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Nutritional and technological properties of Tepary bean (*Phaseolus acutifolius*) cultivated in Mexican Northeast

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Abstract: The nutritional, cooking and technological properties of the Tepary bean (TB) cultivated in Mexican northeast comparing to two common beans varieties (Pinto Americano and Black Jamapa) were evaluated in this study. Nutritional parameters evaluated of TB resulted significantly different from common beans varieties analysed, except lipid fraction. Cooking times of soaked (4 and 8 h) and non-soaked varieties varied significantly; TB shows between 55.1–80.49 min by cooking time. The textural profile analysis (TPA) of TB showed a significant reduction of hardness, chewiness and adhesiveness in soaked compared to non-soaked. In addition, TB presented a similar behaviour to Pinto Americano in TPA non-soaked and cooked and soaked 8h and cooked, except to adhesiveness. Technological properties of TB and resistant and non-resistant starch content showed significant differences between species. Due to, TB has nutritional, cooking and technological properties comparable to other edible legumes as common bean, mainly Pinto Americano variety.

Keywords: ethnical crops; legumes; technological properties; texture profile analysis

Legumes contribute significantly to human consumption. After cereals, they are the most consumed grains worldwide (Mudryj *et al*. 2014). Within the legume family, there is the common bean (*Phaseolus vulgaris* L.), which is the most cultivated and consumed legume in the world, especially in developing countries. However, the genus *Phaseolus* has been partially explored and not in a systematic way (Acosta-Díaz *et al.* 2014).

Tepary bean (*Phaseolus acutifolius* Gray) is a legume grown mainly in the states of Sonora and Sinaloa. However, its demand is very low and most of it is for self-consumption (Jiménez-Galindo & Acosta-Gallegos 2012). *P. acutifolius* is an edible bean and it is adapted to arid/semi-arid conditions, it is resistant to adverse agronomic conditions such as high concentrations of salt, limited water conditions, pests and microorganisms that affects the common bean. Also,

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the nutritional quality of Tepary bean is promising for human consumption (Parsons & Howe 1984; Marsh & Davis 1985).

Unfortunately, Tepary bean have not been investigated in recent years, so there is a lack of information about its nutritional and technological properties. For this reason, it has not been exploited and its consumption is limited. In order to increase the production and consumption of this legume, it is necessary to study its nutritional quality, cooking and technological properties, since they are criteria for consumer acceptance (Mederos 2006). Therefore, the nutritional and technological properties of the Tepary bean cultivated in Mexican northeast were evaluated and compared to common bean varieties (Pinto Americano and Black Jamapa).

MATERIAL AND METHODS

Biological materials. The seeds of Tepary bean (*P. acutifolius*) and Pinto Americano (*P. vulgaris*) were cultivated and harvested in 2015 (Faculty of Agronomy of the Universidad Autónoma de Nuevo León). Black Jamapa (*P. vulgaris*) was purchased at a convenience store in the city of Monterrey (Nuevo León). The dried beans were stored at 4°C and protected from a light.

Sample preparation. For the analysis of raw bean, a sample of 100 g was cleaned and milled using a M20 Universal mil-IKA, until a fine powder was obtained. The samples were stored in polyethylene bags at 4°C until use. Subsequently, a second sample of beans was cleaned and cooked by a traditional method, according to (Ramírez-Jiménez *et al.* 2014) with slight modifications. Briefly, 100 g of beans were placed in four beakers, with 300 ml of boiling distilled water. The samples were cooked at a temperature of 100°C until they were suitable for consumption. Once cooked, the beans and the cooking broth were milled and dried at 65°C in a SMO3 Shel Lab Forced Air Oven. The dehydrated samples were milled for a second time and stored in polyethylene bags at 4°C.

Proximate composition. The proximate composition analysis was performed based on the methods described by AOAC (1990). To determine the moisture content, the method 925.10 was followed, for ash the method 936.07, for protein fraction the method 968.06 (Dumas method), for lipid fraction the method 920.09, for dietary fiber the method AOAC 985.29, and finally, the content of total carbohydrates was calculated by difference of the percentages of moisture, protein fraction, lipid fraction, and dietary fiber.

Cooking time. Samples of 25 seeds were soaked for periods of 0, 4 and 8 h in 75 ml of distilled water at room temperature of 25°C. After soaking, the seeds were drained and cooked in heating plates Cimarec S88850100 (Thermo Scientific, USA). Once the water reached the boiling point, the beans were placed into beakers. The time required for the beans to reach a soft granular texture was taken. This was tested by compressing a seed between the index finger and the thumb, as well as biting a grain with the incisor teeth, according to the method described by Elías *et al.* (1986).

Textural properties. A test of texture profile analysis (TPA) in Tepary seeds without soaking and with soaking of 8 h was performed using a texture analyser (XT2i; Stable Micro Systems Ltd., UK). A 70% compression of deformation was performed, at a crosshead speed of 2 mm/min. This test is based on imitating mastication by a texturometer which makes a double compression. Several textural parameters can be calculated by graphing force against time. Thus, the hardness, cohesiveness, chewiness and adhesiveness were determined, reporting the average of ten determinations (Szczesniak 1975).

Hydration capacity and index. A total of 50 bean seeds were weighed and placed in a 125 ml Erlenmeyer flask; 100 ml of distilled water was added and the beans were soaked for 18 h at a room temperature. Subsequently, the grains were drained and the surface water was removed with absorbent paper. The seeds were re-weighed and hydration capacity was calculated as follows (Wani *et al.* 2015):

$$\text{Hydration capacity} = (\text{weight after soaking} - \text{weight before soaking})/50 \quad (1)$$

The hydration index was calculated according to Wani *et al.* (2015):

$$\text{Hydration index} = \text{Hydration capacity per seed}/\text{weight of one seed (g)} \quad (2)$$

Swelling capacity and index. Samples of 2 g were weighed and placed in a 25 ml graduated cylinder, then 10 ml of distilled water was added. To achieve hydration, the final volume occupied by the sample was measured after 18 h of soaking. The results were expressed as ml/g of sample. The swelling capacity was calculated as follows (Wani *et al.* 2015):

https://doi.org/10.17221/331/2017-CJFS

Swelling capacity = volume after soaking –
– volume before soaking)/weight of sample (3)

Swelling index was calculated as follows (Wani *et al.* 2015):

Swelling index = swelling capacity of seeds/
/volume of one seed (4)

Water and oil absorption capacity. Water absorption capacity (WAC) tests were performed according to the method of Kaur and Singh (2006). Briefly, 3 g of bean flour were weighed and placed in pre-weighed centrifuge tubes. The sample was dispersed in 25 ml of distilled water over a period of 30 min with manual stirring, followed by a 25 min centrifugation period at 3000 rpm. The supernatant was decanted and the excess of moisture was removed by placing the tubes in the oven at 50°C for 25 minutes. Finally, the sample was reweighed and the results were expressed as grams of water absorbed per grams of sample in dry basis.

The oil absorption capacity (OAC) was performed following the method of (Julianti *et al.* 2015) with slight modifications. One gram of sample was suspended in 5 ml of corn oil in a pre-weighed centrifuge tube. The tube was shaken for 1 min at room temperature and then centrifuged at 3000 rpm for 25 minutes. The supernatant was discarded and the samples reweighed. The results were expressed as grams of oil absorbed per grams of sample in a dry basis.

Resistant and non-resistant starch. The determinations were performed following the method described McCleary (2002). Briefly, the samples recently prepared were incubated in a shaking water bath with pancreatic α-amylase and amyloglucosidase (AMG) for 16 h at 37°C, during this period, the non-resistant starch was solubilized and hydrolysed to L-glucose by the action of the two enzymes. The reaction was finished by the addition of an equal volume of ethanol and the resistant starch was recovered in the pellet obtained after centrifugation. The pellet was washed with 50% (v/v) ethanol followed by a second centrifugation and the supernatant was removed by decantation. The resistant starch present in the pellet was dissolved with 2M KOH during vigorous stirring in an ice water bath on a magnetic stirrer. Subsequently, the solution was neutralized with acetate buffer and the starch was hydrolysed to glucose with AMG. D-glucose was measured using the Agilent Cary 60 UV-vis spectrophotometer at 510 nm with the glucose oxidase / peroxidase reagent (GOPOD), indicating the resistant starch content in the sample. The non-resistant starch was determined by combining the supernatants from the washes mentioned before, adjusting the volume to 100 ml and spectrophotometrically measuring the D-glucose content with the GOPOD reagent. The determination was made recently cooked beans.

Statistical analysis. The results are reported as mean of three replicate analyses. One-way analysis of variance (ANOVA) was carried out to compare means between species, and whenever appropriate, Tukey's test was used in order to determine differences from the mean using the software SPSS 22 for Windows (IBM Corp., 2013). Differences in the mean values were determined at $P < 0.05$.

RESULTS AND DISCUSSION

Proximate composition. The proximate composition of beans is presented in Table 1. The moisture of Tepary bean was 7.41%, significantly different ($P < 0.05$) from common beans cultivars with values ranged from 4.9% to 10.04%. The ash content observed for Tepary bean was 4.96% that was significantly different from Pinto Americano (5.72%) but did not

Table 1. Proximate composition of seeds of tepary bean (*P. acutifolius*) and two common bean varieties (*P. vulgaris* L.)

Parameter (%)	Tepary	Pinto Americano	Black Jamapa
Moisture	7.41 ± 0.19^{a}	4.91 ± 0.02^{b}	10.05 ± 0.21^{c}
Ash	4.96 ± 0.04^{a}	5.72 ± 0.31^{b}	4.87 ± 0.05^{a}
Total protein	20.50 ± 0.29^{a}	19.13 ± 0.37^{b}	23.95 ± 0.08^{c}
Lipid	1.52 ± 0.09^{a}	0.70 ± 0.04^{a}	2.42 ± 1.35^{a}
Dietary fiber	16.15 ± 1.83^{a}	19.01 ± 0.15^{ab}	20.01 ± 1.34^{b}
Total carbohydrate	49.46 ± 2.02^{a}	50.53 ± 0.26^{a}	37.72 ± 1.84^{b}

Composition of seeds is on dry weight basis; values expressed are mean ± standard deviation ($n = 3$); means in the row with different superscript are significantly different at $P < 0.05$

differ from Black Jamapa (4.87%). Protein content varied significantly from 19.13% to 23.95% among common beans and between Tepary bean (20.50%). Fat and dietary fiber content of common beans were in the range of 0.7–2.42 and 19.01–20.01%, respectively; the fat content of common beans did not vary significantly from Tepary bean values (1.52%). However, significant difference was observed for the dietary fibre content of Tepary beans (16.15%). The total carbohydrate content for Tepary bean was 49.46%. Significant difference was found between total carbohydrates of Black Jamapa (37.72%) but did not varied significantly from Pinto Americano (50.53%). Comparable results for composition of Tepary and common beans have been reported by González *et al.* (1992) and Sánchez-Arteaga *et al.* (2015). The differences in composition observed in these results could be due to genetic differences between species and varieties.

Cooking time. In order to evaluate the cooking quality of beans, cooking times have to be considered, since longer cooking times result in a loss of nutrients. The cooking time of Tepary bean cultivar (80.49 min) without prior soaking varied significantly ($P < 0.05$) from cooking times of unsoaked Pinto Americano and Black Jamapa beans (87.33 and 62.67 min, respectively), as shown in Table 2. The same significant differences were observed for the cooking times of Tepary and common beans among the different soaking conditions. The lowest cooking time was found in Black Jamapa and the highest for Pinto Americano. Cooking time of the cultivars after soaking decreased; in case to 8 h this value was reduced to 25.32, 33 and 23.67 min, respectively. This demonstrates that soaking beans prior to cooking causes a significant decrease in cooking periods. It is known that during cooking, the starch inside the cells starts to change due to gelatinization (Vindiola *et al.* 1986). The difference in cooking times among the beans could be related to the rate at which pulses are softened due to the breakdown of the middle lamella, leading to the easy separation of cells (Sefa-Dedeh & Stanley 1979a). Pinto Americano required longer cooking times; this could be attributed to its larger seed size, compared to Tepary and Black Jamapa beans. It has been reported that seed size governs the distance to which water must penetrate in order to reach the innermost portion of seeds (Sefa-Dedeh & Stanley 1979b).

Table 2. Cooking time (min) of Tepary bean (*P. acutifolius*) and two common bean varieties (*P. vulgaris* L.) seeds

Soaking conditions	Tepary	Pinto Americano	Black Jamapa
Unsoaked	80.49 ± 3.38^a	87.33 ± 0.58^b	62.67 ± 1.15^c
4 h	64.16 ± 1.14^a	72.67 ± 0.58^b	40.0 ± 1.00^c
8 h	55.10 ± 0.69^a	54.33 ± 0.58^b	39.0 ± 1.00^c

Values expressed are mean ± standard deviation (n = 3); means in the row with different superscript are significantly different at $P < 0.05$

Textural properties. Textural properties (Table 3) of Tepary beans, non-soaked and soaked for 8 h, were evaluated using a texture analyser (Model XT2i; Stable Micro Systems Ltd., UK). Hardness of non-soaked seeds varied significantly from 354.79 N to 98.87 N of soaked beans, reducing 72%. Cohesiveness was observed from 0.18 to 0.16; however, this did not represent a significant difference. Chewiness was observed to significantly reduce from 18.62 kg to 2.24 kg, decreasing 88%. Adhesiveness varied significantly from 0.98 kg/s to 0.15 kg/s, being reduced 85%. Comparing to Pinto Americano and Black Jamapa, tepary bean behave is dissimilar to both at 8 h soak. After being cooked without soaked, Tepary bean present values without significantly difference with Pinto Americano and Black Jamapa in hardness, cohesiveness, and chewiness; not same to adhesiveness, presenting 71.5 and 52.1% less adhesiveness than Pinto Americano and Black Jamapa, respectively. When Tepary bean where soaked by 8 h and cooked, the behaviour was different, showing similar values to Pinto Americano (cohesiveness and chewiness) but not the case with Black Jamapa, presenting significantly differences in the four parameters measured, being softer but less cohesive, less chewy and less adhesive. In addition, Tepary bean, cooked with or without soaked, show a similar behave in hardness, cohesiveness and chewiness, but not in adhesiveness, showing a decrease near to 100% in this parameter.

The observed difference in the degree of softening in the seeds may be explained due of the components of the grains. It has been reported that components like fiber, lignin, cellulose, and hemicellulose are responsible for hardness of seeds, at same time to amylose – amylopectin ratio (Kaur & Singh 2007). Likewise, seed coats possessing good hydration properties facilitate rapid softening of the seed during soaking (Sefa-Dedeh & Stanley 1979b).

Technological properties. General technological properties of beans are shown in Table 4. For hydra-

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tion capacity and hydration index, significant difference was observed among the three bean flours. Pinto Americano presented the highest hydration capacity (0.37 g/seed), followed by Black Jamapa (0.21 g/seed), and finally Tepary bean (0.11 g/seed). For hydration index, Black Jamapa and Pinto Americano (0.98 and 0.97, respectively) showed no significant difference, however, they did significantly differ from Tepary bean values (0.54). These results were similar to report for other pulses as cowpea (*Vigna unguiculata*) (Hamid *et al.* 2014). Hydration capacity is determined by the extent to which

Table 3. Texture profile analysis of Tepary bean (*P. acutifolius*) and two common bean varieties (*P. vulgaris* L.) seeds

Parameter	Tepary	Pinto Americano	Black Jamapa
Unsoaked			
Hardness (N)	354.79 ± 67.31^{a}	> 686.47*	> 686.47*
Cohesiveness	0.18 ± 0.09	–*	–*
Chewiness (kg)	18.62 ± 16.54	–*	–*
Adhesiveness (kg/s)	0.98 ± 0.92	–*	–*
Soaked 8 h			
Hardness (N)	98.87 ± 31.24^{a}	182.43 ± 33.47^{c}	152.78 ± 26.93^{b}
Cohesiveness	0.16 ± 0.03^{a}	0.47 ± 0.06^{b}	0.14 ± 0.03^{a}
Chewiness (kg)	2.24 ± 1.65^{a}	3.52 ± 1.14^{a}	12.83 ± 1.20^{b}
Adhesiveness (kg/s)	0.15 ± 0.14^{a}	0.28 ± 0.04^{b}	0.37 ± 0.06^{c}
Unsoaked and cooked			
Hardness (N)	54.10 ± 11.01^{a}	61.83 ± 7.85^{a}	58.60 ± 12.60^{a}
Cohesiveness	0.30 ± 0.12^{a}	0.26 ± 0.04^{a}	0.27 ± 0.05^{a}
Chewiness (kg)	1.60 ± 0.76^{a}	1.65 ± 0.46^{a}	1.68 ± 0.66^{a}
Adhesiveness (kg/s)	–4.44 ± 3.00^{a}	–15.58 ± 5.21^{c}	–9.27 ± 3.42^{b}
Soaked 8 h and cooked			
Hardness (N)	50.58 ± 8.99^{a}	67.22 ± 11.54^{b}	64.63 ± 8.80^{b}
Cohesiveness	0.26 ± 0.08^{a}	0.26 ± 0.05^{a}	0.31 ± 0.05^{b}
Chewiness (kg)	1.40 ± 0.70^{a}	1.84 ± 0.62^{b}	2.05 ± 0.59^{b}
Adhesiveness (kg/s)	ns	–30.81 ± 12.14	–9.32 ± 4.22

Values expressed are mean ± standard deviation (n = 10); means in the row with different superscript are significantly different (P < 0.05); *overcharged the 70 kg·f (686.47 N); ns – not significant (not registered by texturometer)

Table 4. Technological properties of tepary bean (*P. acutifolius*) and two common bean varieties (*P. vulgaris* L.)

Parameter	Tepary	Pinto Americano	Black Jamapa
Hydration capacity (g/seed)	0.11 ± 0 .01^{a}	0.37 ± 01^{b}	0.21 ± 0.004^{c}
Hydration index	0.54 ± 0.02^{a}	0.97 ± 0.03^{b}	0.98 ± 0.02^{b}
Swelling capacity (ml/seed)	0.76 ± 0.01^{a}	0.24 ± 0.05^{b}	0.36 ± 0.02^{c}
Swelling index	3.66 ± 0.06^{a}	0.71 ± 0.14^{b}	2.08 ± 0.12^{c}
WAC (g/g)	3.09 ± 0.09^{a}	2.44 ± 0.07^{b}	2.64 ± 0.08^{b}
OAC (g/g)	1.13 ± 0.11^{a}	0.91 ± 0.02^{b}	0.86 ± 0.05^{b}
Resistant starch 0 h (%)	0.19 ± 0.01^{a}	0.27 ± 0.01^{b}	0.35 ± 0.01^{c}
Non-resistant starch 0 h (%)	4.46 ± 0.24^{a}	3.41 ± 0.45^{b}	4.63 ± 0.21^{a}

Values expressed are mean ± standard deviation (n = 3); means in the row with different superscript are significantly different at P < 0.05

seeds absorb water during soaking. The differences observed among the three bean varieties might depend upon chemical composition of seed coats and cotyledons, reflecting the relative hardness and permeability of the seed coats (Shimelis & Rakshit 2005). A larger hydration capacity is desirable to the end-user since it leads to better cooking quality (less cooking time and texture, and quicker sprouting).

Swelling capacity and swelling index (Table 4) also showed significant differences among the cultivars. The swelling capacity varied as follows: 0.76 ml/g for Tepary bean, 0.24 ml/g for Pinto Americano, and 0.36 ml/g for Black Jamapa. The swelling indices were 3.66, 0.71 and 2.08, respectively. The results obtained for Tepary beans, were similar to other reported pulses (Hamid *et al.* 2014), as well as for the common bean cultivars (Wani *et al.* 2015).

The capacity of water absorption is a key factor for raw materials since higher water retention affects quality, sensory attributes, and induced microbial growth (Ramírez-Jiménez *et al.* 2014). In this study, the WAC of *P. acutifolius* (3.09 g/g) was significantly higher from common bean; however, this parameter did not differ among *P. vulgaris* cultivars. The difference observed for this parameter between species, can be explained because of the dependence of water absorption capacity upon the composition of seed and compactness of the cells in the seed (Muller 1967). The same behaviour was observed for the oil absorption capacity, since *P. acutifolius* presented significantly higher values (1.13 g/g) than *P. vulgaris* cultivars. These results suggest that Tepary bean has more lipophilic interaction sites than common bean. This oil binding capacity can be explained because of variations in the presence of nonpolar side chains that might bind to hydrocarbon side chains of oil among the flours (Adebowale & Lawal 2004).

About the resistant starch content of seeds (Table 4), Tepary bean showed significantly lower values (0.19%) than those of Pinto Americano and Black Jamapa (0.27 and 0.35%, respectively). On the other hand, Tepary beans and Black Jamapa showed similar contents of non-resistant starch (4.46 and 4.63%), but significantly different from Pinto Americano (3.41%). The results obtained in this study for starch contents were similar to those reported by Silva-Cristobal *et al.* (2010), where the legumes analysed were common beans, lentils and chickpeas. Tepary and common beans contained significant amounts of resistant starch compared with other grains, such as cereals, therefore the starch digestion rate and the release of glucose into the blood stream might be slower after the ingestion of this type of seeds, leading to a reduced glycemic response in comparison with cereal grains (Jenkins *et al.* 1982).

CONCLUSIONS

The parameters analysed in this study for *P. acutifolius* resulted significantly different from those of common beans varieties. However, various nutritional and technological properties of Tepary beans were observed to be similar as other edible legumes like cowpeas and chickpeas. Comparing the nutritional, cooking and technological parameters of new promising cultivars, like those of Tepary beans, with different edible beans and legumes, might be useful to promote its consumption on the Mexican population.

References

Acosta-Díaz E., Hernández-Torres I., Amador-Ramírez M.D., Padilla-Ramírez J.S., Zavala-García F. (2014): Las especies silvestres de Phaseolus (Fabaceae) en Nuevo León, México. Revista Mexicana de Ciencias Agrícolas, 8: 1459–1465.

Adebowale K., Lawal O. (2004): Comparative study of the functional properties of bambarra groundnut (*Voandzeia subterranean*) jack bean (*Canavalia ensiformis*) and Mucuna bean (*Mucuna pruriens*) flours. Food Research International, 37: 355–365.

Elías L.G., García-Soto A., Bressani R. (1986): Métodos para establecer la calidad tecnológica y nutricional del frijol. Guatemala, C.A.: Ins. De Nutrición de Centro América y Panamá (INCAP).

González R., Llano J., Medina L.A., y Castellanos E. (1992): Chemical composition in seeds of *Phaseolus vulgaris*, *Phaseolus acutifolius* and *Vigna unguiculata* grown under water stress conditions. National Agricultural Library, 69–70.

Hamid S., Muzaffar S., Wani I.A., Masoodi F.A., Bhat M.M. (2014): Physical and cooking characteristics of two cowpea cultivars grown in temperate Indian climate. Journal of the Saudi Society of Agricultural Sciences, 4. doi: 10.1016/j.jssas.2014.08.002

Jenkins D.J.A., Thorne M.J., Camelon K., Jenkins A.L., Rao A.V., Taylor R.H., Francis T. (1982): Effect of processing in digestibility and the blood glucose response: study of lentils. The American Journal of Clinical Nutrition, 36: 1093–1101.

Jiménez-Galindo J.C., Acosta-Gallegos J.A. (2012): Caracterización de genotipos criollos de frijol Tepari (*Phaseolus acutifolius* A. Gray) y común (*Phaseolus vulgaris* L.)

https://doi.org/10.17221/331/2017-CJFS

bajo temporal. Revista Mexicana de Ciencias Agrícolas, 3: 1565–1577.

Julianti E., Rusmarilin H., Yusraini E. (2015): Functional and rheological properties of composite flour from sweet potato, maize, soybean, and xanthan gum. Journal of the Saudi Society of Agricultural Sciences, 30: 1–7.

Kaur M., Singh N. (2006): Relationships between selected properties of seeds, flours, and starches from different chickpea cultivars. International Journal of Food Properties, 9: 597–608.

Kaur M., Singh N. (2007): Comparison between the properties of seed, starch, flour and protein separated from chemically hardened and normal kidney beans. Journal of the Science of Food and Agriculture, 87: 729–737.

Marsh L.E., Davis D.W. (1985): Influence of high temperature on the performance of some Phaseolus species at different development stages. Euphytica, 34: 431–439.

McCleary B.V. (2002): Measurement of resistant starch by enzymatic digestion in starch and selected plant materials: collaborative study. Journal of AOAC International, 85: 1103–1111.

Mederos Y. (2006): Indicadores de la calidad en el grano de frijol (*Phaseolus vulgaris* L.). Cultivos Tropicales, 27: 55–62.

Mudryj A.N., Yu N., Aukema H.M. (2014): Nutritional and health benefits of pulses. Applied Physiology, Nutrition and Metabolism, 39: 1197–1204.

Muller F.M. (1967): Cooking quality of pulses. Journal of the Science of Food and Agriculture, 18: 292–295.

Parsons L.R., Howe T.K. (1984): Effects of water stress on the water relations of *Phaseolus vulgaris* and the drought resistant *Phaseolus acutifolius*. Plant physiology, 60: 197–202.

Ramírez-Jiménez A.K., Reynoso-Camacho R., Mendoza-Díaz S., Loarca-Piña G. (2014): Functional and technological potential of dehydrated *Phsaseolus vulgaris* L. flours. Food Chemistry, 161: 254–260.

Sánchez-Arteaga H.M., Urías-Silvas J.E., Espinosa-Andrews H., García-Márquez E. (2015): Effect of chemical composition and thermal properties on the cooking quality of common beans (*Phaseolus vulgaris*). CyTA-Journal of Food, 13: 385–391.

Sefa-Dedeh S., Stanley D.W. (1979a): The relationship of microstructure of cowpeas to water absorption and dehulling properties. Cereal Chemistry, 56: 379–386.

Sefa-Dedeh S., Stanley D.W. (1979b): Textural implications of the microstructure of legumes. Food Technology, 33: 77–83.

Shimelis E.A., Rakshit S.K. (2005): Proximate composition and physico-chemical properties of improved dry bean (*Phaseolus vulgaris* L.) varieties grown in Ethiopia. LWT-Food Science and Technology, 38: 331–338.

Silva-Cristobal L., Osorio-Díaz P., Tovar J., Bello-Pérez L.A. (2010): Chemical composition, carbohydrate digestibility, and antioxidant capacity of cooked black beam, chickpea, and lentil Mexican varieties. CyTA-Journal of Food, 8: 7–14.

Szczesniak A.S. (1975): General foods texture profile revisited-ten years' perspective. Journal of Texture Studies, 6: 5–8.

Vindiola O.L., Seib P.A., Hoseney R.C. (1986): Accelerated development of the hard-to-cook state in beans. Cereal Foods World, 31: 538–552.

Wani I.A., Sogi D.S., Wani A.A., Gill B.S. (2015): Physical and cooking characteristics of some Indian kidney bean (*Phaseolus vulgaris* L.) cultivars. Journal of the Saudi Society of Agricultural Sciences, 30: 1–9.

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