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ENVIRONMENT DIRECTORATE
JOINT MEETING OF THE CHEMICALS COMMITTEE AND
THE WORKING PARTY ON CHEMICALS, PESTICIDES AND BIOTECHNOLOGY

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Task Force for the Safety of Novel Foods and Feeds

DRAFT CONSENSUS DOCUMENT ON COMPOSITIONAL CONSIDERATIONS FOR NEW VARIETIES OF COMMON BEAN (Phaseolus vulgaris L.) - First Draft Version

20th meeting of the Task Force, OECD, 11-12 April 2013

Contact: bertrand.dagallier@oecd.org; tel:+ 33 (0)1 45 24 84 51

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At the 17th meeting of the Task Force for the Safety of Novel Foods and Feeds (June 2010), Brazil suggested to develop a new Consensus Document on common bean (*Phaseolus vulgaris*). A room document and slides were presented in support to the item. Then a formal proposal [ENV/JM/FOOD(2010)5] was submitted to the 18th meeting (May 2011) and agreed. An Ad hoc expert drafting group was established, including participants from Brazil (lead), Argentina, Canada, Mexico, Spain, United States and CIAT-Colombia.

This first draft Consensus Document [ENV/JM/FOOD(2003)2] was elaborated by a team composed of B. Dave Oomah[1]; Carmen Jacinto-Hernández, Ramón Garza-García and Dagoberto Garza-García[2]; Daniel Debouck[3]; Irma Bernal-Lugo[4], Priscila Zaczuk Bassinello, Alcido Elenor Wander, Pedro A. Arraes and Tereza Borba[5], Jose Luiz V. Carvalho and Marilia Nutti[6].

This first version will be revised, following comments and additions by other delegates. Some points to clarify and few missing sections are highlighted in the text. The draft document being almost complete and containing already solid information/data on nutrients and anti-nutrients, the ad hoc group wishes to circulate it to the whole Task Force for getting feedback in advance to the next plenary meeting.

The document, along with comments and additional inputs received, will be discussed at the 20th meeting of the Task Force to be held in Paris on 11-12 April 2013.

ACTION: This document is submitted to all delegates to the Task Force for COMMENTS and ADDITIONS, to be sent to the lead country *(marilia.nutti@embrapa.br)]* **with copy to the OECD Secretariat, *by 29 March 2013*.**

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1 Agriculture and Agri-Food Canada - Pacific Agri-Food Research Centre -Summerland, British Columbia -Canada V0H 1Z0; contact: Dave.Oomah@agr.gc.ca

2 Bean Program. Campo Experimental Valle de México. CEVAMEX-INIFAP, Apdo.10-56230, Km 13.5 carretera Los Reyes-Texcoco - Coatlinchan, Estado de México, México; contact: jacinto.carmen@inifap.gob.mx

3 CIAT, Cali, Colombia, contact: d.debouck@cgiar.org

4 Departamento de Bioquímica, Facultad de Química, UNAM. México D. F. 04510, México; contact: irmofel@unam.mx

5 Embrapa Rice and Beans, Rodovia GO-462, Km 12, Zona Rural, Santo Antonio de Goiás – Brasil – 75375-000; contact: priscila.bassinello@embrapa.br

6 Embrapa Food Technology , Av. das Américas. 29.501, Guaratiba, RJ, Brasil – 23020-470 – contact: marilia.nutti@embrapa.br

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SECTION I - BACKGROUND

A. General description of common bean

1. Evidence has accumulated since the 1960s about the presence and distribution of wild common bean [*Phaseolus vulgaris* L., tribe Phaseoleae, family Leguminosae (Schrire, 2005)] in Central and South America where it is part of the native flora (Gepts and Debouck, 1991; Freytag and Debouck, 2002). All cultivated varieties grown in the world today originate in two independent domestication events from few wild populations at different pre-Columbian times (Kaplan and Lynch, 1999; Piperno, 2012), in western Mexico (Kwak and Gepts, 2009) and in central Peru (Chacón-Sánchez et al., 2005). By human selection three races assembling dozens of landraces were formed in each region (Singh et al., 1991), possibly for 2-3,000 years in Mesoamerica twice to three times that duration in the Andes (Kaplan and Lynch, 1999; Piperno, 2012). From there after 1492 common bean was taken to SW Europe (Rodiño et al., 2006), the Mediterranean region (Angioi et al., 2010), to (mostly eastern) Africa (Westphal, 1974) and parts of Asia (Zhang et al., 2008), and back to the Americas (Albala, 2007; Gepts et al., 1988). At mild temperate latitudes, given the short growing season, snap bean varieties for consumption as green pod with immature seeds were selected (Myers & Baggett, 1999). Given that geographical and ecological expansion, there is no wonder that this crop has been given an ample diversity of names, such as 'frijol' in Spanish speaking Latin America, 'feijao' in Brazil, 'judia' in Spain, 'haricot; haricot vert' in French, and many more (Voysest and Dessert, 1991). Apart from common bean, four other species were domesticated, for example the Lima bean also domesticated twice (Motta-Aldana et al., 2010).

2. Common bean is a herbaceous vine with fibrous roots, annual and monocarpic (some of its most primitive forms and its wild relatives are pluriannual and polycarpic vines in montane forests in Mexico and Central America (Freytag and Debouck, 2012), with bush determinate and indeterminate growth habits being selected for earliness, mono-cropping and mechanical harvesting. Although leaves (rarely flowers) are consumed (Purseglove, 1968), its main products are seeds, harvested either before (green shelled beans) or after physiological maturity (dry beans); green pods are also consumed (snap beans). The latter two have given rise to an important canning industry; recently deep-frozen and dried food products have appeared on world markets. Dried stems and pods have been used as hay for animal feeding (Hendry, 1918; Westphal, 1974). Most dry bean varieties are consumed after water cooking; grains of some landraces, mostly central Andean, are consumed after toasting (Tohme et al., 1995). In pre-Columbian America, beans were often associated with maize, a system that with the combination of local races of maize and beans has been adopted by many Amerindian civilizations, because of its agronomic resilience and its nutritional value. Today beans are a no fat source of carbohydrates, proteins (22-30%) and minerals [namely iron and zinc (Beebe et al., 2000)] with positive attributes against Type 2 diabetes, high cholesterol and breast cancer (Thompson et al., 2008).

B. Production

3. Exact production of common bean on a worldwide basis is very difficult to assess, first because a very substantial part of the production is consumed on-farm by the family who has planted the bean crop. Auto-consumption has been a long tradition all across the Americas since domestication, but also in small-

scale agricultures where the bean crop has been introduced, namely the East African highlands, the Iberian Peninsula, the Balkans, and scattered places of the Near East (Kaplan and Kaplan, 1992; Voysest and Dessert, 1991). In all these places auto-consumption on-farm is also associated with limited sale on local markets. The second reason for this uneasy assessment lays in the fact that not all dry beans subject of national or international trade are discriminated at the species level. So, pulses or beans may mean more than common bean (botanically *Phaseolus vulgaris* L.) (Lackey, 1981; Voysest, 1983). Finally, one should keep in mind that all the different uses afore-mentioned refer all to the same crop. Snap beans or green shell beans may be computed separately from dry beans while they refer to the same botanical species (Heiser, 1990; Voysest and Dessert, 1991).

4. Keeping these caution notes in mind, it seems that the largest area of production in the world still is its native America, with Brazil, the United States of America and Mexico as the larger producers (FAO, 2009). High figures reported for Myanmar and China (FAO, 2009) would call for caution, precisely because of confusion with *Ceratotropis Vigna* species or other legumes such as the winged bean or the asparagus bean, as mentioned by others (Broughton et al., 2003). Central American countries, while all producers, are importing dry beans for the national consumption, with the possible exception of Nicaragua, that some years turns into an exporter towards neighbouring countries (FAO, 2009). The principal islands of the Caribbean produce dry beans during the winter period, but the production does not suffice and are all importers. Countries of eastern Africa with the highest rates of consumption *per capita* in the world, produce dry beans but need to import at varying levels pending on the harvest. Consumption levels in North America and Europe are not at the expected level given the potential of beans to reduce diabetes, cholesterol and cancer (Thompson et al., 2008).

5. Dry beans represent an important staple, both in the developing as well as in the developed world, with an average global production estimated at 22.46 million tonnes from 2008/2009 to 2010/2011 (FAO, 2011). Dry beans are used mainly for human consumption. Dry beans are an important source of protein in the tropics; based on protein consumption per capita per day, it ranks seventh among the major food crops (FAO, 2011).

6. World bean production has increased from 15.4 million tons (Mt) in 1984-1986 (3-years-average) to 22.5 Mt in 2009-2011 (Table 1). The five countries with the highest production of dry beans in 2009-2011 were India (3.9 Mt), Myanmar (3.4 Mt), Brazil (3.4 Mt), China (1.5 Mt) and the United States of America (1.2 Mt) (FAO, 2011).

7. The global estimated harvest area of dry beans increased from 26.42 million hectares in 1984-1986 to 28.24 million hectares in 2009-2011 (Table 2).

8. Dry beans are produced, mainly by smallholders, in subtropical and tropical regions, of all continents. In 2009-2011 average, the world average yield of dry beans was 0.80 t/ha, with an average of 1.80 t/ha in Europe, 0.97 t/ha in Americas, and 0.89 t/ha in Oceania (Table 3). The yield varies with the cultivar, season of planting, soil type, and fertility. The average dry bean yields in 2009-2011 are far below the yields that may be obtained under optimum conditions which can result ranging from 3.0-6.0 t/ha.

9. 1. Dry beans represent a food crop which is mainly consumed in countries where it is produced. Only 14% of production is being internationally traded. Main importers are the European Union, India, United States of America and United Kingdom. Main exporters are China, Myanmar, United States of America, Argentina and Canada (FAO, 2011).

Table 1. Estimated global dry beans production

Bean[(a)] production (Million tonnes – Mt)	Years (3-years-average)[(b)]					
	1984-1986	**1989-1991**	**1994-1996**	**1999-2001**	**2004-2006**	**2009-2011**
Africa	2.03	2.44	2.35	2.92	3.17	4.17
Americas	5.43	6.03	6.79	6.47	6.88	7.16
Asia	7.14	7.60	7.63	7.87	8.67	10.62
Europe	0.82	0.59	0.53	0.57	0.46	0.45
Oceania	0.02	0.02	0.03	0.05	0.05	0.05
World	***15.44***	***16.67***	***17.32***	***17.88***	***19.22***	***22.46***

Source: FAOSTAT (2013)
[(a)] Data on beans are aggregated and include two mains species: Common beans (*Phaseolus vulgaris* L.) and Cowpeas (*Vigna unguiculata* (L.) Walp).
[(b)] Each column represents an average of three years, i.e. 1984-1986 represents an average of the years 1983/1984, 1984/1985 and 1985/1986.

Table 2. Estimated global dry beans harvested area

Bean[(a)] harvested area (Million hectares)	Years (3-years-average)[(b)]					
	1984-1986	**1989-1991**	**1994-1996**	**1999-2001**	**2004-2006**	**2009-2011**
Africa	3.02	3.31	3.80	4.55	5.27	6.08
Americas	9.01	9.05	9.16	7.85	7.61	7.38
Asia	13.37	13.58	12.77	10.98	13.64	14.47
Europe	0.97	0.59	0.41	0.40	0.29	0.25
Oceania	0.04	0.03	0.04	0.05	0.03	0.06
World	***26.42***	***26.56***	***26.17***	***23.83***	***26.83***	***28.24***

Source: FAOSTAT (2013)
[(a)] Data on beans are aggregated and include two mains species: Common beans (*Phaseolus vulgaris* L.) and Cowpeas (*Vigna unguiculata* (L.) Walp).
[(b)] Each column represents an average of three years, i.e. 1984-1986 represents an average of the years 1983/1984, 1984/1985 and 1985/1986.

Table 3. Estimated global dry beans average yield

Bean[(a)] harvested area (Million hectares)	Years (3-years-average)[(b)]					
	1984-1986	**1989-1991**	**1994-1996**	**1999-2001**	**2004-2006**	**2009-2011**
Africa	0.67	0.74	0.62	0.64	0.60	0.69
Americas	0.60	0.67	0.74	0.82	0.90	0.97
Asia	0.53	0.56	0.60	0.72	0.64	0.73
Europe	0.84	0.99	1.29	1.40	1.60	1.80
Oceania	0.48	0.62	0.71	1.03	1.44	0.89
World	***0.58***	***0.63***	***0.66***	***0.75***	***0.72***	***0.80***

Source: FAOSTAT (2013).
[(a)] Data on beans are aggregated and include two mains species: Common beans (*Phaseolus vulgaris* L.) and Cowpeas (*Vigna unguiculata* (L.) Walp).
[(b)] Each column represents an average of three years, i.e. 1984-1986 represents an average of the years 1983/1984, 1984/1985 and 1985/1986.

C. Processing *To be developed*

D. Uses *To be developed*

E. Appropriate comparators for testing new varieties

10. This document suggests parameters that common bean breeders should measure when developing new modified varieties. The data obtained in the analysis of a new common bean variety should ideally be compared to those obtained from an appropriate near isogenic non-modified variety, grown and harvested under the same conditions.[1] The comparison can also be made between values obtained from new varieties and data available in the literature, or chemical analytical data generated from other commercial common bean varieties.

11. ***(Paragraph to be checked)*** Components to be analysed include key nutrients, anti-nutrients ***(…)***. Key nutrients are those which have a substantial impact in the overall diet of humans (food) and animals (feed). These may be major constituents (fats, proteins, and structural and non-structural carbohydrates) or minor compounds (vitamins and minerals). Similarly, the levels of known anti-nutrients and allergens should be considered. Key toxicants are those toxicologically significant compounds known to be inherently present in the species, whose toxic potency and levels may impact human and animal health. Standardized analytical methods and appropriate types of material should be used, adequately adapted to the use of each product and by-product. The key components analysed are used as indicators of whether unintended effects of the genetic modification influencing plant metabolism have occurred or not.

F. Breeding characteristics screened by developers

12. Non-profit organizations from first-world countries recognize the nutritional benefits and contribution of beans as the most important grain legume for direct human consumption (Miklas et al., 2006). It represents an important source of protein (~22%), vitamins (folate), and minerals (Ca, Cu, Fe, Mg, Mn, Zn), especially in developing countries (Broughton et al., 2003).

13. Common beans are a crop adapted to many niches, both in agronomic and consumer preference, but despite its importance and adaptation range, the majority of the bean production occurs under low input agriculture on small-scale farms in developing countries (Miklas et al., 2006). Under such conditions, yield is mostly below its potential and since globalization of trade plays an important role in agricultural products it is highly plausible that the pressure to improve bean yields will increase in the next years.

14. Among different breeding programs, improving stress tolerance/resistance and yield in crops are major goals for agriculture (Suárez et al., 2008). In common bean breeding programs it could not be different, several strategies are being pursued to improve yield potential, since it is an "ultimate" goal, the development of cultivars with improved tolerance/resistance for biotic and abiotic stresses, nitrogen fixation ability and the growth habit are also along the primary goals. Currently, other characteristics are

[1] For additional discussion of appropriate comparators, see the Guideline for the Conduct of Food Safety Assessment of Foods Derived from Recombinant DNA Plants CAC/GL 45/2003 of the Codex Alimentarius Commission (paragraphs 44 and 45).

being explored by breeding programs such as nutrition factors (protein, minerals and vitamins) focusing on biofortification.

15. Environmental conditions are severe limiting factors for growth and yield in crops. Among these abiotic stresses which affects common bean as a crop are drought stress, salinity, and extreme temperatures, which dehydrate the plant tissues and cause irreversible cellular damage and death (Bartels and Sunkar, 2007). Among the former abiotic stresses, drought has being considered as an appealing scientific subject due to its high magnitude of impact and wide distribution. In the in the early years of the 21st century, it was estimated that up to 73% of the total Latin American and 40% of the total African bean production occurred under micro-climates that presented moderate to severe mean water-deficits at some time during the cropping season (Broughton et al., 2003). Although great effort has been applied from traditional breeding programs to improve abiotic stress tolerance, which led to some success, it was considered limited as a result from the multigenic nature of such traits.

16. Besides abiotic stresses, common bean also faces diseases and insects as some of the most important risks that farmers confront (Broughton et al., 2003). Diseases cause severe losses (20–100%) to yield and quality of common bean worldwide (Singh and Schwartz, 2010). At least five major diseases [anthracnose, angular leaf spot, common bacterial blight, BGYMV, and bean common mosaic virus (BCMV)] are widespread, and several others are important locally or regionally (Broughton et al., 2003). As well as diseases, various insect pests and nematodes also cause severe losses (35–100%) globally to the yield and quality of dry and green common bean (Singh and Schwartz, 2011). Breeding efforts for disease and pest resistance/tolerance has minimized crop losses by maintaining production and yield stability in areas where the crop would otherwise have been abandoned (Broughton et al., 2003). Most commonly, breeders aim for resistance to one or two diseases/pest insects within the same cultivar. Substantial progress has been achieved in breeding to common bean diseases and pest insects, but improvement to some of them remains slow and localized.

17. Improved stress resistance can reduce reliance on pesticides in high input systems, prevent risk of yield loss from disease/insect pests in low- and high-input systems, and allow more stable bean production across a diverse range of environments (Miklas et al., 2006). Within this scenario, biochemistry, physiology, genetics, structural biology and informatics are nowadays implemented as important research areas striving for the knowledge of common bean´s genomics, transcriptomics, and proteomics. Since they permit the study of many (and sometimes all) genes of a particular organism (Broughton et al., 2003). Traditional breeders can be beneficiated from such integrated view of the organism, pursuing genes related to traits with agronomical relevance. Moreover, when traditional breeding is not feasible, new trait improvement approaches such as interspecific horizontal gene transfer via genetic engineering may to be utilized in order to complement the limitations encountered by conventional breeding (Aragão et al., 2002).

SECTION II - NUTRIENTS

A. A food legume of major importance

18. Common bean (*Phaseolus vulgaris* L.) is the most important food legume to more than 500 million people, mainly in Latin America and Africa. In Brazil, common bean is a staple food for most of the population, indeed being the main source of vegetable protein. Dry beans together with maize (*Zea mays* L.) are the basic staple for much of the Mexican people (Arias et al., 1999). Beans native to México are highly diverse in physical, culinary and chemical characteristics. This diversity stimulates that consumers demand different bean types. The demand is satisfied with both native and improved varieties. As expected there is more information on the composition of improved varieties, whose colour and shape variability is less than that found in native varieties. For marketing in Mexico, varieties are classified according to their colour in three classes: 'Black', 'Clear' colour and 'Other' classes.

19. Common bean is a crop of extensive economic, social, nutritional value and recently is gaining importance on specific functional characteristics. World production of beans is more than 20 million tons per year, being grown mainly by small farmers from all continents. Common bean is one of the leading providers of protein in the diet of poor people around the world. This legume is widely consumed in Mexico, Central America, South America and African countries. Furthermore, assumes a great importance in food, mainly due to its low cost, in addition to being a relatively nutritionally a balanced food (FAO, 2010; Carneiro et al., 2005; Wander et al., 2007).

20. Brazil, as well as other countries, had a framework for epidemiological and nutritional transition, which is represented by the increase in non-communicable chronic diseases, and certain food intolerances. The modern life style replaces food quality for fast food like snacks, sandwiches and other similar items on the daily diet. Many times in substitution of healthy rice and bean dish. The reduction in the consumption of these grains can unbalance daily intake of energy and protein (Brasil, 2006; Irga, 2008).

21. The daily consumption of beans contributes with 28% protein and 12% of calories intake. Indeed the importance of beans is due especially to the lower cost of its protein when compared with protein of animal origin. Furthermore, common bean, due to its composition, provides several health benefits, utilized on the diet therapy of various diseases such as heart disorders, diabetes mellitus, obesity and cancer (Cuppari, 2005; Ibge, 2011). Beans are free of cholesterol and contain a small amount of lipids, but contain predominantly unsaturated fatty acids (Anderson et al., 1999).

B. Main nutrients and beneficial elements

Proximal composition

22. According to Delfino and Canniatti-Brazaca (2010), the proximal composition in Table 4 highlights the importance of common bean regarding protein, minerals and carbohydrates contents, showing similar values to those presented in the Brazilian Table of Food Composition-TBCA (USP, 2007).

The beans before and after cooking did not differ significantly when data are compared on a dry basis, with the exception of dietary fibre that exhibits variation with cooking, due to their chains breakdown.

Table 4. Proximal composition (% dry basis) of common bean

Cultivar "Perola" before and after cooking:

%	Raw Bean	Cooked Bean
Moisture	13.07 ± 0.00[1]b[2]	80.79 ± 0.00a
Ash	4.65 ± 0.00a	4.09 ± 0.00a
Protein	24.96 ± 0.01[a]	25.77 ± 0.00a
Lipids	1.78 ± 0.00a	1.95 ± 0.00a
Carbohydrates	68.61 ± 0.00a	68.19 ± 0.00a
Dietary Fibre	21.94 ± 0.00a	11.90 ± 0.01b

Source: Delfino and Canniatti-Brazaca (2010)

[1] Means of 3 repetitions ± standard deviation; [2] Different letters in row are significantly different ($p \leq 0.05$)

Health effect considerations

23. Beans also have other components which make its consumption advantageous. The high amount of phenolic compounds with antioxidant activity found in their teguments has been linked to lowering the risk of developing cancer, and provides anti-inflammatory activity (Oomah et al., 2010). There is also strong evidence that the consumption of beans frequently significantly reduces the concentration of blood serum cholesterol by preventing coronary diseases (Anderson et al., 1999). Beans have low glycemic index because it is digested slowly and produce low blood glucose level.

24. Diabetic patients are encouraged to consume at least half a cup of cooked beans daily. For similar reasons, and because beans decrease hunger sensation, and satiety, it can be used in the diet for obese patients as an aid in weight loss or maintenance (Leterme, 2002). Beans are also a rich source of folic acid, which is especially important for women of childbearing age, due to low levels of this compound during pregnancy can lead to neural tube defects in their babies (Gupta; Gupta, 2004).

25. Moreover, common bean was shown to exert anti-carcinogenic effects in animal models (Hughes et al., 1997). These benefits associated with bean consumption may be attributable to the presence of multiple functional components in the grain, such as diverse phytochemicals including phenolic compounds (Cardador-Martínez et al., 2002), dietary fibre (Hughes, 1991), and alpha-amylase inhibitor (s) (Le Berre-Anton et al., 1997). Phenolic compounds are known to possess both anti-carcinogenic and antioxidant properties (Hollman and Katan, 1999). Antioxidants are strong scavengers of the free radicals and reactive oxygen species and play a role in inhibiting oxidative mechanisms that lead to chronic diseases (Koleckar et al., 2008).

26. Tannins, which are mostly found in red-coloured beans (Reed, 1995), are polyphenolic compounds with diverse bioactivities such as anti-inflammatory, antiproliferative, and antimicrobial functions (Dos Santos et al., 2006; Taguri et al., 2006; Matito et al., 2003). They also have the ability to inhibit lipid peroxidation and prooxidative enzymes (Koleckar et al., 2008). Anthocyanins, another class of

antioxidants found in beans, are pigments that do not only colour the inhabited beans but also possess antioxidant properties that further lead to secondary health benefits such as anti-carcinogenic and anti-inflammatory functions in addition to beneficial roles in the management if diabetes and obesity and the prevention of cardiovascular disease (He and Giusti, 2010). Last but not least, flavonols in beans have been shown to have an antioxidant effect as well as a protective effect against chronic disorders (Hollman and Katan, 1999) such as vascular disease (Woodman and Chan, 2004) and some cancers (Nothlings et al., 2007; Hirvonen et al., 2001).

Carbohydrates

27. Carbohydrate content is 60-65%, composed mainly of starch, with small amounts of monosaccharides and disaccharides. Carbohydrates in the form of fibre include 17-23% and are composed basically by pectin, cellulose and hemicellulose (Shiga; Cordenunsi; Lajolo, 2009). The total starch content in different bean varieties was estimated from 43.7 to 64.3% (Jacinto and Campos 1993, Jacinto et al. 2002). The amylose content in some varieties is 17.3% whereas the amylopectin varies from 26 to 30% (Jacinto et al. 2002). The lowest Resistant Starch level was found in Flor de Mayo (2.43%) and the varieties with higher total starch (40.24-42.81%) also had higher resistant starch content (5.41-6.4%). Digestibility values in terms of hydrolysis percentages were 34 in Flor de Mayo and 37 in Peruano, coinciding with their available starch values (Vargas-Torres et al., 2006).

28. Beans are a good source of dietary fibre, especially soluble fibre, making it effective in reducing serum levels of total cholesterol and, consequently in reducing cardiovascular disease in the general population. It is believed that the fibres carry gastrointestinal functions through its physical action, through the hydration capacity and to increase the volume and speed of transit of food and fecal bolus (Cuppari, 2005; Raupp et al., 1999).

29. Raffinose family oligosaccharides are present in different amounts in mature legumes, including the raffinose (ranging from 0.2% in the pink beans to 0. 6% in pinto beans), stachyose (ranging from 0.2% in the pink beans to 3.3% in navy beans) and verbascose (ranging from 0.0% in the navy beans to 0.15% in pinto beans) (Geil; Anderson, 1994). Other carbohydrates in common bean include pectic substances, arabinogalactans and xyloglucans (Reddy et al., 1984; Sathe; Salunkhe, 1984). These sugars require enzyme-hydrolysis to galactosidade. As the human digestive system does not contain this enzyme, these compounds remain non-digested and subject to microbiological anaerobic fermentation, resulting in production of gas or flatulence (Geil; Anderson, 1994). Carbohydrate composition differs significantly between types of beans, but the higher differences are in hemicellulose.

30. In a 2005 publication, Pires et al. compared carbohydrates, lipids and ash contents of several Brazilian cultivars of common bean, summarized in Table 5.

Table 5. Carbohydrates, lipids and ash contents (g/100g) of cooked and dried samples from Brazilian common bean cultivars

Bean Cultivars	Type	Carbohydrates	Lipids	Ash
Aporé	Beige (Carioca)	68.92e	0.98e	4.17a
Aruã	Beige (Carioca)	74.70b	1.01e	3.36f
Rudá	Beige (Carioca)	76.56a	1.30c	3.57de
Pérola	Beige (Carioca)	73.39c	1.35bc	3.96b
Carioca	Beige (Carioca)	76.75a	1.29cd	3.45ef
Ouro Branco	White	73.00c	1.41ab	3.62d
RAO 33	Purple	74.53b	1.00e	3.64c
A 774	Mulatinho	74.92b	1.04e	3.80c
Vermelho Coimbra	Red	71.49d	1.33bc	3.98b
Ouro Negro	Black	76.75a	1.21d	3.87bc
Diamante Negro	Black	71.86d	1.43a	3.96b

Source: Pires et al. (2005)

Values are means of triplicates. Means in columns followed by the same letter are not different by Tukey at 1% probability

Dietary Fibres

31. Fibre-poor diets often have been linked to coronary artery disease, diabetes, colon cancer and diverticular disease and a host of other disorders of the gastrointestinal tract. This has stimulated the scientific community to examine the role of fibre in nutrition and human health.

32. Although there is disagreement about the desirable level of daily intake of fibre, the National Cancer Institute of the United States recommends an average intake of 30 g day-1 as adequate amounts to prevent pathologies arising from the consumption of diets low in fibre. The SBAN (Brazilian Society of Food and Nutrition, 1990) recommends a daily intake of 20 g or 8 to 10 g1000 kcal-1. The Subcommittee of the NAS-NRC (National Research Council, 1989) acknowledges that the American fibre intake should be increased, however, recommends that the desirable amount must be achieved, not by the addition of dietary fibre concentrates, but by the increased consumption of fruits, vegetables, legumes and whole grains, which, along with fibre, they also provide minerals and vitamins.

33. Dried beans contain a substantial amount of carbohydrates as raw fibre in the form of cellulose and hemicellulose, with the amount ranging from 3 to 7% in cooked dry beans. The variability in these quantities is because of the different definitions and the methods of analysis used to determine fibre content. The beans contain between 20 and 25% of total dietary fibre, considerable amount, when considering the daily intake recommendations 18-20 g day-1 in European countries and Brazil, and the United States, 15 g day-1. Beans are high in soluble fibre, which significantly reduces the cholesterol and blood glucose in humans. The intestinal transit time decreases considerably in rats when the wheat starch,

into their diets, it is replaced by an equivalent amount of beans (Hellendoorn, 1976, quoted by Geil; Anderson, 1994).

34. Recently, the functional significance of the bean has acquired a new dimension for possible beneficial effects provided by the ingestion of dietary fibre, joined to the question of resistant starch.

35. The plant foods contain both soluble and insoluble fibre at levels that vary according to the food and its preparation. Beans, like other legumes and oats and barley, present interesting balance between these fractions: the cooked carioca beans, for example, contain 17.9% insoluble fibre and 7.9% soluble fibre, on a dry basis. The ability of dietary fibre to reduce the risk of degenerative diseases (cardiovascular diseases, diabetes, colon cancer, among others) has been extensively researched, but a complete scenery about the possible mechanisms of action involved is not yet fully established. The beneficial health effects appear to result from the combination of four physiological actions: increase in fecal bolus and intestinal transit, binding with bile acids, its transformation into short chain fatty acids in the intestine and increased viscosity.

36. The increase of the fecal bolus and the decrease of transit are physiological effects associated with the insoluble fibre fraction, with little participation of the soluble fraction. On the other hand, binding of bile acids is primarily associated with soluble fibre (pectin and hemicelluloses), which is transformed, in the large intestine, in short chain fatty acids in proportions greater than the insoluble fibre. Soluble fibre is also responsible for the increase of viscosity in the intestinal lumen and the consequent reduction of digestive and absorption processes. As the beans are among the few whole foods that contain significant amounts of insoluble and soluble fibre, its consumption produces the four physiological actions described above (Costa and Borém, 2003).

Proteins

37. The average protein content of common beans is 14%. Oliveira (2005) demonstrated, through the proximal composition analysis of seven common bean varieties, that black, white and pink ones are the most nutritious because they present a more complete profile on the protein and mineral salts, surpassing in 25% protein content and in 300% the calcium content of similar beans in food composition tables.

38. The amino acid profile of common bean protein is characterized by its deficiency in sulphur amino acids and tryptophan, being the methionine the limiting amino acid, while lysine is an amino acid which is found in greater proportion. The protein digestibility of raw beans is around 25 to 60%, and can be increased to 65 to 85%, depending on the variety of beans and cooking process used (Batista et al., 2010b; Kiers et al., 2000). Since beans are deficient in sulphur amino acids and rich in lysine, it is important its complementation with other sources, such as cereals. Bean mixture with rice supplies the essential amino acids and has 80% digestibility (Teba et al., 2009). Table 6 presents some of the results reported in the literature of mixtures of cereals and beans. Some researchers have found that the protein digestibility increased when they were consumed mixed beans with corn in the form of tortilla at a rate of 13:87. Another experiment found a great amount of protein quality with a mixture of beans and corn 25:75, obtaining a protein efficiency ratio (PER) of 2.62, compared with 1.64 for corn only and 0.98 PER in the bean alone. Recently, IDRC-IPN (National Polytechnic Institute), in Durango, Mexico has developed whole snacks with corn/bean mixture 70%:30%, prepared by extrusion, showing values of PER of 2.31. The *in vitro* digestibility of the protein (method Saterlee et al., 1979) of improved Mexican bean varieties was detected between 76.0 and 82.2% in raw grain (Jacinto and Campos, 1993). It was observed that the extent to which protein digestibility of beans increased once cooked was very variable, some varieties showed 8-12% higher digestibility compared to raw beans, while others only improved their digestibility by 3-4% (Jacinto and Campos, 1993). Cooked beans reported protein digestibility values of 84.1 to 93.2% (Jacinto and Campos, 1993; Jacinto et al., 2002).

39. The protein nutritional value of bean is increased by heat processing, especially under moist heat (Gallardo et al., 1974, cited by Poel et al., 1990). This can occur due to anti-nutritional factors denaturation of protein nature, since in order to perform their negative effects *in vivo*, these factors need to maintain their structural integrity (Burns, 1987, cited by Poel et al., 1990). In addition, increased nutritional value can be the result of greater accessibility of enzymatic attack of bean proteins (Romero; Ryan, 1978, cited by Poel et al., 1990). The thermal process must ensure sufficient inactivation of anti-nutritional factors and, at the same time, prevent significant degradation of essential amino acids.

Table 6. Protein quality of cereals and common beans combinations Protein distribution in diet *TItle?*

Cereal Protein (%)	**Bean Protein** (%)	**Protein Efficiency Ratio** (PER)	**Increase** (%)
Rice 100	0	2.25	
Rice 80	20	2.62	16.40
Corn 100	0	0.90	
Corn 50	50	2.00	122.20
Wheat 100	0	1.05	
Wheat 90	10	1.73	64.70

Source: Velasco e Velasco-Gonzáles (2008)

40. In a 2005 publication, Pires et al. compared protein contents of several Brazilian cultivars of common bean, summarized in Table 7.

Table 7. Protein contents of cooked and dried samples from Brazilian common bean cultivars

Bean Cultivars	**Type**	**Protein** (g/100g)
Aporé	Beige (Carioca)	25.93a
Aruã	Beige (Carioca)	20.93e
Rudá	Beige (Carioca)	18.57g
Pérola	Beige (Carioca)	21.30de
Carioca	Beige (Carioca)	18.51g
Ouro Branco	White	21.97cd
RAO 33	Purple	20.83e
A 774	Mulatinho	20.24f
Vermelho Coimbra	Red	23.20b
Ouro Negro	Black	18.17g
Diamante Negro	Black	22.75bc

Source: Pires et al. (2005)

Values are means of triplicates. Means in columns followed by the same letter are not different by Tukey at 1% probability.

41. The crude protein content in the improved Mexican varieties (Table 8) is 20 to 28% (Garza-Garcia et al., 2009), while in landraces has been estimated from 16 to 27% (Muñoz et al., 2009). The nitrogen analysis was performed using the Kjeldahl method, using Kjeltec-1030 equipment (conversion factor 6.25).

Table 8. Physical characteristics and grain quality of some improved bean varieties from Mexico

Variety	**Commercial class**	**100 grain weight** (g)	**Cooking time** (min)	**Protein content** (%)
Bayomex	Bayo	41	50-85	22-27
Flor de Durazno	Flor de Mayo	43	50-85	23-27
Negro Perla	Negro Querétaro	25	65-100	21-24
Bayo Mecentral	Bayo	31	40-85	23-26
Negro-8025	Negro Jamapa	19	55-95	22-26
Negro Otomí	Negro Querétaro	32	65-100	20-25
Flor de Mayo M-38	Flor de Mayo	26	60-95	20-26
Bayo Inifap	Bayo	27	65-110	22-26
Canario-107	Canario	40	70-85	24-27
Cacahuate-72	Cacahuate	43	45-90	24-47
Bayo Azteca	Bayo	28	50-85	23-28

Source: Garza-García *et al. (2009)*

Data are related to grains produced in different cultivation years (2007-2011)

42. The methionine content quantified in a saline extract of bean flour (Method of Mendoza and Carrillo-Castañeda, 1979) ranged between 0.109 and 1.20 varieties g/100 g, while the tryptophan (method Hernandez and Bates, 1969) varied between 1.2 and 1.7 g/100 g protein (Jacinto and Campos, 1993; Jacinto et al., 1996) The lysine content ranged from 3.9 to 5.7 g/100 g protein (Jacinto and Campos, 1993) (Table 9).

Table 9. Content of essential amino acids in Mexican dry beans

Essential amino acids (g/100 g protein)	Content	Minimum daily requirement
Phenylalanine + Tirosine	5.3 - 8.2	6.3
Isoleucine	2.8 - 5.8	2.8
Leucine	4.9 - 9.9	6.6
Lisine	6.4 - 7.6	5.8
Methionine + Cistein	1.2 - 1.5	2.5
Threonine	4.4 - 7.0	3.4
Triptophan	--	1.1
Valine	4.5 - 6.7	3.5

Source: Guzmán-Maldonado et al. (2002)

Vitamins

43. Common beans are relatively good source of water-soluble vitamins, particularly thiamine (0.86 to 1.14 mg 100 g-1), riboflavin (0.136 to 0.266 mg 100 g-1), niacin (1.16 to 2.68 mg 100 g-1), vitamin B6 (0.336 to 0.636 mg 100 g-1) and folic acid (0.171 to 0.579 mg 100 g-1); but are poor sources of fat soluble vitamins and vitamin C (Geil and Anderson, 1994).

44. Although the commercial methods of preparation of canned beans can cause significant loss of water-soluble vitamins, home cooked common beans seem to cause less effect on nutrient retention. In terms of the specification of the US Recommended Daily Allowances (RDA – recommended daily limits in the United States) for adults, one cup of cooked dry beans can provide 30% of the folic acid required, 25% thiamine, 10-12% of pyridoxine and less than 10% of niacin and riboflavin, 29% iron for women and 55% for men, 20-25% of phosphorus, magnesium and manganese, approximately 20% of potassium and copper and 10% zinc and calcium. However, minerals from plant sources are less bioavailable than those of animals.

45. The bioavailability of vitamins in baked beans and their interactions with other components of food are still uncertain (Geil and Anderson, 1994).

46. The retention values of vitamins during cooking vary from 70.9% (vitamin B6) to 75.9% (riboflavin). The variability of thiamine, globally and within classes of beans, is relatively low. On cooked beans, the retention of thiamine can be slightly modified but not to a very high degree. With regard to riboflavin, this vitamin shows great variability, among sites and within bean classes which is, significantly

greater than of thiamine. Cooking, like other treatments in any food, introduces another source of direct and indirect variability (Augustin et al., 1981).

47. Dry beans are good sources of B vitamins (thiamin, riboflavin, niacin, pantothenic acid and vitamin B6) and folates. Thiamin, riboflavin and pantothenic acid are central to energy metabolism, production and liberation, respectively. Niacin is required in several reactions involving folate metabolism and vitamin B6 participates in glycogen catabolism and modulates the activity of some steroidal hormones. Folate deficiency increases the risk of chronic diseases, including neural tube defects in infants, meganoblastic anaemia, Alzheimer's and cardiovascular diseases and some cancers in adults. Folate is an essential dietary component important for human health and its fortification for cereal products has been mandated in the United States and other North American countries, whereas other countries strongly recommend dietary increase of foods rich in folates. Dry beans are considered a prominent source of dietary folate with tetrahydrofolic acid as the most abundant vitamer ***(?)*** in fresh beans (Rychlik et al., 2007).

48. The vitamin content of dry beans varies widely depending on market classes, origin, growing environment and analytical methodology used for analysis (Table 10). This variation is most considerable in folate content ascribed primarily to the purification of folates prior to measurement by sophisticated liquid chromatography mass spectrometry that can differentiate the various folate vitamers ***(?)*** or the common microbiological method (Rychlik et al., 2007). Canadian grown beans reported by Wang and Daun (2004) are extremely low in folate and vitamin contents, although earlier investigation revealed folate content of 1.43-1.60 mg/kg for great northern, navy and pinto beans (Hans and Tyler, 2003).

49. Beans are good sources of thiamine that protects the body from oxidative stress. The thiamine content of dry beans is high and varies from 3.9 to 11.4 mg/kg for dark red kidney beans grown in Canada and the United States, respectively. Cooked black, navy, pinto and kidney beans, considered good sources of thiamine provide 28%, 25%, 21% and19 %, respectively of the daily recommended dietary allowance (Sangronis and Machado, 2007). Beans also contain 1.0-2.9 mg/kg of riboflavin, 3.3-26.8 mg/kg of niacin, 2.7-10.1 mg/kg of pantothenic acid and 0.4-5.7 mg/kg of vitamin B6. Vitamin B6 is involved in DNA synthesis and its deficiency may increase the risk of cancer, particularly since higher intake of vitamin B6 has been associated with lower risk of colorectal cancer (Lee et al., 2009).

Table 10. Vitamin composition (mg/kg) of dry beans

Beans	Folate	Thiamin	Riboflavin	Niacin	Pantothenic acid	Vitamin B_6
Black[1]	5	10.1	2.2	22.0	10.1	3.2
Black Turtle[2]	3.2	11.1	2.4	20.9		3.4
Black Turtle[3]	0.4-0.8	4.1-4.8	1.1	12.2-12.9	4.5-4.6	1.8-4.5
Cranberry[2]	2.1	9.7	2.7	15.7		3.6
Cranberry[3]	0.5	4.6-5.2	1.4-1.7	11.0-11.8	3.6-3.7	1.8
Dutch Brown[3]	0.2-0.4	4.7-5.2	1.4	12.3-16.1	4.1-4.4	1.8
Great Northern[1]	5.4	7.3	2.7	21.9	12.3	5.0
Great Northern[2]	1.0-1.7	9.4-9.8	2.6-2.9	14.9-19.2		4.0-5.7

Beans	Folate	Thiamin	Riboflavin	Niacin	Pantothenic acid	Vitamin B_6
Great Northern[3]	0.7-1.2	4.8-4.9	1.3	7.1-10.4	5.1-5.4	1.3-3.6
Kidney[1]	1.8-2.6	11.4	1.5-2.2	21.5		4.5-4.6
Kidney[2]	4.5	6.0-6.3	1.8-2.5	12.5-23.3	5.0-8.8	2.4-4.5
Light red[3]	0.4	8.9-10.9	2.2-2.4	3.3	2.7-3.6	0.4-2.5
Navy[1]	1.8-2.6	9.4-9.8	1.4-2.3	24.3-26.8		4.8-5.0
Navy[2]	1.2-4.1	6.6-8.8	1.9	14.9-24.9	3.5-8.5	2.4-4.9
Navy[3]	0.7-1.5	4.2-9.1	1.1-2.0	6.0-16.6	2.7-3.6	0.4-2.5
Pink[1]	4.8-5.8	9.2	1.5	11.6-14.4		5.0-5.7
Pink[3]	0.7-1.5	5.6-6.7	1.2	9.0-9.9	4.0-4.8	1.6-2.4
Pinto[1]	4.6	8.6-9.9	1.4-2.3	17.8		4.8
Pinto[3]	0.7-1.1	6.2-7.6	1.2	9.4-12.9	3.1-4.4	1.6-2.0
Red Kidney[3]	0.6	3.9-7.3	1.6	9.1-12.9	4.1-4.8	1.7-2.5
Small Red[1]	1.8	9.6	1.6	12.5		5.3
Small Red[3]	0.7-1.0	5.0-6.4	1.1	7.3-8.4	3.8-4.3	1.5-1.9
Small White[1]	3.0	8.9	1.6	19.9		4.9
White[2]	4.4	4.9	1.6	5.4	8.3	3.6
White kidney[3]	0.2	6.5-8.0	1.0-1.3	9.8-12.6	3.5-3.6	1.4-1.7
Overall range	0.2-5.8	3.9-11.4	1.0-2.9	3.3-26.8	2.7-10.1	0.4-5.7

[1] Augustin et al. (1981); [2]Tiwari and Singh (2013); [3] Wang and Daun (2004)

Minerals

50. Minerals impart physiological benefits in humans by regulating several mechanisms with considerable specificity and selectivity, as components of enzymes and other molecular complexes. Beans are good source of the macronutrients, phosphorous (P), potassium (K), calcium (Ca) and magnesium (Mg) (Table 11). The mineral content of beans depends on market class, genotype and growth environment and varies in the range 0.82-4.25 g/kg for calcium, 1.53-3.26 g/kg for magnesium, 2.30-8.42 g/kg for phosphorous and 14.56-20.24 g/kg for potassium. Among beans, white beans have the highest calcium, magnesium, iron contents and the largest variation in potassium content.

51. Beans are also excellent source of the essential micronutrients iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), selenium (Se) and boron (B). Iron and zinc are the most studied minerals in beans because of their nutritional importance and iron bioavailability in humans is reduced by the presence of

polyphenols and phytic acid (Petry et al., 2010). For example, polyphenols from red bean with 50 and 200 mg gallic acid equivalent lowered iron absorption in humans by 14 % and 45 %, respectively from a simple bread meal (Petry et al., 2010). Variation is considerable in iron (31.4-120.7 mg/kg) and zinc (0-62.4 mg/kg) contents of beans primarily due to location and genetic effects. Germplasm (CIAT) and landraces (Chile, Portugal, Rwanda and Tanzania) of common bean display natural genetic variation in iron (8.9-152.4 mg/kg) and zinc (8.9-112.9 mg/kg) concentrations (Dwivedi et al., 2012). Iron and zinc concentrations in common beans can be increased by 80% and 50%, respectively, according to studies of over 1000 accessions of beans grown at the same location during the same year at the International Center for Tropical Agriculture (CIAT) (Welch and Graham, 2004; Bebe et al., 2000). Moreover, selecting for a higher Fe level in bean will also select for increased Zn levels in the seeds. Copper and manganese contents range from 0-13.6 mg/kg and 0-26.3 mg/kg, respectively. Recently, two red- mottled beans have been registered by CIAT with high iron (76-81 mg/kg) and zinc (33-34 mg/kg) contents and these germplasm are adapted and stable in a wide range of environments (Blair et al., 2010). Common bean accumulate different proportion of total seed micronutrients, iron, zinc and manganese in the seed coat, embryo, and cotyledons with the highest amount of these micronutrients stored in the cotyledons of mature seeds (Cvitanich et al., 2011). Boron content of Canadian beans range from 9.4-14.4 mg/kg (Oomah et al., 2008). Selenium, an antioxidant microelement associated with enzyme activation and immune system function range from 34.8 mg/kg in black beans to 144.3 mg/kg in white beans (Tiwari and Singh, 2012).

(Add references to Tables 11A and 11B where relevant in the text)

Table 11. Mineral composition of dry beans

Beans	Calcium	Magne-sium	Phospho-rous	Potassium	Iron	Zinc	Copper	Manga-nese
	(g/Kg DM)				(mg/Kg DM)			
Black[1]	1.30-1.38	1.80-2.07	3.96-5.66	14.09-17.07	51.8-56.4	0-56.6	0-12.3	0-19.4
Great Northern[1]	1.67-1.76	1.96-2.31	4.63-7.03	17.77-19.61	31.4-61.3	38.1-40.9	9.3-12.3	15.9-19.0
Kidney[1]	1.09-1.62	1.59-1.99	4.61-5.94	15.93-20.15	92.9-99.7	31.6-41.9	10.9-11.3	11.6-15.9
Navy[1]	1.67-1.76	1.96-2.31	4.63-7.03	17.77-19.61	62.5-86.5	0-32.2	0-8.4	0-19.0
White[1]	2.71-4.25	2.14-3.26	2.30-3.39	14.56-20.24	117.7-120.7	0-41.4	0-11.1	0-20.3
Dark Red (Canada)[2]	0.82	1.53	5.66	17.09	66.6	28.3	7.1	10.8
Small Red (Canada)[2]	1.34	1.68	5.73	17.31	34.1	18.9	0.4	13.2
Brown (Brazil)[3]	1.09-1.79				48.1-78.2	25.1-31.9	6.1-13.6	10.0-26.3
Red (Nicaragua)[4]	1.02-1.41		4.00-4.44		61.8-71.9	21.0-25.1		
Red (Columbia)[5]			7.44		58.3-73.0	35.5-39.5		

Beans	Calcium	Magne-sium	Phospho-rous	Potassium	Iron	Zinc	Copper	Manga-nese
	(g/Kg DM)				(mg/Kg DM)			
Cream (Columbia) [5]			6.04-8.34		63.3-90.4	30.0-52.3		
Pink (Columbia) [5]			8.42		52.3	26.7		
Purple (Columbia) [5]			7.00		80.1	39.6		
Yellow (Columbia) [5]			7.52		86.1	62.4		
Beige (Brazil)[3]					53.1-68.8	33.5-42.7		

[1] Tiwari and Singh, (2012); [2] Oomah *et al.*, (2008); [3] Carvalho *et al.*, (2012; [4] Martinez Meyer *et al.*, (2013); [5] House *et al.*, (2002)

Table 11A. Content of minerals in Mexican dry beans

Minerals (m/100 g)	Content	Minimum daily requirement
Calcium	9 - 200	800 - 1000
Phosphorus	460	800 - 1000
Iron	3.8 - 7.6	15
Magnesium	200	300 - 400
Zinc	2.2 - 4.4	15

Source: Guzmán-Maldonado et al. (2002)

Table 11B. Minerals (mg/100 g) in cooked and dry Brazilian bean cultivars

Bean Cultivars	Fe	Ca	Mn	Mg	Cu	Zn	K
Aporé	5.32 b	135.08 e,f	2.16 a	239.47 a	1.53 a	2.34 a	1452.45a,b,c
Aruã	6.40 a	153.53 c	1.87 a,b	198.04 b	1.86 a	3.21a,b	1232.53 e,f
Rudá	5.67 a,b	156.86 c	1.89 a,b	206.51 b	1.64 a	3.12 a,b	1222.53 f
Pérola	5.25 b	151.38 c,d	1.54 c,d	210.34 b	1.44 a	3.10 a,b	1382.49 b,c,d
Carioca	5.33 b	172.23 b	1.62 b,c	205.50 b	1.81 a	3.24 a,b	1332.51d,e

Bean Cultivars	Fe	Ca	Mn	Mg	Cu	Zn	K
Ouro Branco	4.46 c	122.53 f	1.31 d	164.56 c	2.00 a	3.29 a,b	1172.55 f
RAO 33	5.37 b	172.51 b	1.47 c,d	215.98 b	2.31 a	2.78 b	1362.50 c,d
A 774	6.00 a,b	207.41 a	1.38 c,d	210.14 b	1.53 a	3.07 a,b	1482.47 a,b
Verm. Coimbra	5.56 b	137.46 d,e	2.14 a	198.64 b	1.22 a	3.35 a	1492.46 a
Ouro Negro	5.79 a,b	127.31 e,f	1.88 a,b	205.90 b	1.53 a	3.33 a	1542.45 a
Diamante Negro	5.39 b	174.16 b	1.86 a,b	214.07 b	2.74 a	3.23 a,b	1512.46 a

Source: Pires et al. (2005).

Values are means of triplicates. Means in columns followed by the same letter are not different by Tukey at 1% probability.

Meaning for a, b, c, d, e, f is missing ?

52. However, the beans also contain high concentrations of phytates, which decreases the availability of iron. The availability of minerals, especially iron, is also affected by the presence of tannin and dietary fibre. As sources of minerals, specifically, that would be of great importance in our country and in the world by the high prevalence of iron deficiency and iron deficiency anaemia, existing data show that the iron present in beans has low bioavailability (amount actually absorbed by the body from the quantity available of these minerals present in varieties of beans).

53. Bioavailability studies have shown that carioca, white and black varieties, proved to be the most nutritious, especially in relation to calcium levels (Oliveira, 2005). The minerals present in soy and beans are absorbed by the body, most notably calcium and magnesium and, to a lesser extent, copper and zinc. Therefore, it is considered that very important finding because, in Brazil, the diet is generally poor in calcium. The beans can compensate for this loss and prevent that calcium deficiency in bone structure leads to a premature osteoporosis.

54. The food processing, such as baking and brewing, knowingly, not only affects the availability of iron, but also the factors that act as proponents or antagonists of mineral absorption (Lombardi-Bocce et al., 1995).

55. Lombardi-Bocce et al. (1995) studied the effect of peeling and cooking on the iron content of two varieties of beans. The iron and the constituents of the grain (phytate, tannins and fibre) are distributed differently in the hull and in the cotyledon. Stripping significantly decreased the dialisability ***(?)*** of iron, while cooking had the same influence on coloured variety, but not on the white variety. The tannin-protein interaction can be the main cause of the difference in iron dialisability ***(?)***. There are 30 years, Miller et al. (1981) developed an *in vitro* technique simulating the digestive processes that occur in humans, in which an isolated food or a meal is digested by gastric and pancreatic enzymes and the content of a particular mineral is assessed through their dialisability ***(?)*** through a membrane pore (RAO, 1994).

56. The effect of reheating of beans on the iron content was studied by Amaya et al. (1991). In whole bean, without broth, they did not detect any change during cooking. In the case of beans with broth, there was increase of insoluble iron in grains. In the broth it was detected decrease in both soluble and insoluble iron.

57. Iron deficiency is the most prevalent nutritional deficiency in the world (Haas et al., 2005). Diets with shortage of iron and zinc can cause anaemia, reduced working capacity, immune system problems,

developmental retardation and even death. Iron deficiency anaemia is probably the most important nutritional problem in Brazil, with prevalence of approximately 30 up to 80% on groups of children under five years old (WHO, 2009). It should be noted that this deficiency occurs regardless of social class or geographic distribution (Fávaro et al., 1997).

58. The prevalence of folate and zinc deficiency in the world has not yet been established, but it is estimated that it is significant once the micronutrient deficiencies rarely occur isolated. One reason for this is that these deficiencies usually occur when there is a lack of diversity in the usual diet or when it is entirely dependent on a single staple food, as is the case of diets that are based on cereals or tubers (FAO, 2002). Zinc deficiency is not as studied as iron deficiency, but, since the sources of these two nutrients are the same, the incidence of zinc deficiency is also very high. Zinc is required for the activity of more than 300 enzymes that act on the immune system and in the expression of genes, among other functions. Little is known about zinc deficiency in developing countries, but normally bioavailable iron rich foods are also high in bioavailable zinc (Mccall et al., 2000).

59. The introduction of agricultural biofortified products - improved varieties that have a higher content of minerals and vitamins – one can complement existing nutrition interventions and provide a sustainable and low-cost way to reach populations with limited access to formal market systems and health. Once the investment is made in the development of nutritionally improved varieties in centralized research facilities, the seeds obtained can be adapted to the conditions of planting of numerous countries. Biofortified varieties have the potential to provide continued benefits, year after year, in developing countries, at a recurrent cost lower than the supplementation and the post-harvest fortification (UNNEVEHR et al., 2007).

60. In Brazil, there are related activities developed by international programs meeting global challenges called HarvestPlus Challenge Program on Biofortification and AgroSalud Program, coordinated by the national research Embrapa, including several of their Research Units and other institutions that are part of the network of food Biofortification and are funded by various international institutions, for the most part, and by some national ones. AgroSalud program is focused on Latin America and Caribbean, and post-harvest processing studies. The main crops of the basic diet involved in programs in Brazil are: cassava, sweet potatoes, rice, beans, maize, Cowpea and wheat.

SECTION III - OTHER CONSTITUENTS: ANTI-NUTRIENTS, TOXICANTS, ALLERGENS, SECONDARY PLANT METABOLITES

A. Anti-nutritional factors

61. In spite of good nutritional quality, common beans present some undesirable anti-nutritional factors as attributes, which interfere in the absorption and use of minerals, form complexes that make proteins unavailable and inhibit digestive enzymes. Polyphenols, phytates, enzyme inhibitors, phytohemaglutinins, and factors of flatulence and anti-nutritional substances are cyanogenic and toxic substances present in the beans. Heat treatment given with the purpose of cooking the beans reduces the effect of these substances (Batista et al., 2010b; Berrios, 2006; Ramírez-Cárdenas et al., 2008).

62. One of the means for the heat treatment of the bean is the raw flour extrusion. The extrusion process generates the extruded flour that has the nutritional quality similar to the raw grain flour, decrease of anti-nutritional factors, besides the increase in protein and starch digestibility (Batista et al., 2010a; Berrios, 2006).

63. During storage, compounds present in the seed coat can undergo oxidation or other chemical modifications that lead to new compounds that change the colour of the seed. The exact causes of the post-darkening are not well known, but they seem to take into account a combination of genetic, environmental and chemical changes that occur in the tegument. The darkening is accelerated by exposure to light, high temperature and humidity during storage (Martin-Cabrejas et al., 1997). It has been demonstrated that phenolic compounds are correlated with grain darkening when in the presence of oxygen, caused by enzymatic oxidations by peroxidase (PER) and polifenoloxidases (POX), occurring in the hull (Sartori, 1982). Among the polyphenols of most importance, it can be pointed out the phenolic acids, flavonoids and tannins. Among the polyphenols of legumes and cereals it is predominated the source flavonoid tannins (Shiga et al., 2004). There are varieties of beans with different amounts of tannins (colourless), which affect the quality of the beans when they are converted into pigments visible during dehydration and oxidation, and the ability to interact with proteins, resulting in the reduction of digestibility of protein and minerals (Junk-Knievel et al., 2008). The condensed tannins are present in dietary fibre fraction of different foods and can be considered indigestible or poorly digestible (Bartolomé et al., 1995). In legumes and cereals, they have received great attention due to their adverse effects on colour, taste and nutritional quality.

64. Among the anti-nutritional factors found in legumes is phytic acid or hexaphosphoric acid (IP6), constituting around 1 to 2% of the weight of the seed (Kasim; Edwards, 1998). Its derivatives can form ions with chelating minerals (Ca and Mg), forming soluble complexes, resistant to the action in the intestinal tract, and decreasing the availability and, although this is its greatest effect, phytates also interact with basic residues of proteins, participating in the inhibition of digestive enzymes such as pepsin, pancreatin and amylase (Agostini; Ida, 2006). In the processes of fermentation, storage, germination, processing and digestion of the seeds, the phytic acid can be dephosphorilated, producing pentaphosphate (IP5), tetraphosphate (IP4) triphosphate (IP3) and, probably, the inositol diphosphate (IP2) (Zhou; Erdman, 1995), and the negative effect on the bioavailability of minerals is associated to the IP5 and IP6.

65. A decrease in quality of polyphenols also occurs as a result of the cooking process used to destroy anti-nutritional substances in beans. Apparent losses of polyphenols of 61-98% in cooked beans (when expressed as equivalent catechin) have been reported (Bressani et al., 1982). Cooking is not able to destroy the tannins, but these are partially removed with the cooking broth (Bressani; Elias, 1980). According to Ziena et al. (1991), less than 10% of total tannins are broken down during cooking, while about 50% are washed down to the cooking liquid. Although large amounts of polyphenols can be eliminated in wash water and water used for cooking, the residue is retained mainly by cotyledons. This is due to the apparent migration of tannins of the tegument to the cotyledons. The quantities of ingested tannins will then depend on how the beans are processed and consumed (Bressani; Elias, l980).

66. The phytate is the storage form of phosphorus found in all seeds of leguminous plants, at concentrations ranging around 0.3 to more than 2.5% on a dry basis (Stanley; Aguilera, 1985). Other authors mention values in levels of approximately 5% w/w (De Boland et al., 1975). It accounts for more than 80% of the total phosphorus of beans and is located preferentially in the cotyledon (Deshpande et al., 1982).

67. Among the methods of processing, fermentation and germination seem to be more effective in decreasing the phytate concentration, while the soaking and cooking can remove 50 to 80% or more of endogenous phytate in grains of beans (Sathe and Salunke, 1984).

B. Anti-nutrients compounds

Phenolics

68. The phenolic compounds are secondary metabolites that protect the seeds against pathogens and predators. They are one of the most important bioactive compounds in beans exhibiting antioxidant, anti-inflammatory and other specific physiological activities that benefit human health (Campos-Vega et al., 2012). The major polyphenolic compounds of beans consist mainly of phenolic acids and flavonoids. Beans with the highest polyphenolic content are the dark, highly pigmented varieties also rich in anthocyanins. Phenolic content (50 – 483 [1104] mg/kg) and composition vary widely among and within market classes depending on growing environment and analytical conditions (Table 12A). The primary phenolic acid in common beans are ferulic, sinapic, p-coumaric, caffeic, p-hydroxybenzoic, syringic and vanillic acids. Ferulic acid is the most abundant phenolic acid and intermediate levels of p-coumaric and sinapic acids are present in 10 market classes of commonly consumed dry beans in the United States (Luthria and Pastor-Corrales, 2006). The high phenolic acids values of beans from the United States result from the base hydrolysis performed on the samples prior to phenolic acid determination. Chlorogenic, gallic and protocatechuic acids and vanillin have also been reported in beans (Xu and Chang, 2009; Espinosa-Alonso et al., 2006). Phenolics concentrate primarily in the bean seed coat or hulls (Oomah et al., 2005), and seed coat colour is therefore attributed primarily to the presence and quantity of flavonols, flavonoids, and anthocyanins. Seed coat polyphenols are partly responsible for the after-darkening and hard-to-cook phenomenon in beans (Campos-Vega et al., 2012). Differential accumulation of polyphenolics, particularly tannins and the flavonol kaempferol in bean seed coats is associated with post-harvest seed darkening (Marles et al., 2008). Moreover, post-harvest darkening is controlled by a single gene and the slow-darkening trait in pinto beans is controlled by a recessive allele (Junk-Knievel et al., 2008) providing an essential tool in selecting this important marketable trait.

69. Kaempferol is the most abundant flavonol in beans with red bean containing the highest amount (14 -209 mg/kg) than black or grey (20 mg/kg) (Diaz-Batalla et al., 2006) or pinto beans (148 mg/kg) (Xu and Chang, 2009). Three kaempferol compounds, kaempferol-3-O-glucoside, kaempferol-3-O-

xylosylglucoside, and an unidentified kaempferol-monoglucoside differentiated two major Italian bean ecotypes, Sarconi and Zolfino (Dinelli et al., 2006).

70. Quercetin, another flavonol is present in black (9.7-23.5 mg/kg), cream-red (6.7-9.4 mg/kg) and grey (7.9 mg/kg) beans (Diaz-Batella et al., 2006). Bean anthocyanins are simple, non-acylatedanthocyanidins containing glucose as the only sugar; however, malvidin 3-galactoside has been detected in black beans grown in the United States (Xu and Chang, 2009). Six anthocyanidins, delphinidin, (49-81%); petunidin, (4-32%); cyanidin, (1-23%); malvidin, (4-14%); pelargonidin, (0.4-6.5%); and peonidin, (0.5-3.7%) are present in coloured beans (Espinosa-Alonso et al., 2006). The relative percentage of anthocyanidins, particularly the dominant components, delphinidin, petunidin and malvidin, may differ among genotypes and market class with delphinidin always present in greater proportion (Table 12B). However, the most recent study reported cyanidin and pelargonidin as the major anthocyanidins in dark beans with small amounts of acylateddelphinidin (0.11 mg/kg) and pelargonidin 3-glucosides (0.38 mg/kg) (López et al., 2013).

71. Proanthocyanidins have been detected in different Mexican varieties of common bean (9.4-37.8 mg catechin equivalents per g), mainly in the seed coat. Aparicio-Fernández et al. (2005), using also electrospray Food biotechnology 219 ionization (ESI) mass spectrometry high-performance liquid in the positive ion mode (m/z 150-2000) with a photodiode array (PDA), identified flavonoids such as anthocyanins, flavanol monomers, and heterogeneous flavanol oligomers up to hexamers in a 100% methanolic extract from the seed coat of black Jamapa bean. Interestingly, this is the first time that myricetin glycoside and proanthocyanidin oligomers containing (epi)-gallocatechin have been reported in black beans.

72. Results obtained for the total phenolics, total flavonoids and total anthocyanins are shown in Table 12C. The total phenolics content obtained by Santana et al. (2012) for *Phaseolus vulgaris* (carioca) were higher than those observed by Espinosa-Alonso (2006), analyzing Mexican beans from GeneBank. However, the lower values were observed for the total flavonoids and total anthocyanins.

Table 12A. Phenolic composition (mg/kg) of beans

Beans	Total	CMA	FA	SIN	PHBA	VA	SYR	CA	VAL
Mexico									
Black	52.7-111.3	3.4-8.7	14.9-34.0	8.5-16.3	6.5-22.9	7.3-22.7	0-13.3	0-20.6	0-9.3
Caffeto	50.2-92.7	1.7-8.9	10.3-28.4	7.6-20.2	8.4-11.9	6.5-22.1	0-6.7	0-16.7	0-6.0
Cream-red	61.4-266.7	4.8-7.1	20.4-27.6		8.8-13.8	5.2-11.9			
Grey	49.6-119.4	2.2-7.6	10.2-32.7	4.0-19.6	4.8-27.6	12.3-32.9		0-28.3	0-10.0
United States									
Alubia	198	53	106	40					
Black	244-471	70-116	117-255	57-40					
Great Northern	304-325	40-63	170-172	90-94					
Navy	483	124	266	92					

Beans	Total	CMA	FA	SIN	PHBA	VA	SYR	CA	VAL
Pink	344	68	194	82					
Pinto	1103.7			264	16.6	113.2			94.6
Pinto	267-360	45-56	152-229	59-70					
Red	209-286	18-70	148-174	38-57					

Source: Espinosa-Alonso *et al.*, (2006)

Phenolicacids: CMA, para-coumaric; FA, formic; SIN, sinapic; PHBA, para-hydroxybenzoic; VA, vanillic; CA, caffeic; SYR, syringic; and VAL, vanillin.

Table 12B. Anthocyanin composition (mg/kg) of beans

Beans	Delphinidin	Petunidin	Cyanidin	Malvidin	Pelargonidin	Peonidin	Total
Black (Mexico)[1]	290-1440	60-600	10-150	30-220	10-30	10-20	440-2360
Black (USA)[4]	2197	838					4012
Black (Korea)[5]	2014	167					
Dark (Spain)[6]	3.7		88.4		51.6		143.9
Grey (Mexico)[1]	90-720	10-90	30-120	20-40	10-30	10	190-1000

1 Espinosa-Alonso et al., (2006); 2 Luthria and Pastor-Corrales, (2006); 3 Díaz-Batalla et al., (2006); 4 Xu and Chang, (2009); 5 Choung, (2005); 6 López et al., (2013)

Table 12C. Total phenolics, total flavonols and total anthocyanins

Cultivars	Origin	Total Phenolics (mg/100g cathechin)	Total Flavonols (mg/100g quercetin)	Total Anthocyanins (mg/100g quercetin)
Phaseolus vulgaris[*]	Irecê	1218.4 ± 0.002^{B}	1.89 ± 0.003^{C}	0.00028 ± 0.001^{BC}
Phaseolus vulgaris[*]	Guanambi	1495 ± 0.002^{A}	5.67 ± 0.003^{AB}	0.00016 ± 0.001^{C}
Phaseolus lunatus L. [**]	Guanambi	610.2 ± 0.001^{D}	4.78 ± 0.003^{B}	$0.00023 \pm 0.001B^{C}$
Phaseolus lunatus L. [**]	Guajeru	517.8 ± 0.002^{D}	1.96 ± 0.001^{C}	0.00037 ± 0.001^{B}
Phaseolus vulgaris[***]	Irecê	849.8 ± 0.006^{C}	6.48 ± 0.002^{A}	0.00161 ± 0.004^{A}

Source: Santana et al. (2012)

Means followed by the same letter in columns do not differ by Tukey ($p>0.05$). [*] Carioca bean; [**] Fava bean; [***] Black bean

Phytates

73. Phytates are essential phosphorous storage molecules for plant development and constitutes between 54 and 82% of seed phosphorous depending on the dose of fertilizer used in dry bean production (Lolas and Markakis, 1975). Phytates regulate various cell functions and thereby exert beneficial health effects based on antioxidant and anticancer properties due to strong iron chelation, as well as on cardiovascular disease, and renal function (Oomah et al., 2008). Phytic acid is produced in a complex biosynthetic pathway that converts glucose into myo-inositol to myo-inositol hexakisphosphate (IP6) through less phosphorylated intermediates (IP3, IP4 and IP5) (Raboy 2003). Common bean is rich in phytates concentrating mostly in the cotyledons and embryo axes (up to 3% of total seed weight) (Blair et al., 2012). Phytate content within the same bean market type vary widely due to differences in cultivars, growing conditions, agricultural practices and locations (Table 13). In beans, phytate phosphorus content constitutes a major portion of the total phosphorus, accounting for 57-81% in navy, 68-72% in red kidney, 55-80% in Great Northern and 70% in California small white beans (Reddy, 2001). The large natural variability in phytate levels is controlled by the seed-expressed myo-inositol (3) P1 synthase gene (MIPS) and low phytate bean germplasm have recently been developed (Campion et al., 2009). Inositol penta- (IP5) and -hexaphosphate (IP6) are the most commonly detected inositol phosphate isomers varying widely in raw dry beans. IP6 is the most predominant isomer, ranging from 64% in red kidney beans to 98% in pinto beans (Chen, 2004). Large variations are generally observed in the concentrations of inositol tris- (IP3), tetrakis- (IP4) and pentakis (IP5) phosphate pools that coincide with variations in the specific rate of phytate synthesis up to 32 days after flowering, with peak phytate accumulation at about 22 days after flowering (Coelho et al., 2005). Phytic acid, particularly its reduction and interaction with proteins and carbohydrates has been associated with development of and susceptibility to hard-to cook defect of beans during storage (Gupta, 2011).

Table 13. Phytic acid composition (g/kg) of common beans and its components

Beans	**Phytic acid**	**IP4**	**IP5**	**IP6**	**Whole[1]**	**Cotyledon[1]**	**Whole2**	**Dehulled2**	**Hull2**
Black	4.4-19.9	0-0.1	0.6-1.1	3.8-14.8	10.4-29.3	36.1	10.62	17.09	1.91
Brown	8.9		0.6	8.3					
Great Northern	9.1-23.7	0.10-0.22	0.4-1.27	8.4-17.8	5.0-27.0	32.6			
Navy	9.0-25.1	0.07-0.5	0.4-1.04	8.2-18.8					
Pink	9.9-13.7		0.4	9.5					
Pinto	6.5-23.8	0.09-1.5	0.2-4.9	5.9-17.8	6.1-23.8	25.6	12.00	11.48	1.30
Red	5.6-17.6		0.2-0.25	5.4-12.4	13.0-20.7	30.5	8.05	8.71	2.63
Red Kidney	7.0-19.9	0.08-0.1	0.2-1.1	6.8-14.7	12.0-26.3	34.7			
White	6.1-16.2		0.27	5.85	5.5-18.0	16.3	11.15	9.83	2.30

Data compiled from Morris and Hill (1996), Oatway et al., (2001), House et al., (2002), Phillippy (2003), Chen (2004), Diaz-Batalla et al. (2006), Oomah et al., (2008), Tako et al., (2009); [1]Reddy, 2001; [2]Hu et al., 2006

Trypsin inhibitors, tannins and lectins

74. Trypsin inhibitor activity (TI) measured with Smith et al. (1980) method, in uncooked beans ranged from 7.24 mg TI g-l in Canario-107 up to 11.46 mg g-l in Jamapa (Jacinto and Campos, 1993), these values are comparable to those reported by Dhurandhar and Chang (1990). Whereas, Sotelo et al. (1995) compared the chemical composition of wild and cultivated beans (*Phaseolus vulgaris*), including trypsin content, showing that wild beans presented a higher content of trypsin inhibitors (28 TUI per mg) than did the cultivated beans (21 mg per TUI). De Mejia et al. (2003) found the content of TI in the range 6.3 TUI/mg to 14.5 TUI/mg for five popular bean cultivars of common beans Flor de Mayo Criollo, Flor de Mayo M-38, Flor de Junio Marcela (three members of the Jalisco race), Bayo Victoria and Pinto Villa (two members of Durango race) grown at five semiarid different highlands of Mexico; whereas Gonzalez de Mejia et al. (2005) reported 27 TUI/mg for the Flor de Mayo cultivar. In the cooked beans TI activity ranged between 0.21 mg g-l in the Negro Perla (Jacinto and Campos, 1993) up to 2.5 in Bayo Victoria (Jacinto et al. 2002). Trypsin inhibitor activity tended to decrease the more prolonged was cooking time ($r = - 0.79$ **).

75. The grain size can influence the trypsin inhibitor loss during cooking. Jamapa, whose 100 seeds volume was 20.3 ml (the lowest) before cooking presented higher activity of trypsin inhibitor, whereas after 72 minutes of cooking retained 4.4% of TI activity. On the other hand, Bayomex - whose 100 seeds volume was 39 ml, after 77 minutes of cooking showed 8% residual activity. The protein digestibility of beans was increased on average 10% as a result of cooking.

76. Trypsin inhibitors (TI), tannins, and lectins appear to have a role in preventing chronic diseases in humans. The genetic variability of these traits in common bean needs to be ascertained in order to increase levels through breeding. The variability of TI, tannin, and lectins was determined in five bean cultivars grown at five locations in Mexico. TI and tannins contents in coloured beans that belong to the Jalisco race were higher (11.1−11.9 trypsin units inhibited (TUI)/mg and 29.0−38.1 mg catechin equivalent (CE)/g, respectively) than cultivars of the Durango race (7.9−8.3 TUI/mg and 16.8−19.9 CE/mg, respectively). Bayo Victoria, a Durango race cultivar, had three times more lectins than levels reported for soybean. Cultivar influenced TI and tannins contents ($p < 0.001$), on the other hand the site affected lectins ($p < 0.001$). An increase in levels of TI and tannins could be enhanced through breeding (De Mejia, 2003)

Oligosacharides

77. Dry beans are basic grains for Mexican nutrition; however a limiting factor is the presence of raffinose-family oligosaccharides (RFO's), which are implicated in causing flatulence. On the other hand there is evidence that α-oligosaccharides play an important role in the acquisition of seed desiccation tolerance and also as a substrate for embryo growth during germination. Those means that it would be desirable to have varieties with enough amount of RFO's to favour agronomic performance and make it possible to partially reduce the amount of RFO's once grain is ready for consumption to reduce the flatulence potential (Jacinto-Hernández et al. 2006).

78. Considerable variability exists among Mexican common bean genotypes in oligosaccharide content (Table 14), as well as in sucrose content. In 13 varieties of different commercial class Stachyose was the main α-galactoside with values between 9.4 and 36.7 mg g-1 while raffinose was between 1.63 and 7.04 mg g-1 (Jacinto-Hernández et al. 2007).

79. Soaking beans is a common practice for some households. The amount of RFOs removed through soaking was from 7% of raffinose+stachyose in Flor de Mayo M-38 up to 59-60 % in Bayo Zacatecas and Bayo Victoria (Jacinto-Hernández et al. 2006)

Table 14. Grain weight and soluble sugar content in Mexican common bean varieties

Genotype	100 grain weight (g)	Dry grain			Soaked grain		
		Sucrose	Raffinose	Stachyose	Sucrose	Raffinose	Stachyose
		Concentration (mg/g)			Concentration (mg/g)		
Bayo Victoria	54.72 a	43.90 a	4.43 abc	36.66 a	26.07 abc	2.57 cde	14.08 ab
Azufrado Higuera	54.32 a	34.56 bc	1.63 c	26.98 cde	28.50 ab	1.94 de	22.14 ab
Flor de Durazno	47.18 b	31.66 bcd	2.20 abc	31.33 abc	14.66 d	1.61 e	16.48 abcd
Azufrado Peruano	41.78 bc	34.43 bc	2.06 bc	34.27 ab	20.66 bcd	1.73 e	20.41 ab
Bayo Zacatecas	40.20 c	33.25 bcd	5.39 ab	26.39 cde	18.80 bcd	2.08 cde	10.76 cd
Azufrado Regional 87	37.66 cd	28.83 bcd	1.72 c	23.32 de	27.30 ab	1.82 e	20.32 ab
Bayo Mecentral	33.38 de	26.36 cd	6.16 a	9.43 f	18.99 bcd	3.36 bcde	8.03 d
Flor de Junio M.	31.28 e	35.47 b	5.38 ab	28.06 bcd	28.43 ab	3.78 bc	18.75 abc
Negro Otomí	28.90 e	34.67 bc	3.87 abc	26.76 cde	23.19 abcd	2.45 cde	16.36 abcd
Flor Mayo M38	28.72 e	30.40 bcd	3.94 abc	26.50 cde	30.08 a	3.74 bcd	24.48 a
Alubia	28.62 e	25.37 d	5.65 a	20.56 e	15.92 cd	3.13 bcde	12.82 bcd
Negro Jamapa	18.52 f	32.72 bcd	7.04 a	35.22 a	28.43 ab	6.00 a	24.76 a
Negro 8025	18.30 f	27.72 bcd	6.55 a	23.62 de	19.70 bcd	4.73 ab	21.53 ab

Source: Jacinto-Hernández *et al*. (2006)

Meaning for a, b, c, d, e, f is missing ?

SUMMARY CONCLUSION

80. In conclusion, the common bean (*Phaseolus vulgaris*) is indeed not only a dietary element that provides basic nutrition, but also a functional food item that potentially influences health and well-being. As aforesaid it may be beneficial for managing diabetes, preventing cardiovascular disease, preventing cancers, and providing dietary fibre and a variety of antioxidants that likely contribute to the mentioned functions and provide additional health advantages. Given these benefits, in addition to the known nutritional value of common beans, it may be useful to include them in abundance in the diet and encourage their consumption. Nevertheless, the amount of available literature is very limited and more studies are needed, namely clinical studies to establish a strong relationship and develop guidelines for the human diet. Governmental and academic institutions can easily invest in studies involving this crop that is widely abundant, relatively inexpensive, and generally safe to consume.

SECTION IV - SUGGESTED CONSTITUENTS TO BE ANALYSED RELATED TO FOOD USE
(*To be developed*)

SECTION V - SUGGESTED CONSTITUENTS TO BE ANALYSED RELATED TO FEED USE

(To be developed)

SECTION IV - REFERENCES

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