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Physical Properties of Three White Bean Varieties (*Phaseolus vulgaris* L.) Grown in Tunisia

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ABSTRACT

Background: The common bean (Phaseolus vulgaris L.) is the most widely grown edible legume species in Tunisia. The physical properties of three white varieties of beans (Phaseolus vulgaris L.) namely; 'Twila', 'Coco', and 'Beldia' were investigated. **Objective:** This study projects the physical properties of beans in view of designing the equipments necessary for harvesting, handling, sorting, and processing. Methods: Physical and morphological studies were done for each variety by conventional methods. Seed mass, seed size, seed density, hydration capacity, hydration index, hydration coefficient, swelling capacity, swelling index, and swelling coefficient was determined for the three varieties. **Results:** The bean varieties which used in this study showed large variability in all physical and morphological features. The results revealed that seed mass, seed size, seed density, hydration capacity, hydration index, hydration coefficient, swelling capacity, swelling index, and swelling coefficient ranged from 27.63-50.95 g/ 100 seeds, medium-large, 1.26-1.34 g/ mL, 0.22-0.53 g/ seed, 0.47-0.52, 1.94-2.12 %, 0.21-0.50 mL/ g, 0.23-0.57, and 2.22-2.48 %, accordingly. **Conclusion:** In view of nutritional importance of (Phaseolus vulgaris L.) seeds, impact of soaking, cooking, autoclaving, and germination on their antinutritional factors needs further insight.

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INTRODUCTION

Dry beans (*Phaseolus vulgaris* L.) or common beans have been characterized as a nearly perfect food because of their high protein, fiber, prebiotic, vitamin B, and chemically diverse micronutrient composition (Lyimo *et al*., 1992; Geil *et al*., 1994). Dry beans can also be grown in a variety of eco-agricultural regions and distributed in multiple forms, such as unprocessed seeds, as part of mixes, canned products, or as a gluten free wheat flour substitute. As a result, dry beans are used throughout the world representing 50 % of the grain legumes consumed as a human food source. Bean forms a good source of income for farm families. In Tunisia, bean is a major source of food security, readily available and popular food to both the urban and rural population. In 2009, Food and Agriculture Organization, (FAO) estimated Tunisia's bean consumption as 0.80 kg/capita/year. Beans provide about 8.00 kcal/capita/day of the total calories and 0.50 g/capita/day of the protein intake, of the diet of many Tunisians. The crop is also an important source of income in Tunisia due to the increasing demands both in the domestic and export markets. Of the different dry bean varieties grown in Tunisia; 'Twila', 'Coco', and 'Beldia' account for vast majority in terms of production and consumption (NARIT, 2013). Although all the varieties contain similar major components (protein, fat, carbohydrates, and minerals), each have unique minor physical profiles that can affect their functional food outcomes. Yet, dry beans are understudied with research programs remaining critically underfunded compared to other commodities. Therefore, the objective of this study is to provide physical information on white dry beans as an important crop not only for Tunisia agriculture sector but as a potential functional food for western societies.

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MATERIAL AND METHODS

Plant materials:

The three white dry bean varieties of (*Phaseolus vulgaris* L.) were bought from the National Agricultural Research Institute of Tunisia (NARIT), during February-March 2013. The beans were selected and cleaned manually. It was ensured that the seeds were free of dirt, broken and immature ones, and other foreign materials. The experiments were carried out for the three varieties of (*Phaseolus vulgaris*): 'Twila', 'Coco', and 'Beldia' (Fig. 1).

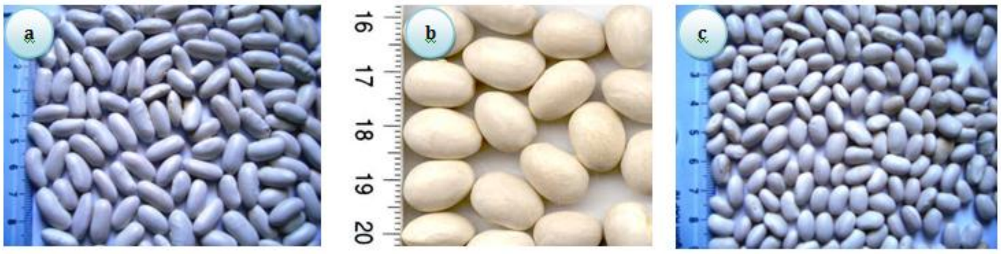

Fig. 1: Seeds of white dry beans (*Phaseolus vulgaris* L.): (a) 'Twila'; (b) 'Coco'; and (c) 'Beldia'

Hydration capacity (H_c) and index (H_i):

Seeds, weighting 100 g, were counted and soaked overnight. After the water was drained, the soaked seeds were blotted dry and weighted. Hydration capacity (H_c) was calculated as change in weight per number of seeds and hydration index (H_i) was determined as the ratio of hydration capacity (H_c) per seed to the weight of one seed (M_b):

$$H_c(g/seed) = \frac{(M_a - M_b)}{N} \quad (1)$$

$$H_i = \frac{H_c}{M_b} \quad (2)$$

Where M_b, weight of seeds before soaking; M_a, weight of seeds after soaking; N, number of seeds.

Swelling capacity (S_c) and index (S_i):

Seeds, weighting 100 g, were counted, their volume noted and soaked overnight. The volume of soaked seeds were noted in a graduated cylinder (Bishnoi and Khetarpaul, 1983). Swelling capacity (S_c) was calculated as change in volume per number of seeds and swelling index (S_i) was determined as the ratio of swelling capacity (S_c) per seed to the volume of one seed (v_b):

$$S_c(mL/seed) = \frac{(v_a - v_b)}{N} \quad (3)$$

$$S_i = \frac{S_c}{v_b} \quad (4)$$

Where v_b, volume of seeds before soaking (mL); v_a, volume of seeds after soaking (mL); N, number of seeds.

Hydration and swelling coefficients:

Hydration and swelling coefficients were determined using the typical Youssuf method (1978). The raw bean seeds were soaked in distilled water for 24 hours 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:

$$H_{Coefficient}(\%) = \frac{M_a}{M_b} \times 100 \quad (5)$$

$$S_{Coefficient}(\%) = \frac{v_a}{v_b} \times 100 \quad (6)$$

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).

Hundred seed mass (100-SM):

A hundred seed mass was determined by weighting 100 whole seeds in quadruplicate and calculating the average.

Seed volume and density:

The bulk density of the bean seeds was calculated using the standard method of Shimelis and Rakshit (2005). 100 g of the sample seeds were transferred to a measuring cylinder, which had 100 mL distilled water at 20 ºC. Seed volume (mL/ 100 g seeds) was obtained after subtracting 100 mL from the total volume (mL). The bulk density was then calculated and recorded in g/ mL.

Statistical analysis:

Results were expressed as the mean values ±standard deviation (SD) of four separate determinations. Data were subjected to analysis of variance using a completely randomized design.

RESULTS AND DISCUSSION

Physical and chemical properties of agriculturally, nutritionally, and industrially valuated seed materials are important in designing the equipment for harvest, transport, storage, processing, cleaning, hulling, and milling (Akaaimo and Raji, 2006; Coskuner and Karababa, 2007; Sirisomboon *et al*., 2007). In Table 1, various physical parameters evaluated for different varieties of kidney beans were hydration capacity, hydration index, hydration coefficient, swelling capacity, swelling index, swelling coefficient, seed weight, seed size, and seed density.

Table 1: Physical properties of white dry bean varieties.

Variety	Hydration			Swelling			Seed		
	Capacity†	Index	Coefficient	Capacity‡	Index	Coefficient	Mass††	Size ‡‡	Density
	g/ seed		%	mL/ seed		%	g/ 100 seeds		g/ mL
Twila	0.539 ±0.014§	0.525 ±0.003§	2.120 ±0.005§	0.500 ±0.009§	0.570 ±0.004§	2.480 ±0.050§	50.952 ±0.005§	Large	1.267 ±0.013§
Coco	0.382 ±0.008¶	0.470 ±0.001¶	1.940 ±0.003¶	0.370 ±0.010¶	0.415 ±0.010¶	2.220 ±0.040¶	44.675 ±0.010¶	Large	1.342 ±0.011¶
Beldia	0.222 ±0.008#	0.475 ±0.008¶	2.027 ±0.033#	0.210 ±0.008#	0.236 ±0.010#	2.290 ±0.080¶	27.630 ±0.008#	Medium	1.296 ±0.025§

All values are the mean ±SD (standard deviation) of four independent determinations.
†Mean increases in mass of seeds due to water uptake over 12 h divided by the number of seeds.
‡Mean increases in volume of seeds due to water uptake over 12 h divided by the number of seeds.
§, ¶, #Means in the same horizontal lines not sharing a common superscript letter are significantly different at $P<0.05$ level.
††Mass of 100 bean seeds.
‡‡Small size, less than 25 g/ 100 seeds or 3-4 mm; medium size, 25-40 g/ 100 seeds or 4-6 mm; large size, greater than 40 g/ 100 seeds or 6-8 mm.

Hydration and swelling capacities and indices:

Table 1 illustrates the hydration, swelling capacities and their indices. Significant differences ($P<0.05$) were observed among the bean varieties for hydration and swelling capacities as well as hydration and swelling indices. 'Twila' beans possessed the highest swelling index (0.570±0.004) whereas 'Beldia' beans the lowest (0.236±0.010). High value of swelling index revealed the high swelling ability of 'Twila' seeds. The swelling ability of any seed depends upon its water retention capacity or hydration capacity. The hydration capacity of 'Twila' seed was found to be 0.539±0.014 g/ seed. The increase in the swelling capacity of 'Twila' samples (0.500±0.009 mL/ seed) could be due to their high protein contents (Chang *et al*., 1981). The high swelling capacities of these beans will make them useful in the preparation of soups, puddings, and sauces. Elevated hydration and swelling capacities of 'Twila' shows their softness and high permeability. These characteristics help to process 'Twila' seeds (Shimelis and Rakshit, 2005) (e.g., soaking, germination, dehusking, and fermentation) for extraction of active principles or to eliminate antinutritional components. Also, a large hydration capacity leads to better cooking quality (less cooking time and texture). As cooking of 'Twila' variety would require less fuel and energy, it should be preferred. The hydration index of 'Coco' (0.470±0.001) was less than those of 'Twila' (0.525±0.003) and 'Beldia' (0.475±0.008). These differences may be attributed to difference in size, seed coat thickness, and water absorption characteristics of seeds (SefaDedah *et al*., 1979). In 1994, Ercan and co-workers conducted some physical experiments on eight genotypes of dry beans (six advanced lines and two varieties, 'Horozoturak' and 'ESK-855') grown in two locations in Turkey. The growing locations were Meriç and Yenikent. They found that hydration and swelling capacities varied in the range of 0.171-0.534 g/ seed and 0.165-0.493 mL/ seed, respectively. They suggested that the large variation observed for physical parameters could be explained by the big difference in climatic conditions and soil composition of the two locations as well as the great diversity of the bean genotypes. Mavromatis *et al*., (2012) from the Laboratory of Genetics and Plant Breeding of the University of Thessaly, Greece, assessed the hydration capacity of 5 common bean cultivars (*Phaseolus vulgaris*): 'Byzitsa Br.', 'Xanthi', 'Pyrgetos', 'Rodopi', and 'Starazagorski'. Hydration capacity among the 5 tested bean cultivars varied from 0.46 to 0.59 g/ seed. The highest value observed in 'Xanthi' and the lowest in 'Starazagorski'.

Hydration and swelling coefficients:

As shown in Table 1, substantial differences occurred in physical characteristics of (*P. vulgaris*) beans. Hydration and swelling coefficients that reflect the capacity to imbibe water in a reasonable length of soaking time was substantially affected by the genotype (*P*<0.05). The hydration coefficient (imbibition value) varied from 1.940±0.003 to 2.120±0.005 %. Rapid uptake of water is a desirable attribute of legume grain used for food. In the present study, the value of hydration coefficient was highest in 'Twila' beans (2.120±0.005 %). The swelling coefficient behaved in the same way as hydration coefficient because swelling depends mainly upon the amount of water absorbed. Shimelis 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. In one side, 'Awash' possessed the highest value of hydration coefficient, while 'Gofta' exhibited the lowest value. In other side, 'Mexican' was characterized by an elevated value of swelling coefficient (2.564 %) and 'Gobirasha' by a low value (1.157 %). In 2012, Mavromatis and his colleagues, evaluated also the hydration coefficient as well as the swelling coefficient of 5 common beans (*P. vulgaris*; 'Byzitsa Br.', 'Xanthi', 'Pyrgetos', 'Rodopi', and 'Starazagorski'), in parallel with 5 runner bean landraces (*P. coccineus*; 'Zagora', 'Grevena', 'Byzitsa G.', 'Prespes', and 'Florina'), cultivated under organic growing conditions. The hydration coefficient varied from 2.03 to 2.70 %, the highest being in 'Xanthi' (*P. vulgaris*) and the lowest being for 'Starazagorski' (*P. vulgaris*). The swelling coefficient after 24 h varied from 2.00 to 2.43 %, the lowest being recorded for 'Xanthi' (*P. vulgaris*) and the highest value for 'Florina' (*P. coccineus*). 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 (Ahmed and Shehata, 1982; Williams *et al*., 1983; Koehler *et al*., 1987; El-Refai *et al*., 1988; Sharma, 1989; Latunda, 1991; Bishnoi and Khetarpaul, 1993; Wang *et al*., 2003).

Size and 100-seed mass:

The size feature of the common bean (*P. vulgaris*) is considerably crucial parameter in terms of designing the seed metering mechanism of seed drills, and transportation, separating and sizing systems, and food processing. Therefore, the size data of beans is of mostly importance to Agrofood engineers, machine manufacturers, and machine designers (Kara *et al*., 2013). The size of the seed was determined according to the classification made regarding 100-seeds weight. Referring to Table 1 and Figure 1, it can be seen that 'Twila' and 'Coco' beans were larger than 'Beldia' beans. This variability in size may have important effects on both the cooking time and the efficiency in removing of antinutritional compounds from beans. Hundred seeds weight is important in terms of the quality of the seeds. Both agricultural and commercial this characteristic has always been considered (Balkaya and Odabas, 2002). The proximate 100-seed mass of the dry beans are shown in Table 1. The hundred seed mass differed significantly (*P*<0.05) among the various genotypes. The variety with the highest hundred seed mass was 'Twila' (50.952±0.005 g) while the lowest was 'Beldia' (27.630±0.008 g). This variability may be due to the seeds being derived from diverse market classes. The market classes are grouped as small ≤ 25 g/ 100 seeds, medium 25-40 g/ 100 seeds, and large ≥ 40 g/ 100 seeds. The hundred seed mass results indicated that 'Twila' and 'Coco' fall in the large category. Whereas, the 'Beldia' fell in the medium category. Kaur and co-researchers from the Department of Food Science and Technology, Punjab, India, evaluated the seed weight of 50 Kidney bean lines, which were grown at the Regional Station of the National Bureau of Plant Genetic Resources (NBPGR) located in Phagli area of Shimla. They observed that the highest 100-seed weight (51.68 g/ 100 seeds) was allocated to 'PLB 10-1', whereas 'EC530969' was shown the lowest seed weight (10.16 g/ 100 seeds). Deshpande *et al*., (1984) reported 100-seed weight of dry bean cultivars in the range between 15.0 and 50.3 g. In a research paper published in Asian Journal of Plant Sciences (Borji *et al*., 2007), the seed mass of 10 genotypes of dry bean was studied. The averages of weight values were found to be in the range of 23.20-38.43 g/ 100 seeds. Gathu and co-workers (2012) from the Technology and Nutrition University of Nairobi, Kenya, reported the 100-seed mass values of eight bean lines (*Phaseolus vulgaris*). The values varied from 15.77 to 36.90 g/ 100 seeds, for 'DNB 1110' and 'Kenya Early', respectively. In other investigation done by Izuchukwu and Folarin (2013), the average mass of the 100 bean-seed sample of (*Phaseolus vulgaris* L.) was 40.51 g. In the light of these observations, it could be assumed that the seed mass of (*P. vulgaris*) was clearly influenced by both environmental and genetics factors.

Seed density:

Examining Table 1, it can be seen that the seed density of 'Coco' seeds (1.342±0.011 g/ mL) was higher than those of 'Beldia' (1.296±0.025 g/ mL) and 'Twila' seeds (1.267±0.013 g/ mL). The density of dry beans was higher than 1 g/ mL indicating that the seeds are heavier than water and hence sink. The values were statistically different (*P*<0.05). A group of investigators from Asian Institute of Technology, Bangkok, Thailand (Shimelis and Rakshit, 2005), studied the physical properties of eight improved bean varieties namely: 'Roba', 'Mexican', 'Red wolayita', 'Awash', 'Gofta', 'Beshbesh', 'Gobirasha', and 'Tabor'. All varieties, used in their research, were grown at Nazareth Agricultural Research Center in Ethiopia. It was found that the density of varieties varied from 1.177 to 1.343 g/ mL. Here, the seed densities of 'Twila' and 'Coco' are comparable with 'Tabor' (1.266 g/ mL) and 'Mexican' (1.33 g/ mL) beans, respectively. At the School of Agricultural Sciences, Mavromatis and co-workers conducted some morphological, agronomical, and physicochemical analyses on 8 local landraces and 8 commercial cultivars of (*Phaseolus vulgaris* L.) cultivated in Greece. They observed a considerable genetic diversity among the landraces and cultivars in terms of seed density. The highest value was recorded for the cultivar 'Stara Zagorski' by 1.25 g/ mL and the lowest value was obtained by the landrace 'Velestino' by 1.05 g/ mL. Ertas (2011) analyzed some samples of common bean, obtained from local market in Konya, Turkey. This author found that the mean value of seed density was around 1.25 g/ mL.

Conclusion:

This study provided basic information on physical properties of common bean (*Phaseolus vulgaris* L.) The current investigation was conducted on three white dry bean varieties consisted of: 'Twila', 'Coco', and 'Beldia'. Physical attributes including seed mass, seed size, seed density, hydration capacity, hydration index, hydration coefficient, swelling capacity, swelling index, and swelling coefficient were evaluated. The size of seeds varied from medium to large. There were significant differences (P<0.05) in hundred seed mass and density. They were found to be 27.63-50.95 g and 1.26-1.34 g/ mL, respectively. Hydration capacity, hydration index, swelling capacity, swelling index was higher for 'Twila' beans than 'Coco' and 'Beldia' beans indicating the better water absorption capacity of 'Twila'. The results of this study are expected to be useful for plant breeders, consumers, and the food industry.

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