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


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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 consumption 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 IC50 value in DPPH test was observed in canned Black beans and Bayo Victoria cultivars.

Keywords

Canning common beans polyphenols quality radical scavenging activity

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
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-Guzmán 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); Na₂CO₃, 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). 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:

\[ B = f_h \left[ \log f_{ch} \right]_h - \log g_c \]

Where B is the processing time, \( f_h \) is the index of heating rate, \( f_{ch} \) 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 “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 next formula proposed by 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:

\[
\% \text{ Integrity} = \left( \frac{\text{Damage seed} - 100}{100} \right) \times 100
\]

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 \(\mu\)g/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 \(\mu\)g/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).

**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 ($h_p$), 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 ($h_p$), 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 $H_{bp}$ values were not studies for the several cultivars of common beans.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Cooking time (open pan) (min)</th>
<th>Fo (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Saltillo</td>
<td>142 ± 7</td>
<td>9.0 ± 0.1</td>
</tr>
<tr>
<td>Pinto Durango</td>
<td>111 ± 4</td>
<td>10.1 ± 0.1</td>
</tr>
<tr>
<td>Negro</td>
<td>108 ± 2</td>
<td>11.4 ± 0.1</td>
</tr>
<tr>
<td>Bayo Victoria</td>
<td>255 ± 6</td>
<td>7.2 ± 0.1</td>
</tr>
</tbody>
</table>

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
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.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Water Absorption Capacity (WAC) (g of water/g of sample)</th>
<th>Oil Absorption Capacity (OAC) (g of oil/g of sample)</th>
<th>Integrity (%)</th>
<th>L’</th>
<th>Protein (g of water/g of sample)</th>
</tr>
</thead>
</table>
| 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
| Open pan cooked black bean | 2.9 ± 0.14                                            | 0.22 ± 0.02                                       | 94.7 ± 0.8    | 31.0 ± 1.9
| 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
| Open Pan Cooked Pinto Durango Bean | 2.0 ± 0.00                                         | 0.11 ± 0.02                                       | 93.2 ± 2.2    | 58.2 ± 6.6
| 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 ± 0.02                                       | 81.7 ± 5.6    | 50.2 ± 6.1
| Open Pan Cooked Pinto Durango Bean | 2.3 ± 0.14                                         | 0.20 ± 0.00                                       | 92.8 ± 1.7    | 53.8 ± 4.5
| 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
| Open Pan cooked Bayo Bean | 2.9 ± 0.14                                             | 0.20 ± 0.0                                         | 88.5 ± 0.6    | 53.8 ± 4.4

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

**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.

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**References**


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


