

# Natural variation for seed physical, biochemical, and culinary traits in common bean (*Phaseolus vulgaris* L.)

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## ABSTRACT

A total of 20 genotypes of common bean including 17 breeding lines were evaluated for various seed physical, nutritional, and culinary traits viz., seed color, seed shape, seed brilliance, seed coat pattern, seed length, seed breadth, and seed weight, traits protein content, phytic acid, raffinose, water absorption percentage, coat percentage, swelling, and hydration coefficient as well as cooking score. Most of the genotypes were kidney shaped with plain seed coat and medium seed brilliance. Among biochemical traits, the highest protein content was recorded for Arka Anoop (22.15%) followed by WB-341 (21.45%), WB-216 (21.16%), and WB-249 (20.99%). Low phytic acid was recorded in WB-970 (0.440%), WB-258 (0.968%), and WB-102 (1.068 %). Low values for raffinose was recorded for WB-102 (3.800 mg/g) followed by WB-482 (3.833 mg/g). Highest water absorption percentage was recorded for WB-249 (136.363), Arka Anoop (131.818), and SFB-1 (126.923). The swelling coefficient was the highest in the case of WB-642 (300.000), WB-249 (266.667), and WB-335 (250.000), whereas the lowest values for swelling coefficient were recorded in case of WB-341 (114.285), WB-216 (145.454), and WB-1006 (124.554). Among correlations between various seed physical, biochemical and culinary traits, raffinose was positively and significantly correlated with phytic acid. Phytic acid was also significantly and positively correlated with protein, coat proportion, and 100-seed weight. Coat proportion was negatively correlated water absorption percentage, swelling coefficient, hydration coefficient as well as cooking time score. Cooking time score was positively correlated with hydration and swelling coefficients as well as seed weight but negatively correlated with coat proportion.

**KEY WORDS:** Anti-nutritional factors, common bean, culinary traits, nutritional traits

## INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is the most important food legumes of the genus *Phaseolus* and accounts for about 85% of all the *Phaseolus* species grown over the world and is the second most important commercial legume crop after Soybean. It is also known as Dry bean, Green bean, Snap bean, String bean, Wax bean, Field bean, French bean, Pinto bean, Haricot bean, Kidney bean, Black bean, Turtle bean, Navy bean, Great Northern bean, etc. It is the most widely distributed and consumed legume species of the genus *Phaseolus* (Freyt and Debouck, 2002). There are five cultivated species of the genus *Phaseolus* namely the common bean (*P. vulgaris*), the yearlong bean (*Phaseolus polyanthus*), the runner bean (*Phaseolus coccineus*), the

tepary bean (*Phaseolus acutifolius*), and the lima bean (*Phaseolus lunatus*). Among these five domesticated species, the common bean (*P. vulgaris*) accounts for more than 85% of the cultivated crop worldwide and is by far the most widely consumed grain legume in the world. It is grown in both subtropical and temperate regions throughout the world under varied farming systems. Even though cereals comprise the bulk of agricultural production, pulses mainly common bean constitute an important component of the diet due to being a nearly complete food and deeply rooted in food habits and culture. Common bean locally called as *Rajmash* is usually cultivated at higher elevations in hilly states of North and North East. In the northern India, they are largely cultivated in Chamba, Kinnaur, Rajouri, Bhaderwah, Kishtwar, Uri, Kupwara, Shopian, etc.

Quality is an important aspect of common bean breeding. The value of common bean as a component of the diet is due to its being a cheap source of protein. Like other legumes, it supplies ample quantity of proteins. The largest fraction of bean proteins is made up by storage proteins, which contribute to up to 80% of the total protein. Storage proteins are represented by phaseolin and legumin (7S and 11S globulins, respectively) and the APA proteins comprising  $\alpha$ -Amylase inhibitor, Phytohemagglutinin, Arcelin, a group of lectin-related polypeptides. All the protein types except the legumins are glycoproteins. Among the different fractions phaseolins are most abundant accounting for about 50%, followed by APA proteins (15%) and legumins (10%).

However, common bean also contains certain anti-nutritional factors such as phytic acid that chelates iron and reduces its bioavailability as well as raffinose that causes flatulence. Phytic acid (myo-inositol-1, 2, 3, 4, 5, 6-hexakisphosphate) is considered to be the most abundant storage form of phosphorus present in food grains. Phytic acid is accumulated in the bean seeds within single-membrane storage organelles called as protein bodies. These are mostly complexed with minerals (K, Mg, Ca, Fe and Zn) and are known as phytins (Raboy, 1997). Phytic acid represents from 65% to 85% of the total seed P (Reddy *et al.*, 1989). As a polyanion, phytate is an effective chelator of positively charged molecules and has the potential to form stable insoluble complexes with minerals and proteins. These complexes confer to phytate its notorious anti-nutritional properties, which are particularly important for the humans and non-ruminants, such as poultry, swine, and fish that lack the hydrolytic enzyme phytase in their digestive tract and excrete a large fraction of these phytin salts (Cheryan, 1980). Moreover, the amount of phytate that breaks down during the storage of common beans appears to be the most important trait in the development of the hard to cook phenomenon (Coelho *et al.*, 2007).

Many higher plants accumulate raffinose during seed maturation. These carbohydrates consist of Gal units linked to Sucrose via  $\alpha$ -(1 $\rightarrow$ 6) glycosidic linkages. raffinose family oligosaccharides (RFOs) have been proposed to act as protective agents during desiccation and storage of seeds in the dry state (Obendorf, 1997), although there is no evidence for a causal relationship between their accumulation and the acquisition of desiccation tolerance (Bentsink *et al.*, 2000; Buitink *et al.*, 2000). Although RFOs have long been regarded as anti-nutritional factors in human nutrition, recent data support a beneficial role of RFOs as so-called prebiotics, by specifically stimulating the

growth of remedial gut bacteria. Along with indigestible starch, RFOs (raffinose, stachyose, and verbascose) may lead to digestive upset. The human digestive system lacks  $\alpha$ -galactosidase that breaks the  $\alpha$ ,1,6-linkages in raffinose oligosaccharides. As a result, these oligosaccharides pass on to lower intestines where enteric bacteria degrade them to hydrogen, methane, and carbon dioxide which are expelled as flatus. However, breeding for lower raffinose is a tricky situation for plant breeders as it provides membrane stability to seeds in cold wet soils during germination when seeds are rehydrating especially in white seeded beans.

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. Reducing carbon footprints through reduced cooking time is a strong ecological rationale for using this trait while developing varieties. In fact, the most energy-demanding process in the whole market chain is probably cooking. Even in countries like the USA, where agriculture is almost entirely mechanized, and production consumes large amounts of energy, 48% of energy in the food chain is spent in industrial processing and home cooking. Cooking common bean has a particularly high energy requirement because of its relatively long cooking time. Therefore, breeding for short cooking time emerges as a consumer-preferred trait in the developing world. The procedure of evaluation of common bean genotypes for cooking time by CIAT in Cali, Colombia, is based on a cooking time index derived from a bardrop cooker (Jackson and Varriano-Marston, 1981). Although a useful and reliable technique, it is laborious and time-consuming for a large number of samples. It has been suggested that the amount of water dry beans absorb during soaking before cooking may be a reliable indicative of the amount of time required to render them soft and palatable to eat. Hence, the water absorption of a genotype may be a useful and rapid indirect selection method to screen germplasm for cooking time. A large number of studies have been undertaken to assess the variation among the genotypes for various seed traits including water absorption for screening material for seed culinary properties (Krista and Hosfield, 1991; Santalla *et al.*, 1999 and Vakali *et al.*, 2009, Sofi *et al.*, 2014).

## MATERIALS AND METHODS

The present study was carried out during 2014-2015 at Regional Research Station Wadura. 20 genotypes of common bean including 17 breeding lines representing diverse market classes and three released varieties were evaluated for various seed physical properties viz., seed

color, seed shape, seed brilliance, seed coat pattern, seed length, seed breadth, and seed weight. Among nutritional traits, protein content was estimated and among antinutritional factors phytic acid and raffinose were estimated. Among seed culinary traits, water absorption percentage, coat percentage, swelling, and hydration coefficient as well as cooking score were estimated. The three varieties used in the present study were Shalimar Rajmash-1, Shalimar French Bean-1, and Arka Anoop. Shalimar Rajmash-1 is a pulse type variety, whereas Shalimar French Bean-1 is a vegetable type variety released by SKUAST-K. Arka Anoop is a variety released by IIHR, Bangalore. The methodologies used are detailed as below.

### Seed Physical Parameters

Seed length and breadth was measured using vernier calliper and averaged across five representative seeds for each genotype. 100-seed weight was calculated on a randomly drawn sample of 100 sun-dried seeds and averaged across three samples.

### Protein Content

Protein content was estimated using Near Infrared Reflectance Spectroscopy (CROP SCAN 2000G) facility at Seed Technology Laboratory of SKUAST-K. It is a quick and non-destructive method for estimation of protein content.

### Phytic Acid

Phytic acid content was estimated according to modified Haug and Lantzsch (1983) method. The determination was based on the indirect spectrophotometric determination of phytic phosphorus in dry bean extracts. Phytic acid was precipitated by addition of ferric ammonium sulfate. Part of iron forms insoluble ferric phytate, and the remaining iron was determined spectrophotometrically. Calibration curve was prepared by series of standard solutions of the sodium salt of the phytic acid. All reagents were of analytical grade procured from HIMEDIA. 0.5 g of powdered sample was extracted with 100 ml of 2.4% HCl during 3 h with constant stirring. The extract was filtered through Whatman No 41 filter paper. 0.5 ml of extract was transferred into a glass tube with stopper, ammonium iron (III) - sulfate solution (0.2 g of  $\text{NH}_4\text{Fe}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$  dissolved in 100 ml of 2 mol/L HCl and filled to mark with distilled water) was added. The closed glass tube was held in boiling water bath for 30 min, cooled in refrigerator for 15 min and left to attain room temperature. Tube was centrifuged at 3000 r/min. About 1 ml of supernatant was transferred to another glass tube and 1.5 ml of 2,2'-bipyridine solution (10 g 2,2'-bipyridine dissolved

in 10 ml thioglycolic acid and filled to mark with distilled water) was added. After exactly defined time, absorbance was measured at 519 nm.

### Cooking Time

The procedure of cooking in an autoclave followed the method described by Revilla and Vivar-Quintana (2008), with modifications. A total of 50 soaked grains were placed in a glass beaker, filled with 200 mL of distilled water, covered with watch glass, and cooked under the conditions 110°C for 5 min. The following scale was used for scoring cooking properties of bean genotypes.

Scale	Designation	Description
1	Undercooked	Grain is difficult or not able to smash and cotyledon feels hard
2	Slightly undercooked	Grain is less difficult to smash and cotyledon feels slightly hard
3	Average cooked	Grain is firm but smashes easily and cotyledon feels soft
4	Slightly overcooked	There is little resistance to smash grain and cotyledon feels mushy
5	Overcooked	Grain is easily pressed into a mush

### Raffinose

Raffinose was estimated using the Megazyme Kit (Megazyme Inc., Ireland). The basic principle of the estimation of raffinose is based on enzymatic reactions using  $\alpha$ -galactosidase and invertase. The raffinose was estimated spectrophotometrically at 510 nm.

### Water Absorption Percentage

Seed water absorption parameters were calculated as per the procedure of Bishnoi and Khetarpaul, 1993. The moisture contents of the dry bean samples were equilibrated to each other before analysis of water absorption by storing them for 2 weeks in sealed plastic containers at ambient temperatures and relative humidity. The percent water absorption was determined by the first soaking 30 seeds for 24 h in deionized water at room temperature and dividing the difference in weight before and after soaking by the dry weight of the 30-seed sample. Seed coat proportion was determined on 20 seeds per plot, as the ratio in weight between coat and cotyledon expressed in percentage, after removing the seed coat from the cotyledons, both after soaking and keeping them for 24 h at 105°C.

### Swelling and Hydration Coefficients

Swelling and hydration coefficients were determined using the Youssuf's method (1978). The raw bean seeds were soaked in distilled water for 24 h, and the volume

of the bean seeds was estimated before and after soaking by determination of displaced water. The hydration coefficient was calculated as the percentage increase in weight of beans. The swelling coefficient was calculated as the percentage increase in volume of beans after soaking:

$$\text{Swelling coefficient (\%)} = (V_a / V_b) \times 100$$

$$\text{Hydration coefficient (\%)} = (M_a / M_b) \times 100$$

Where  $M_b$ , weight of seeds before soaking (g);  $M_a$ , weight of bean seeds after soaking (g);  $V_b$ , volume of bean seeds before soaking (mL);  $v_a$ , volume of bean seeds after soaking (mL).

## RESULTS AND DISCUSSION

The physical properties of seed are given in Table 1. The 20 genotypes belonged to diverse market classes with seven seed colors recorded (brown, red, white, chocolate, pink, purple, and yellow). Most of the genotypes were kidney shaped with plain seed coat and medium seed brilliance. The results pertaining to mean performance of seed length, breadth, and 100-seed weight also show a wide range of values among genotypes. The highest seed length was recorded for WB-216 (1.766 cm) and the lowest recorded for WB-335 (0.966). The highest value for seed breadth was recorded for WB-185 (0.833 cm) followed by WB-970 (0.828) while as the lowest seed breadth (0.633 cm) was recorded for WB-642, WB-435, Arka Anoop and Shalimar French Bean-1. Substantial variability for seed length, breadth as well as 100-seed weight has been reported in common bean in local and exotic genotypes of J&K by Sofi *et al.*, (2014), Sultan *et al.*, (2014), and Wani *et al.*, (2015).

Among biochemical traits (Table 2), highest protein content was recorded for Arka Anoop (22.15%) followed by WB-341 (21.45%), WB-216 (21.16%), and WB-249 (20.99%), whereas lowest value was recorded for recorded for SFB-1 (17.85%) and WB-921 (17.89%). There is a great variation reported in protein content in common bean. Silva *et al.* (2002) evaluated 100 lines of common bean and found substantial variability in protein content ranging from 19.60 to 30.40%. Aliu *et al.* (2013) estimated protein content in bean populations of Kosovo and recorded an average value of 2.2% with the highest value of 23.84%. Similarly Mahajan *et al.*, (2015) evaluated 51 local genotypes of common bean in J and K and observed protein content in the range of 7-31%. The common bean has high nutritional value, with significant concentrations of protein. It represents the main source of protein for low-income populations especially in developing countries. The identification of lines with high levels of protein and minerals, adds value to the cultivars, without increasing the cost to consumers (Silva *et al.*, 2002).

Substantial variation was recorded for raffinose and phytic acid content also (Tables 2 and 3). Some of the lines had low phytic acid content notably WB-970 (0.440%), WB-258 (0.968%) and WB-102 (1.068%), whereas high phytic acid was recorded for Shalimar Rajmash-1 (4.162%) and WB-216 (3.988%). There are reports of a very wide range of phytic acid in common beans. Vasić *et al.*, (2012) evaluated 24 common bean genotypes and recorded phytic acid in the range of 0.68-1.07%, while as Dhole and Reddy (2015) reported the phytic acid content of 0.58-2.00%. Low values for raffinose was recorded for WB-102 (3.800 mg/g) followed by WB-

**Table 1: Seed physical parameters of 20 common bean genotypes**

Genotype	Seed color	Seed brilliance	Seed coat pattern	Seed shape	Seed length	Seed breadth	Seed weight
WB-83	Purple	Brilliant	Plain	Cuboidal	1.333	0.800	31.106
WB-102	Chocolate	Brilliant	Plain	Oval	1.400	0.800	43.940
WB-185	Red	Brilliant	Plain	Kidney	1.500	0.830	43.863
WB-195	Chocolate	Medium	Plain	Kidney	1.533	0.733	41.106
WB-216	Pink	Medium	Plain	Kidney	1.766	0.766	48.950
WB-249	White	Medium	Plain	Kidney	1.166	0.566	20.592
WB-258	Red	Medium	Plain	Cuboidal	1.400	0.766	34.019
WB-330	Yellow	Brilliant	Plain	Kidney	1.466	0.766	43.205
WB-335	White	Medium	Plain	Oval	0.966	0.733	46.776
WB-341	Red	Brilliant	Plain	Cuboidal	1.266	0.766	38.271
WB-435	Brown	Medium	Mottled	Cuboidal	1.000	0.633	26.932
WB-482	Brown	Medium	Mottled	Kidney	1.436	0.705	39.689
WB-634	Chocolate	Medium	Plain	Kidney	1.533	0.700	32.601
WB-642	Brown	Dull	Plain	Kidney	1.466	0.633	28.349
WB-921	Brown	Medium	Mottled	Kidney	1.367	0.733	42.524
WB-970	Brown	Brilliant	Plain	Kidney	1.587	0.828	41.106
WB-1006	Red	Medium	Plain	Cuboidal	1.233	0.707	30.098
Shalimar French Bean-1	Brown	Medium	Plain	Kidney	1.566	0.633	28.854
Arka-Anup	White	Medium	Plain	Kidney	1.433	0.633	31.184
Shalimar Rajmash-1	Red	Brilliant	Plain	Kidney	1.633	0.733	42.524



**Table 2: Mean performance of twenty common bean genotypes for seed quality and culinary traits**

Genotype	Raffinose Mg/g	Phytic acid (%)	Protein content	Water absorption percent	Coat proportion	Swelling coefficient	Hydration coefficient	Cooking time score
WB-83	6.183	2.554	19.43	55.779	18.450	184.234	155.779	3
WB-102	3.800	1.068	17.97	80.645	15.909	214.285	180.645	4
WB-185	4.172	2.323	19.03	121.052	15.254	220.000	221.052	3
WB-195	6.741	2.738	19.41	127.587	19.149	200.000	227.587	4
WB-216	6.068	3.988	21.16	120.930	19.048	145.454	220.930	5
WB-249	5.588	2.076	20.99	136.363	23.125	266.667	236.363	4
WB-258	4.234	0.968	19.12	62.500	14.286	191.667	162.500	2
WB-330	4.108	1.486	19.08	112.121	12.727	242.857	212.121	5
WB-335	5.358	2.928	20.41	115.161	22.642	250.00	215.151	4
WB-341	6.421	1.743	21.45	44.444	20.000	114.285	144.444	3
WB-435	4.397	2.447	18.56	100.000	16.667	275.00	200.000	3
WB-482	3.833	1.743	19.09	110.714	20.000	185.714	210.714	3
WB-634	4.877	1.202	19.84	126.087	17.143	216.667	226.087	3
WB-642	6.951	2.341	20.30	115.000	18.182	300.000	215.000	3
WB-921	5.055	1.576	17.89	110.000	11.111	177.778	210.000	4
WB-970	5.112	0.440	18.36	120.689	14.286	212.500	220.689	3
WB-1006	4.004	2.097	18.38	76.967	21.766	124.554	176.967	2
Shalimar French Bean-1	5.067	1.976	17.85	126.923	14.286	200.000	226.923	3
Arka-Anup	5.358	1.577	22.15	131.818	5.000	240.000	231.818	4
Shalimar Rajmash-1	5.078	4.162	19.97	116.667	19.298	225.000	216.667	3
LSD	1.630	0.472	0.844	39.146	10.073	123.313	39.146	0.367

**Table 3: Descriptive statistics of eleven seed physical, biochemical, and quality traits**

Trait	Mean	Range	Standard error
Raffinose (mg/g)	5.120±0.999	3.800-6.951	0.217
Phytic acid (%)	2.076±0.810	0.440-4.162	0.207
Protein content	19.522±1.273	17.850-22.150	0.278
Water absorption percent	105.572±27.393	44.444-136.363	5.990
Coat proportion	16.916±4.377	5.000-23.125	0.961
Swelling coefficient	209.331±48.705	114.285-300.000	10.632
Hydration coefficient	205.571±27.393	144.444-236.363	5.990
Cooking time score	3.400±0.837	2.000-5.000	0.183
100-Seed weight	36.784±9.225	20.592-48.950	2.026
Seed length	1.402±0.198	0.966-1.766	0.045
Seed breadth	0.723±0.074	0.566-0.830	0.016

482 (3.833 mg/g) whereas highest value was found for WB-642 (6.951 mg/g) followed by WB-195 (6.741 mg/g) and WB-341 (6.421 mg/g). The released varieties had significantly higher raffinose content as compared to the breeding lines. Raffinose is an anti-nutritional factor in that it causes flatulence, but it is reported to provide cell membrane stability during seed maturation and desiccation thereby preventing cracking (Lugol and Leopold, 1995). In the present study, higher raffinose content was recorded in case of white and light seeded lines which is a desirable feature as such genotypes are susceptible to membrane damage during seed germination and maturation. Considerable variability existed among common bean genotypes in raffinose content between 1.63 and 7.04 mg/g (Hernández *et al.*, 2002). Variability for raffinose content has also been reported in beans by McPhee and Meyers (1996), Casanas *et al.*, (1999) and McPhee *et al.*, (2002).

Among water absorption traits that define the culinary properties of beans, water absorption percentage, coat proportion, swelling and hydration coefficients as well as cooking time score were recorded. 15 out of the 20 genotypes absorbed more water than their weight. Highest water absorption percentage was recorded for WB-249 (136.363), Arka Anoop (131.818) and SFB-1 (126.923), whereas few breeding lines absorbed water less than their weight and the lowest value was recorded for WB-341 (44.444), WB-83 (55.779), WB-258 (62.5000) and WB-1006 (76.967). The water absorption percentage was invariably low in case of small red types. The seed coats in small red types are tightly attached with the cotyledons that might limit water imbibition upon soaking. Similar trend was observed for hydration coefficient. The coat percentage was lowest in the case of Arka Anoop (5.000%) followed by WB-921 (11.111%) and WB-330 (12.727%) whereas highest proportion of coat was recorded for WB-249 (23.125%) followed by WB-335 (22.642%) and WB-1006 (21.776%). The swelling coefficient that determines the increase in volume on soaking was highest in the case of WB-642 (300.000), WB-249 (266.667) and WB-335 (250.000), whereas lowest values for swelling coefficient were recorded in case of WB-341 (114.285), WB-216 (145.454) and WB-1006 (124.554). Hydration and swelling coefficients that reflect the capacity of seeds to imbibe water in a reasonable length of soaking time. Rapid uptake of water is a desirable attribute of legume grain used for food. The swelling coefficient behaved in the same way as hydration coefficient because swelling depends mainly on the amount of water absorbed. Shimelis

**Table 4: Correlation between various seed physical, quality and culinary traits**

Trait	Raffinose (mg/g)	Phytic acid (%)	Protein content	Water absorption percent	Coat proportion	Swelling coefficient	Hydration coefficient	Cooking time score	Seed weight (g)
Raffinose (mg/g)	-	0.379*	0.551**	0.060	0.197	0.030	0.060	0.201	0.028
Phytic acid (%)	-	-	0.340*	0.174	0.444**	0.004	0.174	0.226	0.344*
Protein content	-	-	-	0.113	0.095	0.073	0.113	0.290	0.030
Water absorption percent	-	-	-	-	-0.166	0.524**	0.999**	0.439*	0.061
Coat proportion	-	-	-	-	-	-0.136	-0.166	-0.162	-0.001
Swelling coefficient	-	-	-	-	-	-	0.524**	0.181	-0.448**
Hydration coefficient	-	-	-	-	-	-	-	0.439*	0.061
Cooking time score	-	-	-	-	-	-	-	-	0.504**
Seed weight	-	-	-	-	-	-	-	-	-

and Rakshit (2005) determined the hydration and swelling coefficients for 8 different bean varieties, cultivated in Ethiopia. They noticed that the hydration and swelling coefficients varied widely across the bean varieties. It was reported that the legumes having the higher hydration and swelling coefficients require less cooking time. Hardness after cooking increases with a decrease of hydration capacity (g/seed) in the different varieties, but decreases with cooking time. Hence, the consumers and processors alike prefer varieties with low cooking time and low hardness value (Bishnoi and Khetarpaul, 1993; Wang *et al.*, 2003; Sofi *et al.*, 2014). Desirable cooking time score was recorded for WB-216 and WB-330 (5) followed by WB-102, WB-195, WB-249, WB-335, WB-921 AND Shalimar French Bean-1 (4) while as other lines were medium to hard in cooking.

Among correlations between various seed physical, biochemical and culinary traits, raffinose was positively and significantly correlated with phytic acid. This is possibly due to the fact that the biosynthetic pathways of synthesis of both raffinose and phytic acid share a common intermediate myoinositol-1-phosphate. In fact, the mutations in the MIPS enzyme have been reported to decrease the both in soybean (Hitz *et al.*, 2011). Similar results have been reported by Zhawar *et al.*, (2011) in chickpea. Phytic acid was also significantly and positively correlated with protein. The positive correlation of phytic acid and protein content has been also reported in beans (Coelho *et al.*, 2007a), chickpea and pigeonpea (Chitra *et al.*, 1995), Soybean (Raboy *et al.*, 1984) and in wheat (Raboy *et al.*, 1990) and in rice (Wei *et al.*, 2007). Increasing level of PA decreases protein availability by forming phytate-protein bounds as well (Reddy *et al.*, 1982). Henrik *et al.* (2002) revealed that PA was stored in protein-crystalline in grains of cereal and legumes and speculated that the synthesizing metabolism of grain PA probably was closely related to the accumulation of protein in rice grains. However, no significant correlation between the content of PA and the accumulation of total protein was found in a study on the legume seeds (Morre

*et al.*, 1990) and study on rice varieties (Wu *et al.*, 2007). Although PA can inhibit iron absorption due to their ability to form non-absorbable complexes with iron in the gastrointestinal tract, they also fulfill essential biological functions in the plant. PA, stored in seeds, provides the growing seedling with phosphorous and essential minerals at the whole-plant level and also appears to be involved in signaling and response to plant pathogens. (Bohn *et al.*, 2008; Murphy *et al.*, 2008). Therefore, plant breeders have to maintain a certain level of phytic acid while breeding for reduced anti-nutritional factors in beans. Phytic acid was also positively correlated with coat proportion and 100-seed weight. Coat proportion was negatively correlated water absorption percentage, swelling coefficient, hydration coefficient as well as cooking time score. Cooking time score was positively correlated with hydration and swelling coefficients as well as seed weight but negatively correlated with coat proportion. Mavromatis *et al.*, (2012) also made a comparative study in common bean for seed physicochemical traits and concluded that seed physicochemical traits including the traits used in present study could be effectively used for comparing large set of germplasm lines for cooking qualities as the varieties that have high hydration and swelling capacities are usually fast to cook (Jackson and Varriano-Marston, 1981, Castillo *et al.*, 2008). However, the lines that have lower hydration and swelling capacities usually have longer storage life. Similar results in correlation among seed physical and culinary traits have been reported by Sofi *et al.*, (2014).

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