swelling index. Seed dry weight was correlated with hydration capacity and swelling capacity but not with cooking time. The data presented in the experiment revealed valuable information to compare the relationship and relative importance of the test parameters in selecting superior bean accessions for cooking quality.

Declaration of conflict of interests

The authors report that they have no other financial or personal relationships that could inappropriately influence or bias the content of the paper.

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