International Food Research Journal 20(3): 1087-1093 (2013)

Journal homepage: *http://www.ifrj.upm.edu.my*

Evaluation of culinary quality and antioxidant capacity for Mexican common beans (*Phaseolus vulgaris* L.) canned in pilot plant

[1]Rocha-Guzman, N. E., [2*]Gallegos-Infante, J. A., [2]Gonzalez-Laredo, R. F., [2]Cardoza-Cervantes, V., [1]Reynoso-Camacho, R., [1]Ramos-Gomez, M., [3]Garcia-Gasca, T. and [4]De Anda Salazar, A.

[1]*Universidad Autónoma de Querétaro, Facultad de Química, Departamento de Investigación y Posgrado en Alimentos (DIPA), Centro Universitario, Cerro de las Campanas s/n, Querétaro, México*

[2]*Instituto Tecnológico de Durango, Departamento de Ingeniería Química y Bioquímica, Felipe Pescador 1830 Ote., Col. Nueva Vizcaya, 34080, Durango, Dgo., México*

[3]*Universidad Autónoma de Querétaro, Facultad de Ciencias Naturales, Av. de las Ciencias s/n. Juriquilla, Querétaro, México*

[4]*Universidad Autónoma de San Luis Potosí, Facultad de Ciencias Químicas. Ave. Manuel Nava 5, Zona Universitaria, San Luis Potosí, SLP., México*

Article history

Received: 24 August 2012
Received in revised form: 12 December 2012
Accepted:13 December 2012

Keywords

Canning
common beans
polyphenols
quality
radical scavenging activity

Abstract

Common beans are rich in bioactive phytochemicals such as polyphenolic compounds. Unfortunately, they need to be thermally processed to be consumed. The health benefits related to common beans comsumption depends mainly on their thermal processing. The objective of this work was to evaluate the effect of thermal processes on the antioxidant capacity and industrial quality of four Mexican common beans cultivars (Black bean 8025, Pinto Saltillo, Pinto Durango, and Bayo Victoria). The common beans were thermally processed by two methods: sterilization (canning), and open pan cooking. Optimal cooking time and Fo parameter (Defined as being equivalent, in sterilizing capacity, to the cumulative lethal effect of all time/temperature combinations experienced at the slowest heating point) were obtained for each cultivar. Grain size, water absorption capacity (WAC), oil absorption capacity, integrity and color were the physical parameter evaluated. Chemical parameters analyzed were total phenolic content (TPC), and DPPH radical scavenging activity. Bayo beans showed biggest size, Pinto beans, medium size, and Black beans, the smallest size. Lowest optimal cooking time (open pan) was observed in Pinto Saltillo cultivar. Lowest Fo parameter of the container during the thermal process was observed for Bayo Victoria cultivar. Higher WAC values were observed in Bayo Victoria and Black bean cultivar (open and canned). Higher value of integrity was found for Bayo Victoria beans. After any thermal processing L^* value was lower in all cultivars. Higher values of TPC in cooked common beans cultivars were observed in Black beans and Bayo Victoria cultivars. Lower IC_{50} value in DPPH test was observed in canned Black beans and Bayo Victoria cultivars.

Introduction

Common edible beans (*Phaseolus vulgaris* L.) are one of the basic foods in Africa, India, and Latin America. Pinto beans are preferred in the North of Mexico and the Southwestern of United States, while Central and South of Mexico, Central America and South America eat mostly colored beans (including black beans). Common bean is a legume considered a functional food because it contains bioactive phytochemicals, such as polyphenols and tannins, which show antioxidant capacity (Dueñas *et al*., 2005; Oomah *et al*., 2005).

In vitro antioxidant activities and phenolic compounds in raw (unprocessed) pinto and black beans, yellow and black soybeans have been reported in several studies (Madhujith *et al*., 2004; Oomah *et al*., 2005; Xu and Chang, 2007). They indicate that common beans may serve as an excellent dietary source of natural antioxidants for disease prevention and health promotion. However, the health-promoting capacities of common beans could depend on their

*Corresponding author.
Email: *jinfante@itdposgrado-bioquimica.com.mx*

cooking, since beans must be thermally processed before consumption despite of cultivar. Cooking improves flavor, palatability and bioavailability of legume nutrients. Food legumes are usually cooked by a boiling process before use. In Latin America, pressure boiling (canning) and open pan cooking are methods commonly used for common beans cooking.

Canning quality is a complex trait and is associated with influences that determine the hydration, palatability and preferences of the consumer (Hosfield and Uebersax, 1990). Although all physical and chemical attributes of cooked beans contribute to processing quality, no single characteristic can describe a sample (Hosfield, 1991). In the developed nations, common beans are generally prepared by commercial food processors and consumed as canned beans in sauce. On the other hand, in undeveloped nations, dry beans are soaked for several hours, cooked in open container, and consumed whole or as a mashed paste with a cereal or tuber (Bressani, 1993). There are a lot of reports in the common beans field and their relationship with health. Previous works in common beans have addressed the polyphenolic content in crude (raw) and in cooking beans (Galvez-Ranilla *et al*., 2009; Rocha-Guzman *et al*., 2007) but usually not mention about quality. From our best knowledge this is the first report in this topic.

The polyphenolic components of common beans and their chemical antioxidant activities have been investigated by several research groups (Xu and Chang, 2008; Rocha-Guzmán *et al*., 2007). These studies showed that common beans soaking, boiling, and steaming significantly affected their phenolic components and their antioxidant activities (determined by *in vitro* chemical assays).

The effect of commercial sterilization (canning process) on the antioxidant capacity and industrial quality of Mexican common beans cultivars has not been studied. The objective of the present work was to evaluate the effect of thermal processes on the antioxidant capacity and industrial quality of four cultivars of Mexican common beans cultivars.

Material and Methods

Folin reagent, gallic acid, vainillin, (+)catechine, DPPH were purchased from Sigma Chemicals (St Louis, MO, USA); Na_2CO_3, HCl, ethanol, methanol, ethyl eter were purchased from J.T. Baker (Toluca, Mexico). Four selected dry beans cultivars (Black bean 8025, Pinto Saltillo, Pinto Durango and Bayo Victoria, from 2009 harvesting season) were donated by INIFAP- Bajio (Celaya, GTO, Mexico).

Thermal processing

The Thermal processing was evaluated by the Ball method, following the next formula:

$$B = f_h[\log j_{ch} I_h - \log g_c]$$

Where B is the processing time, f_h is the index of heating rate, j_{ch} is the lag factor, I_h is the initial difference of temperatures ($T_{retort} - T_{initial}$), and g_c is the difference of temperatures at the end of process ($g_c = T_{retort} -$ critical minimum temperature at the central point in ^{o}F) (Ramaswamy *et al*., 2006).

Canning process

In order to evaluate Fo, thermocouple probes (copper/constantan) were carefully placed at different points to the cans in order to identify SHP (Slowing heating point) of the can. Once the thermocouple was placed and the process commenced, the temperature was recorded regularly throughout the heating and cooling phases of the thermal process. The heat penetration data were collected in order to calculate the Fo value of the process.

Common beans were weighted and washed, then submerged in water at room temperature for 1 h, and then soaked in water at 90°C for 5 min. Cans were filled with 140 g of common beans to a final weight of 250 g. Soaking water was used to fill the cans, leaving 1 cm of headspace. Cans were introduced to an exhauster and then sealed. Cans were introduced in a vertical retort (Polyingenieros, México, DF) at 15 lbs of pressure to reach the thermal time obtained by the Ball method. After that, the cans were cooled and stored until they were used.

Culinary quality of canned common beans

Grain size was evaluated following the method proposed by Guzman-Maldonado *et al.* (1995).

Cooking time

The cooking time was evaluated by the method proposed by Guzman-Maldonado *et al.* (1995).

Water absorption capacity (WAC)

The WAC was determined following the method of Anderson et al. (1969). Briefly, a common bean flour sample (2.5 g) was added to water (30 mL), blended and centrifuged at 4000 rpm for 15 min. Results obtained were indicated as mL of adsorbed water per g of dry weight sample.

Oil absorption capacity (OAC)

The OAC was evaluated following the method of Lin *et al.* (1974). Briefly, a sample (0.5 g) and 3 g of corn oil (Mazola) were blended and centrifuged at

4000 rpm for 25 min. Results obtained were indicated as mL of adsorbed oil per g of dry weight sample.

Integrity

Degree of splitting was measured by a visual rating procedure (visual estimation) of 100 seeds of canned beans and expressed in percent using next formula:

$$\% \text{ Integrity} = (\text{Damage seed} - 100 / 100) \times 100$$

Only completely split beans and skins were considered as split.

Color

The color difference of the drained canned beans was determined with a colorimeter Minolta CR-410 (Konica Minolta, Tlanepantla, México). A standard white tile was used to standardize instrument ($L^* = 96.539$, $a^* = -0.425$, $b^* = 1.186$).

Chemical evaluation

Extraction procedure

Samples (80 g) were extracted with 70% aqueous acetone (200 mL) for 24 h at room temperature with agitation. Crude extracts were concentrated under vacuum at 40°C in a rotary evaporator (Buchi, model R-200/250, Flawil, Switzerland). The resulting aqueous solutions were lyophilized to a powder and stored in the dark at 4°C until analyzed. Extractions were performed in duplicate. Experimental samples were always protected from light (Waterman and Mole, 1994).

Polyphenol content

Total phenolic content (TPC) in extracts from experimental samples were determined by a Folin-Ciocalteu modified method (Heimler *et al*., 2006), using gallic acid as standard and expressing the results as *meq* of catechin (mg catechin/g of sample).

Antioxidant capacity assays

The antioxidant capacity as the radical scavenging activity (RSA) was measured using the DPPH* (2,2,-diphenyl-1-picrylhydrazyl) method (Brand-Williams *et al.*, 1995). A calibration curve at 515 nm (UV/Vis Spectrophotometer, Varian, Cary 50, Varian, Palo Alto, CA, USA. Cary 50) was made to calculate the remaining DPPH* concentration in the reaction medium at several concentrations (0-1000 µg/mL). A volume of 1.9 mL of DPPH* in methanol was used. The IC_{50} values are reported as final concentration of extract in the cuvettes defined as µg/mL of dried extracts required to decrease the initial DPPH concentration by 50%. IC_{50} (concentration which results in a 50% reduction, or inhibition, of DPPH) was determined by linear regression (Neri-Numa *et al*., 2013)

Statistical analysis

The experimental data were analyzed by means of ANOVA and Tukey test ($\alpha = 0.05$) using Statistica software Version 8.0 (StatSoft,Tulsa, OK, USA).

Results and Discussion

Grain size

The grain size results are shown in Table 1. From this table is clear that Bayo beans are big grains, Pintos are medium sized and Black beans are the smallest ones. These results agreed with those reported by Guzman-Maldonado *et al*., (1995). Color and grain size are two main factors used to choose beans (Leterme and Carmenza, 2002). However, there are great differences in consumptions patterns. For example, in Guatemala and Brazil, people eat small black beans; in Nicaragua, small and medium size red beans; in Colombia people prefers large red beans (Diamant *et al*., 1989).

Table 1. Grain size of common beans cultivars

Cultivar	Length (mm)	Width (mm)	Thick (mm)
Pinto Saltillo	9.8	7.1	4.5
Pinto Durango	12.7	7.8	5.3
Negro	12.5	8.4	5.1
Bayo Victoria	13.2	9.1	5.9

Cooking Time

Open Pan

Another factor when choosing beans is the softness after cooking. This parameter is related to the cooking time (Leterme and Carmenza, 2002). Results about cooking time are shown in Table 2. Bayo beans showed the highest open pan cooking time. This result agrees with that reported by Hernandez-Jacinto *et al*., (2002) for Bayo Victoria beans. The lowest cooking time was reported for Pinto Saltillo beans. Results were lower than those reported by Aguirre-Santos and Gomez-Aldapa (2010). Differences could be attributed to different cultural practices. Beans require much more energy (300,000 kJ/g) than other staple food for cooking (Brouwer *et al*., 1989), thus lower cooking time is important in the case of absence of modern implements of cooking.

Sterilization

Canning quality in dry beans are influenced by several processing variables such as soaking and blanching time, brine composition, and duration of thermal processing (canning) (Balasubramanian *et al*., 2000). Results of thermal processing time are shown in Table 2. Lowest Fo value (7.5 min) was observed for Bayo Victoria cultivars. This fact is interesting because Bayo Victoria cultivar showed the highest cooking time in the open pan process. There are no reports about this cultivar in canning processing, but Hernandez-Jacinto *et al.*, (2002), reported that higher cooking times for Bayo Victoria is related to the hardness of seed coat and cotyledon. However, the lower Fo value could be related to a better mechanism of heat transfer. It is well understood that fluid-to-particle heat transfer coefficient (h_{fp}), is influenced by several factors as particle size (Ramaswamy and Zaraifard, 2000). They found that an increase in the particle size increase the heat transfer coefficient (h_{fp}), thus this indicated that large size of common beans such as Bayo Victoria could more efficient into the process canning than small size common beans grains. Unfortunately, in the present work the H_{fp} values were not studies for the several cultivars of common beans.

Table 2. Cooking time of common beans cultivar

Cultivar	Cooking time (open pan) (min)	Fo (min)
Pinto Saltillo	142 ± 7	9.0 ± 0.1
Pinto Durango	111 ± 4	10.1 ± 0.1
Negro	108 ± 2	11.4 ± 0.1
Bayo Victoria	255 ± 6	7.2 ± 0.1

Fo = Accumulated lethality (Retort temperature 121.1°C), min

Water absorption capacity

Results about WAC are shown in Table 3. In comparing uncooked beans, the lowest value of WAC was observed in uncooked Pinto Durango bean and the highest value was observed for uncooked Pinto Saltillo beans. The water absorption capacity has been related to the type and amount of protein present in the common bean (Desphande *et al*., 1984). Mwasaru *et al*. (1999) found that WAC was a function of the water protein and water – water molecular interactions. Therefore, they concluded that higher absorption capacity is caused by physical retention of water into the new structure built by protein aggregation. However, the content of protein is higher in Pinto Durango (19.9 ± 0.6%) in comparison to Pinto Saltillo (15.1 ± 0.4%) bean, thus the previous argument is not completely true. Esteves *et al*., (2002) studied six bean cultivars and concluded that there is an inverse relationship among polyphenol and lignin content with peroxide activity, and with water absorption capacity.

Results for WAC for beans cooked in open pan are shown in Table 3. The higher values of WAC were shown by Black and Bayo Victoria beans. Water absorption capacity is related to temperature and time. The optimal cooking times for these cultivars were very long for Bayo (255 ± 6 min) and the shortest for black bean (108 ± 2 min).

Results of WAC for canning common beans flour are shown in Table 3. The lowest WAC value was observed for Bayo Victoria common beans (1.8). The canning process is a complex phenomenon. The first step in this process was related to the heat and mass transfer into the seed. Mwangwela *et al.* (2006) reported an increase in WAC for cowpea related with a fracture of the seed coat and cotyledon. Hernandez-Jacinto *et al*. (2002) reported an increase of 100 % of WAC after open pan cooking Bayo beans. They attribute this behavior to the fracture of the seed coat of Bayo beans. In the present work no evidence of fracture of seed coat was observed this could be explained different behavior of Bayo beans.

Oil absorption capacity

The oil absorption capacity is associated to the physical trapping of oil and with the accessibility of non-polar sites in the polypeptide chain (Rocha-Guzman *et al*., 2008). Results for oil absorption capacity are shown in Table 3. Pinto Durango beans showed the highest value of OAC. No differences were observed between others cultivars. The difference between Pinto Durango and other cultivars may be due to the different protein concentration, degree of interaction with oil, and possibly conformational characteristics (Siddiq *et al*., 2010). High fat absorption may be due to the presence of large proportion of hydrophobic groups and non – polar aminoacids on the surface of protein molecules (Sathe *et al*., 1982). The most interesting results were observed in thermal processed Pinto Durango beans. For this cultivar OAC was lower when the grain was processed. Several authors (Adewobale and Lawal, 2004) have found that the occurrence of protein´s non-polar lateral chains is important, because they allow the binding to oil, and if the protein is denatured, its secondary structure is lost as well as the binding oil activity (El-Adawy *et al.*, 2003). This behavior is true only if the lateral chains of the protein have a non-polar behavior.

Integrity

Integrity results are shown in the Table 3. Best integrity was observed in Bayo Victoria beans. The integrity in Bayo Victoria beans was higher in the

Table 3. Physico-chemical properties and protein content of common beans cultivars

Sample	Water Absorption Capacity (WAC) (g of water/ g of sample)	Oil Absorption Capacity (OAC) (g ofoil/ g of sample)	Integrity (%)	L^*	Protein
Crude Black bean	1.6 ± 0.00	0.13 ± 0.00	----	82.1 ± 0.3	23.2 ± 0.6
Canned Black bean	2.1 ± 0.14	0.22 ± 0.02	79.2 ± 4.5	26.3 ± 2.9	23.2 ± 0.6
Open pan cooked black bean	2.9 ± 0.14	0.22 ± 0.02	94.7 ± 0.8	31.0 ± 1.9	20.2 ± 0.7
Crude Pinto Saltillo	2.1 ± 0.14	0.13 ± 0.00	----	86.0 ± 0.9	15.1 ± 0.4
Canned Pinto Saltillo	2.1 ± 0.14	0.15 ± 0.02	84.7 ± 3.5	57.9 ± 6.6	18.8 ± 0.3
Open Pan Cooked Pinto Durango Bean	2.0 ± 0.00	0.11 ± 0.02	93.2 ± 2.2	58.2 ± 6.6	19.6 ± 0.4
Crude Pinto Durango	1.1 ± 0.14	0.35 ± 0.02	----	82.8 ± 1.6	19.9 ± 0.6
Canned Pinto Durango	2.3 ± 0.14	0.20 ± 0.0	81.7 ± 5.6	50.2 ± 6.1	20.2 ± 0.5
Open Pan Cooked Pinto Durango Bean	2.3 ± 0.14	0.20 ± 0.00	92.8 ± 1.7	53.8 ± 4.5	23.0 ± 0.6
Crude Bayo Bean	1.6 ± 0.0	0.15 ± 0.07	-----	82.1 ± 1.9	21.9 ± 0.7
Canned Bayo Bean	1.8 ± 0.0	0.21 ± 0.02	97.1 ± 0.7	47.6 ± 0.7	12.5 ± 0.3
Open Pan cooked Bayo Bean	2.9 ± 0.14	0.20 ± 0.0	88.5 ± 0.6	53.8 ± 4.4	21.9 ± 0.5

canning process than in the open pan. In contrast, other cultivars showed higher integrity in the open pan process than in canning. This behavior may be due the lower Fo process time for the Bayo Victoria cultivar.

It is important in the canning industry to consider the seed coat splitting as one factor affecting the integrity of the appearance in the final product (Wu *et al.*, 2005). When the seed coat splits, it affects more than just the appearance. It can also result in starchiness and excessive viscosity in the final product. Two types of splits often occur in the canned common beans. The first is called as the transverse crack, which occurs in the region of the hilum and micropyle. The second is longitudinal (Van Buren *et al.*, 1986). The seed coat splitting may have resulted from many different variables.

Color

The color changes should be minimized during thermal processing of foods, unfortunately is inevitable that heating results in color changes. Results obtained are shown in Table 3. L^* color parameter showed more significant changes related to the black beans (canning and open pan cooking). They show darker colors (i.e., lower L^* values) than crude beans. This behavior is in agreement with Bellido *et al.*, (2006) for micronized (infrared heating) black beans. Similar reduction in L^* values behavior was observed in the rest of cultivars used in the present experiment.

Total phenolic content (TPC)

Total phenolic content results are shown in Figure 1. In general, lower TPC values were observed in the extracts from cooked common beans. This result is agreement with that reported by Galvez-Ranilla *et al.* (2009) for two Brazilian cultivars and similar to the reported for Rocha-Guzman *et al.* (2007) for Mexican common beans cultivars. In relative terms, greater losses of TPC were observed in black beans. Several reports indicate that black beans have anthocyanins (Galvez-Ranilla *et al.*, 2009). It is well known that they are very sensitive to heat and can easily convert to the colorless chalcone during heating (Wrolstad *et al.*, 2002). Black beans do not show differences in relative percentage degradation of TPC for canning and open pan cooking. Pinto Durango showed more degradation of TPC in open pan and similar behavior was observed for Bayo Victoria. Pinto Saltillo showed more degradation under the canning process. Bayo Victoria and Pinto Durango had higher cooking times under the open pan process, thus, this variable could influence a deeper degradation of phenolic compounds different to anthocyanins that only had been reported in black beans.

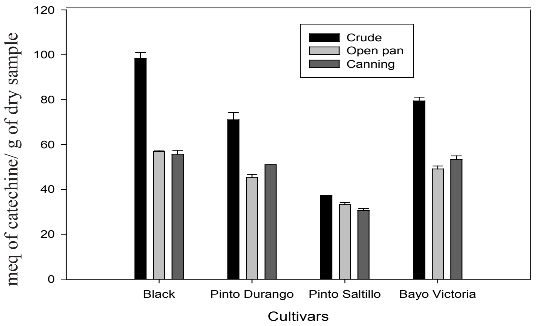

Figure 1. Total phenolics content of crude and processed common beans

DPPH Test

According to the literature, thermal processing generally decreases the total phenol content in legumes. However, sometimes the TPC is not related to the antioxidant capacity. Results for DPPH test are shown in Figure 2. The highest antioxidant capacity was observed in beans without any thermal process (i.e. lower value of IC_{50}). This result does not agree with report by Rocha-Guzman *et al.*, (2007) for Bayo Victoria extracts. Differences could be related to different harvesting season of the Bayo Victoria cultivar. Canning was the thermal process that showed lower values of IC_{50} for Black beans and Bayo Victoria cultivars.

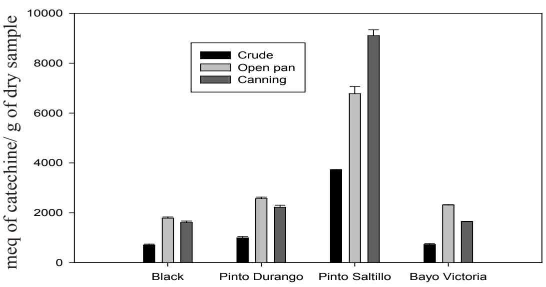

Figure 2. IC_{50} (DPPH test) for crude and processed common beans

Conclusions

The crude (raw) Mexican common bean cultivars showed highest polyphenolic content and antioxidant activity (by DPPH method). The best cultivar for canning process was Bayo Victoria. This cultivar showed higher values for integrity, total phenolic content and antioxidant capacity measured by the DPPH method after the canning process. Black beans showed highest antioxidant capacity for open pan cooking.

Acknowledgements

The present project was funded by DGEST grant 4557.12.

References

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

Anderson, R.A, Conway, H.F, Pfeifer, V.F. and Griffin, E.L. 1969. Gelatinizacion of corn grits by roll and extrusion cooking. Cereal Science Today 14: 4-12.

Aguirre-Santos, E.A. and Gomez-Aldapa, C.A. 2010. Evaluación de las características fisicoquímicas en la especie de frijol *Phaseolus vulgaris* de las variedades; pinto saltillo, bayo victoria y negro San Luis. Revista Salud Pública y Nutrición. Ed. Especial 9-2010, FH110 1-8.

Balasubramanian, P., Slinkard, A., Tyler, R., and Vandenberg, A. 2000. A modified laboratory canning protocol for quality evaluation of dry bean (*Phaseolus vulgaris* L). Journal of the Science and Food and Agriculture 80: 732–738.

Bellido, G., Arntfield, S.D., Cenkowski, S, and Scanlon, M. 2006. Effects of micronization pretreatments on the physicochemical properties of navy and black beans (*Phaseolus vulgaris* L.). Lebensm. Wiss. Technol Food Science and Technology 39:779–787.

Brand-Williams, W., Cuvelier, M.E. and Berset, C. 1995. Use of a free radical method to evaluate antioxidant activity. LWT – Food Science and Technology 28: 25 – 30.

Bressani, R. 1993. Grain quality of common beans. Food Reviews. International 9: 237 – 297.

Brouwer, I.D., Nederveen, L.M., den Hartog A.P. and Vlasveld, A.H.C. 1989. Nutritional impacts of an increasing fuelwood shortage in rural household in developing countries. Progress in Food and Nutrition Sciences 13: 349 – 361.

Desphande, S.S, Sathe, S.K, and Salunkhe, D.K. 1984. Dry beans of Phaseolus: a review. Part 3. CRC Critical Reviews in Food Science and Nutrition 21:137-140.

Diamant, R., Watts, B., Elias, L. and Rios, B. 1989. Consumer utilization and acceptability of raw and cooked black beans (*Phaseolus vulgaris*) in Guatemala. Ecology of Food and Nutrition 22:183–195.

Dueñas, M., Fernández, D., Hernández, T., Estrella, I. and Muñoz, R. 2005. Bioactive phenolic compounds of cowpeas (*Vigna sinensis* L). Modifications by fermentation with natural microflora and with Lactobacillus plantarum ATCC 14917. Journal of the Science and Food and Agriculture 85: 297 – 304.

El-Adawy, T.A., Rahma, E.H,, El-Bedawey, A.A. and El-Beltagy, A.E. 2003. Nutritional potential and functional properties of germinated mung bean, pea and lentil seeds. Plant Foods for Human Nutrition 58: 1-13.

Esteves, A.M., Abreu, C.M.P, Santos, C.D. and Corrêa, A.D. 2002. Comparação química e enzimática de seis linhagens de feijão (*Phaseolus vulgaris* L.). Ciência Agrotecnologica 26: 999-1005

Gálvez Ranilla, L., Genovese, M.I. and Lajolo, F.M.

2009. Effect of Different Cooking Conditions on Phenolic Compounds and Antioxidant Capacity of Some Selected Brazilian Bean (*Phaseolus vulgaris* L.) Cultivars. Journal of Agricultural and Food Chemistry 57: 5734-5742

Guzmán-Maldonado, H., Jacinto, H. C. and Castellanos, Z. J. 1995. Manual de metodologías para evaluar calidad de grano de frijol. SAGAR, INIFAP, CIRCE. 75 p. (Tema Didáctico Núm. 2).

Heimler, D., Vignolini, P., Dini, M.G., Vincieri, F.F. and Romani, A. 2006. Antiradical activity and polyphenol composition of local *Brassicaceae* edible varieties. Food Chemistry 99: 464 – 469

Hernández-Jacinto, C., Hernández-Sánchez, H., Azpiroz-Rivero, H. S., Acosta-Gallegos, J. A. and Bernal-Lugo, I. 2002. Caracterización de una población de líneas endogámicas de frijol común por su calidad de cocción y algunos componentes nutrimentales. Agrociencia 36: 451-459.

Hosfield, G.L. Uebersax, M.A. 1990. The definition and measurement of culinary quality in dry bean. Michigan Dry bean Digest 14: 20 – 27.

Hosfield, G.L. 1991. Genetic control of production and food quality factors in dry bean, Food Technology 45: 98 – 103.

Leterme, P. and Carmenza Munoz, L. 2002. Factors influencing pulse consumption in Latin America. British Journal of Nutrition 88 (suppl. 3): S251–S255.

Lin, M.J.Y, Humbert, E.S. and Sosulsky, F.W. 1974. Certain functional properties of sunflower meal products. Journal of Food Science 39: 368-372.

Madhujith, T., Naczk, M. and Shahidi, F. 2004. antioxidant activity of common beans (*Phaseolus vulgaris* l.). Journal of Food Lipids 11: 220–233.

Mwangwela, A.M., Waniska, R.D. and Minnaar, A. 2006. Hydrothermal treatments of two cowpea (*Vigna unguiculata* L. Walp) varieties: effect of micronisation on physicochemical and structural characteristics. Journal of the Science of Food and Agriculture 86: 35-45.

Mwasaru, M.A., Muhammad, K., Bakar, J. and Che Man, Y. 1999. Effects of isolation technique and conditions on the extractability, physicochemical and functional properties of pigeon-pea (*Cajanus cajan*) and cowpea (*Vigna unguiculata*) protein isolates. I. Physicochemical properties. Food Chemistry 67: 435-443.

Neri-Numa, I.A., Carvalho-Silva, L.B., Pinto Morales, J., Gomes Malta, L., Muramoto, M.T., Macêdo Ferreira, J.E., Carvalho, J.E., Tasca Gois Ruiz, A.L., Maróstica Junior, M.R. and Pastore, G.M. 2013. Evaluation of the antioxidant, antiproliferative and antimutagenic potential of araçá-boi fruit (*Eugenia stipitata* Mc Vaugh — Myrtaceae) of the Brazilian Amazon Forest, Food Research International 50: 70-76

Oomah, B. D., Cardador-Martínez, A. and Loarca-Piña, G. 2005. Phenolics and antioxidative activities in common beans (*Phaseolus vulgaris* L). Journal of the Science and Food Agriculture 85: 935-942.

Ramaswamy, M.M. and Zaraifard, I. 2002. Evaluation of factors infuencing tube-flow fuid-to-particle heat transfer coefficient using a calorimetric technique. Journal of Food Engineering 45: 127 – 138.

Ramaswamy, M. M. 2006. Food processing. Principles and applications. Editorial Taylor and Francis Group P 91-112.

Rocha-Guzmán, N.E., Gallegos-Infante, J.A., González-Laredo, R.F., Bello-Pérez, A., Delgado-Licon, E. and Ortiz-Prado, M.J. 2008. Physical properties of extruded products made with three Mexican common beans (*Phaseolus vulgaris* L). Plant Foods for Human Nutrition 63: 99 – 104.

Rocha-Guzmán, N., González-Laredo, R.F., Ibarra-Pérez F.J., Nava-Berumen, C.A. and Gallegos-Infante, J.A. 2007. Effect of pressure cooking on the antioxidant activity of extracts from common bean (*Phaseolus vulgaris* L.) cultivars, Food Chemistry 100: 31-35.

Sathe, S. K., Desphande, S. S. and Salunkhe, D. K. 1982. Functional properties of lupin protein concentrates. Journal of Food Science 47: 491-497

Siddiq, R. R., Ravi, J.B., Harte, K.D. and Dolan. 2010. Physical and functional characteristics of selected dry bean (*Phaseolus vulgaris* L.) flours, LWT - Food Science and Technology 43: 232-237

Van Buren, J., M. Bourne, D. Downing, D. Queale, E. Chase, and S. Comstock. 1986. Processing factors influencing splitting and other quality characteristics of canned kidney beans. Journal of Food Science 51: 1228-1230

Waterman, P. G. and Mole, S. 1994. Analysis of Phenolic Plant Metabolites. Blackwell Scientific Publications, Massachusetts

Wu, X., James, R., and Anderson, A. 2005. Mineral contents in seed coat and canning quality of selected cultivars of dark red kidney beans (*Phaseolus vulgaris* L.). Journal Food Processing 29: 63-74

Wrolstad, R.E., Durst, R.W., Giusti, M.M. and Rodriguez-Saona, L.E. 2002. Analysis of anthocyanins in nutraceuticals. In: Quality management of nutraceuticals. American Chemical Society. Washington, D.C., 42 – 62pp.

Xu, B. and Chang, S.K.C. 2007. A comparative study on phenolic profiles and antioxidant activities of legumes as affected by extraction solvents. Journal of Food Science 72: S159-S166.

Xu, B. and Chang, S.K.C. 2008. Effect of soaking, boiling, and steaming on total phenolic content and antioxidant activities of cool season food legumes, Food Chemistry 110: 1-13.