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ENVIRONMENT DIRECTORATE

Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology

DRAFT CONSENSUS DOCUMENT ON COMPOSITIONAL CONSIDERATIONS FOR NEW VARIETIES OF COMMON BEAN (Phaseolus vulgaris L.) - KEY FOOD AND FEED NUTRIENTS, ANTI-NUTRIENTS AND OTHER CONSTITUENTS

Series on the Safety of Novel Foods and Feeds
No. 27

For declassification under written procedure by 11 December 2015

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At the 17th meeting of the Task Force for the Safety of Novel Foods and Feeds (2010), Brazil proposed to develop a new Consensus document on the composition of common bean (*Phaseolus vulgaris*) At the 18th meeting (2011), the Task Force supported the formal proposal [ENV/JM/FOOD(2010)5]. An Ad hoc drafting group was established with experts from Brazil (lead country), Argentina, Canada, Mexico, Spain, United States and CIAT-Colombia.

The first draft of the Consensus document **[**ENV/JM/FOOD(2013)2] was examined by the Task Force in 2013. At each step in the development of the document, delegations (including Canada, Denmark, Mexico, Netherlands, Sweden, United States and BIAC) made comments and suggestions that were considered when preparing the successive version. The revised drafts REV1 and REV2 were discussed during the Task Force meetings held in 2014 and 2015 respectively.

At the 22nd Task Force meeting (April 2015), participants agreed on the steps for finalising the document and recommended its declassification by the Joint Meeting. The third revision [ENV/JM/FOOD(2013)2/REV3], prepared by Brazil and reviewed by the Bureau of the Task Force, was circulated to delegates in July 2015, and no adverse comments were received. Final remarks from Netherlands, Sweden and BIAC were taken into account by Brazil and the Bureau in the present document which is now submitted to the Joint Meeting.

Pending declassification by the Joint Meeting, the *Consensus Document on Compositional Considerations for New Varieties of Common Bean (*Phaseolus vulgaris *L.): Key Food and Feed Nutrients, Anti-nutrients, Toxicants and Other Constituents* will be issued as No. 27 of the Series on the Safety of Novel Foods and Feeds.

Action required: ***The Joint Meeting is invited to declassify the document by 11 December 2015.***

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FOREWORD

The OECD's Task Force for the Safety of Novel Foods and Feeds decided at its first session, in 1999, to focus its work on the development of science-based ***consensus documents***, which are mutually acceptable among member countries. These consensus documents contain information for use during the regulatory assessment of a particular food/feed product. In the area of food and feed safety, consensus documents are being published on the nutrients, anti-nutrients or toxicants, information of its use as a food/feed and other relevant information.

This document addresses compositional considerations for new varieties of common bean (*Phaseolus vulgaris*) by identifying the key food and feed nutrients, anti-nutrients, toxicants and other constituents. A general description of these components is provided. In addition, there is background material on the production, processing and uses of common bean, and considerations to be taken into account when assessing new varieties of these crops. Constituents to be analysed, related to food use and feed use, are suggested.

Brazil served as the lead country in the preparation for the document, and the draft has been revised on a number of occasions based on the input from other member countries and stakeholders.

The Task Force endorsed this document, which is published under the responsibility of the Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology of the OECD.

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PREAMBLE

Food and feed products of modern biotechnology are being commercialised and marketed in OECD member countries and elsewhere. The need has been identified for detailed technical work aimed at establishing appropriate approaches to the safety assessment of these products.

At a Workshop held in Aussois, France (OECD, 1997), it was recognised that a consistent approach to the establishment of substantial equivalence might be improved through consensus on the appropriate components (e.g. key nutrients, key toxicants and anti-nutritional compounds) on a crop-by-crop basis, which should be considered in the comparison. It is recognised that the components may differ from crop to crop. The Task Force therefore decided to develop Consensus Documents on phenotypic characteristics and compositional data. These data are used to identify similarities and differences following a comparative approach as part of a food and feed safety assessment. They should be useful to the development of guidelines, both national and international and to encourage information sharing among OECD member countries.

These documents are a compilation of currently available information that is important in food and feed safety assessment. They provide a technical tool for regulatory officials as a general guide and reference source, and also for industry and other interested parties and will complement those of the Working Group on Harmonisation of Regulatory Oversight in Biotechnology. They are mutually acceptable to, but not legally binding on, OECD member countries. They are not intended to be a comprehensive description of all issues considered to be necessary for a safety assessment, but a base set for an individual product that supports the comparative approach. In assessing an individual product, additional components may be required depending on the specific case in question.

In order to ensure that scientific and technical developments are taken into account, member countries have agreed that these Consensus Documents will be reviewed periodically and updated as necessary. Users of these documents are invited to provide the OECD with new scientific and technical information, and to make proposals for additional areas to be considered. Comments and suggestions can be sent to:

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THE ROLE OF COMPARATIVE APPROACH AS PART OF A SAFETY ASSESSMENT

In 1990, a joint consultation of the Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO) established that the comparison of a final product with one having an acceptable standard of safety provides an important element of safety assessment (WHO, 1991).

In 1993, the Organisation for Economic Co-operation and Development (OECD) further elaborated this concept and advocated the approach to safety assessment based on substantial equivalence as being the most practical approach to addressing the safety of foods and food components derived through modern biotechnology (as well as other methods of modifying a host genome including tissue culture methods and chemical or radiation induced mutation). In 2000, the Task Force concluded in its report to the G8 that the concept of substantial equivalence will need to be kept under review (OECD, 2000).

The Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology in 2000 concluded that the safety assessment of genetically modified foods requires an integrated and stepwise, case-by-case approach, which can be aided by a structured series of questions (FAO/WHO, 2000). A comparative approach focusing on the determination of similarities and differences between the genetically modified food and its conventional counterpart aids in the identification of potential safety and nutritional issues and is considered the most appropriate strategy for the safety and nutritional assessment of genetically modified foods. The concept of substantial equivalence was developed as a practical approach to the safety assessment of genetically modified foods. It should be seen as a key step in the safety assessment process although it is not a safety assessment in itself; it does not characterise hazard, rather it is used to structure the safety assessment of a genetically modified food relative to a conventional counterpart. The Consultation concluded that the application of the concept of substantial equivalence contributes to a robust safety assessment framework.

A previous Joint FAO/WHO Expert Consultation on Biotechnology and Food Safety held in 1996 elaborated on compositional comparison as an important element in the determination of substantial equivalence. A comparison of critical components can be carried out at the level of the food source (i.e. species) or the specific food product. Critical components are determined by identifying key nutrients, key toxicants and anti-nutrients for the food source in question. The comparison of key nutrients should be between the modified variety and non-modified comparators with an appropriate history of safe use. Any difference identified would then be assessed against the natural ranges published in the literature for commercial varieties or those measured levels in parental or other edible varieties of the species (FAO/WHO, 1996). The comparator used to detect unintended effects should ideally be the near isogenic parental line grown under identical conditions. While the comparative approach is useful as part of the safety assessment of foods derived from plants developed using recombinant DNA technology, the approach could, in general, be applied to foods derived from new plant varieties that have been bred by other techniques.

SECTION I - BACKGROUND

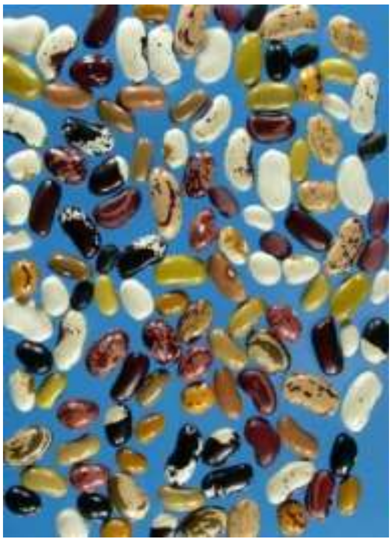
A. General description of common bean (*Phaseolus vulgaris* L.)

1. Common bean (*Phaseolus vulgaris* L.) is a major grain legume which is consumed worldwide for its edible seeds and pods (Heuzé et al., 2013) (Figures 1 and 2). Wild common bean [*Phaseolus vulgaris* L., tribe Phaseoleae, family Leguminosae (Schrire, 2005)] is present throughout Central and South America (Gepts and Debouck, 1991; Freytag and Debouck, 2002). All cultivated varieties grown in the world today originate from two independent domestication events of wild populations at different pre-Columbian times (Kaplan and Lynch, 1999; Piperno, 2012), in western Mexico (Kwak et al., 2009) and in central Peru (Chacón-Sánchez et al., 2005). Human selection has generated dozens of landraces in each region (Singh et al., 1991). After 1492, common bean was taken to South-Western Europe (Rodiño et al., 2006), the Mediterranean region (Angioi et al., 2010), (mostly eastern) Africa (Westphal, 1974), parts of Asia (Zhang et al., 2008), and back to the Americas (Albala, 2007; Gepts et Bliss, 1988).

Figure 1. **Pods of bush-type common bean**

Source: courtesy of D.G. Debouck, CIAT (2015).

Figure 2. **Shape and colour diversity in common bean seed**



Source: courtesy of D.G. Debouck, CIAT (2015).

2. Given this geographical and ecological expansion, common bean is known by a variety of names under generic 'bean' terms such as 'frijol' in Spanish-speaking Latin America, 'feijão' in Brazil, 'judia' in Spain and 'haricot' in French (Voysest and Dessert, 1991).

3. Common bean is an herbaceous vine. While it is an annual and monocarpic plant, some of its most primitive forms and wild relatives are pluri-annual and polycarpic vines in montane forests in Mexico and Central America (Freytag and Debouck, 2002). Cultivars vary widely, with bush determinate and vining indeterminate growth habits, and are selected for earliness. Further description of the common bean taxonomy, centres of origin and diversity, reproductive biology, genetics, hybridisation and introgression, general interactions with other organisms (ecology), common pests and pathogens, and biotechnological developments can be found in the Consensus Document on the Biology of Common Bean (*Phaseolus vulgaris* L.) (OECD, 2015).

4. Common bean is typically cultivated in a mono-crop system and mechanically harvested (Figure 3). Although leaves and rarely flowers are consumed by humans (Purseglove, 1968), its main products are seeds, which are harvested either before or after physiological maturity as green pods such as snap beans (also known as ‘green beans’) or as dry beans, respectively. Both forms have given rise to an important canning industry and, recently, frozen dried food products have also appeared on world markets. Most dry bean varieties are consumed after boiling; grains of some landraces, mostly central Andean, are consumed after toasting (Tohme et al., 1995). Dried stems and pods have been used as hay for animal feeding (Hendry, 1918; Westphal, 1974).

Figure 3. **Large field of common bean crop (Pimampiro canton, Ecuador)**

Source: courtesy of D.G. Debouck, CIAT (2015).

B. Production

5. Common bean is produced in subtropical and tropical regions, most often by small holders, and constitutes a major staple crop in both developing and developed countries. Mainly used for human consumption, common bean is the most important grain legume in the human diet at global level. According to the Consultative Group on International Agricultural Research, common bean provides protein, complex carbohydrates and valuable micronutrients for more than 300 million people in the tropics. In many areas, beans are the second most important source of calories after maize (CGIAR, online factsheet ‘Common bean’).

6. Quantification of the world production of common bean is difficult, firstly because a substantial part of the crop is consumed on-farm, with limited sale on local markets, and has not been documented. The second reason lies in the fact that some dry beans subject to national and/or international trade are not discriminated at the species level. As a result, a category reported as ‘pulses’ or ‘beans’ may include several species other than common bean (*P. vulgaris* L.) (Lackey, 1981; Voysest, 1983). Finally, the diverse products of common bean, while all derived from the same species, may be counted under different categories. For example, snap beans (green beans) may be tallied separately from dry beans (Voysest and Dessert, 1991).

7. According to FAO estimates, the global bean production (covering not only common bean) has risen from 15.4 million tonnes (Mt) in 1984-1986 (3-year-average) up to the record of 23.4 Mt obtained in 2012. This significant growth results from the increase of both cultivation areas and yields over the past thirty years, with Asia and the Americas as the most important producing regions (Table 1). According to other sources, South America alone is producing 30% of the global common bean (Heuzé et al., 2013).

Table 1. **Estimated global dry beans production**

Bean[(a)] production (Million tonnes – Mt)	**Years (3-years-average)[(b)]**						**Year**	
	1984-1986	**1989-1991**	**1994-1996**	**1999-2001**	**2004-2006**	**2009-2011**	**2012**	**2013**
Asia	7.14	7.60	7.63	7.87	8.67	10.62	10.35	10.17
Americas	5.43	6.03	6.79	6.47	6.88	7.16	7.32	7.09
Africa	2.03	2.44	2.35	2.92	3.17	4.17	5.19	4.97
Europe	0.82	0.59	0.53	0.57	0.46	0.45	.049	0.52
Oceania	0.02	0.02	0.03	0.05	0.05	0.05	0.08	0.05
World	***15.44***	***16.67***	***17.32***	***17.88***	***19.22***	***22.46***	***23.42***	***22.81***

Source: FAOSTAT (2015).

(a) Data on beans are aggregated and include two main species: common bean (*Phaseolus vulgaris*) and cowpea (*Vigna unguiculata*), and possibly other bean species.

(b) Each column represents an average of three years, i.e. 1984-1986 represents an average of the seasons 1983/1984, 1984/1985 and 1985/1986 in the Southern hemisphere.

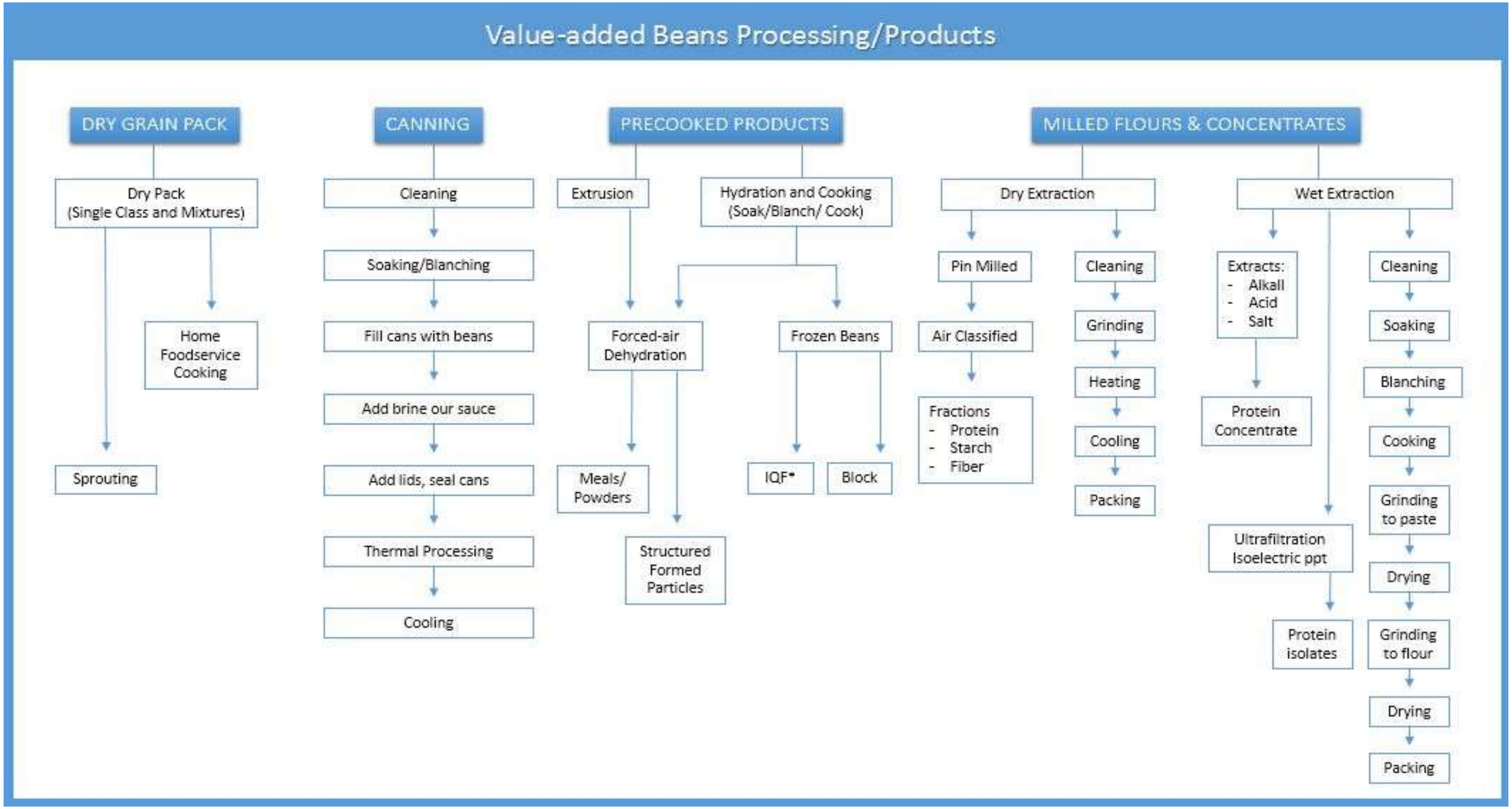
8. The five top producer countries of dry beans during the 2004-2013 decade were, in annual average, India (3.5 Mt), Brazil (3.2 Mt), Myanmar (3.0 Mt), the People's Republic of China (1.5 Mt) and the United States (1.2 Mt) (FAOSTAT, 2015). The top ten producers between 2009 and 2013 included, in addition to the five above-mentioned countries, Mexico and several African countries: Tanzania, Kenya, Uganda, Rwanda and Ethiopia (FAOSTAT, 2015) [*N.B.*: The FAO figures are not limited to common bean and might aggregate data of other legumes such as cowpea (*Vigna unguiculata*) and other *Vigna* species].

9. Common beans are mainly consumed in countries where they are produced. Countries with the highest rates of consumption per capita (in Central America, Caribbean, East Africa and some Asian economies) produce beans and also import them at varying levels, depending on the harvest, for meeting the internal demand. Considering the global imports and exports of dry beans between 2008 and 2012, it seems that 15 to 20% of the world annual production (around 4 MT on average) is traded internationally. Myanmar, China and the United States are the main exporters, with India and the European Union being the largest importers (FAOSTAT, 2015).

C. Processing

10. After harvest, beans are cleaned and then processed into final consumer products or ingredients. Products such as packaged dry beans, canned beans, baked beans, bean pastes, puffed snacks, texturized vegetable protein as meat analogues, cereal products, soups, frozen beans and bean flours all result from processing. The most commonly used processing methods for value-added common bean products are presented in Figure 4.

Figure 4. **Methods of processing for value-added bean products**



(*Individually quick frozen)
Sources: adapted from Siddiq and Uebersax (2012) and White and Howard (2013).

11. Canning is one of the most common forms of bean processing. Canned beans are a convenient alternative to dry beans which require long cooking times. An estimated 90% of navy beans and 45% of pinto beans (both being types of the common bean) consumed in the United States are sold as canned products (USDA-ERS, 2010). In developing countries, canned beans are most commonly a product for higher income consumers (Jackson et al., 2012).

12. The canning process involves seven major steps (Figure 4):

- First, seed sorting and cleaning is performed to remove poor quality, diseased and damaged seed, stones, and debris.
- Next, beans are equilibrated to 12-16% moisture. Higher moisture values reduce the shelf life and lower values increase seed damage and splitting (Matella et al., 2012).
- A soaking and/or blanching step follows. Soaking times may vary from 30 min to 12 h at room temperature. Blanching is high heat treatment for 30 min or less prior to canning. The purpose of both treatments is to increase the water content of the seeds and uniformity of the final product.
- Beans are added to cans, followed by hot brine or sauce. Brine is a mixture of sugar, salt, and calcium chloride. The calcium helps to maintain bean firmness. Sauces most commonly used in canning are tomato-based, but there are many commercial products available with diverse flavour additives.
- Lids are added to the cans, and the cans are sealed and processed in a canning retort for 52 mn to 325 min at 116 to 121°C, depending on can size and brine or sauce type.
- Cans are cooled with water to an internal temperature of 38°C and are equilibrated for two weeks prior to use (Hosfield and Uebersax, 1980).

13. There are many ways to process common bean into flour (Figure 4). One approach uses heat to inactivate the enzymes, as a pre-cooking method. The steps include: cleaning, soaking, blanching, cooking, grinding into a paste, drying, grinding again into flour, drying and packing. Another approach is the dry milling, without pre-cooking the flour. In this case, bean seeds are ground into flour, followed by heating and packing. Both approaches generate breakfast and snack food products, as well as a texturing ingredient in tortilla chips, baked products, pasta and extruded products.

D. Uses

14. Although the major industrial use of common bean is canned beans, processing of the different types of bean through various treatments results in a range of ingredients for food and feed and value-added products: composite flour, extruded products, bread, cakes, pasta and tortillas and others, as presented in Table 2.

Table 2. **Bean processing and products**

Bean type	Pre-treatment	Product
Navy	Untreated (washed, dried, split); Treated (washed, dried, split, roasted)	Conventional bread
Great northern	None	Pup loaf bread
Navy/ Pinto	Dry roasting, air classified bean flour/protein concentrate	Straight dough bread
Black/ Navy/ Pinto/ Small red	Flour blends of 15/25/35% of hard red spring (HRS) wheat flour	Tortilla-wheat/bean
White/ red	Soaked 18 h, boiled 60 min	Corn bean tortillas
Flor de junio Marcela	Cooked 95°C, 85 min, dried, ground	Corn bean tortillas
Black	Blended (paddle type mixer), twin screw extruder, 20% moisture	Extruded product
White/ Mexican	Counter-rotating twin screw extruder	Extruded product
Navy/ Small red	Bean flour + corn starch (15/30/45%) co-rotating twin	Extruded product
Pinto/ Bayo/ Flor de mayo	Soaked 18 h, 25°C, dehulled, dried 50°C	Extruded product – Single screw
Navy	Commercial navy bean flour	Extruded product
Navy/ Pinto/ Black	Dry roasting, dehulled, pin milled, air classified fractions	Composite flour (10%)
Pinto/ Great northern/ Small red/ Kidney	Blend 10/20/30% bean flour	Composite flour
Bean (unspecified)	Dehulled	Extender in beef sausage
Navy/ Pinto	Isolated and purified starch	Bean starch noodle
Navy	Dried to 5-10% moisture	Udon noodles
Navy/ Pinto	Dried 24-30 h at 94-100°F to 10% moisture	Spaghetti (0-25% bean)
Navy	Cotyledon flour precooked 12 min in boiling water, oven dried 40°C overnight	Pasta
Bayo Victoria	Pressure cooked, blended in a food processor	Pasta
Navy	Unheated and heated 240°C/2 min, dehulled, hulls	Cake (roasted bean hulls)
Navy/ Pinto/ Black	Dry roasting 24°C/1 min, dehulled, pin milled, air classified	Fried doughnuts
Navy/ Pinto	Milled to bean flour specifications	Pancake formulation
Navy/ Pinto	Roasted (270°C/1 min)	Short bread cookie
Navy	None	Master mix
Navy	Whole bean, hulls	Cookies
Navy	Soaked 99°C/45 min, steamed 104°C/30 min, macerated and drum dried	Cookies
Navy/ Pinto	Roasted (270°C/2 min)	Pumpkin bread
Navy/ Pinto	Dehulled, pin milled, air classified	Extruded snack
Navy/ Pinto	Milling and fractionation	Dried crackers

Source: adapted from Maskus (2010).

E. Appropriate comparators for testing new varieties

15. This document suggests parameters that common bean breeders should measure when developing new modified varieties of *Phaseolus vulgaris*. 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.

16. Components to be analysed include key nutrients, anti-nutrients and toxicants. 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

17. The majority of common 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 for the crop. Consequently, the yield increase by attenuation of limiting factors is the focus of many breeding programmes (McClean et al., 2008).

18. Improving common bean nutritional quality, stress tolerance, or resistance to pests and diseases are key objectives for different breeding programmes (Angenon et al., 1999; Suárez et al., 2008). Diseases and insects represent crucial biotic stressors that farmers have to face when growing this crop (Broughton et al., 2003). Among the fungal, bacterial and viral diseases that can affect common bean, at least five major ones are widespread: anthracnose, angular leaf spot, common bacterial blight, bean golden yellow mosaic virus and bean common mosaic virus, while several others are important locally or regionally (Broughton et al., 2003). A common bean variety that is resistant to bean golden mosaic virus (BGMV) has recently been developed (Aragão et al., 2013). Most commonly, breeders aim for resistance to one or two diseases and/or pest insects within the same variety. Since wild *Phaseolus* species present traits such as pest and pathogen resistance that are usually infrequent among cultivated common beans, they may be a potential source of novel alleles (Acosta-Gallegos et al., 2007).

19. The development of varieties with improved tolerance/resistant to other biotic stressors and to abiotic stressors is another important goal. Breeding programs are developing agronomic traits such as nitrogen fixation. Other characteristics are also being explored by common bean breeding programmes, such as the increased content of specific nutrients including protein, mineral and vitamins.

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[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).

SECTION II - NUTRIENTS

A. Composition of common bean (*Phaseolus vulgaris* L.) – General points

20. This document addresses composition data relating to seeds only, not green pods (snap beans or green beans), dry shelled pods, or stems.

21. Common bean is highly morphologically variable and adaptable to different environments, creating a wide range of local varieties. As a consequence, the nutritional composition of common bean is impacted by factors such as genotype, geographical origin, environmental and growing conditions (Broughton et al., 2003).

B. Constituents of common bean seed

1. Proximate composition

22. The proximate composition of raw common beans of a number of commercial varieties from the United States, Brazil and Madeira Island is shown in Table 3.

Table 3. **Proximate and total dietary fibre composition of different common bean varieties**

Beans (Raw Mature Seeds)	**Protein**[4] (g/100 g DW)	**Total lipid (fat)**[4] (g/100 g DW)	**Ash**[4] (g/100 g DW)	**Carbohydrate, by difference**[4, 5] (g/100 g DW)	**Moisture** (g/100 g FW)	**Fibre, Total Dietary**[4] (g/100 g DW)
Black beans[1]	24.28	1.6	4.05	59.05	11.02	17.42
Cranberry (roman) beans[1]	26.29	1.40	3.78	56.14	12.39	28.20
Kidney beans, all varieties[1]	26.72	0.94	4.34	56.25	11.75	28.21
Navy beans[1]	25.40	1.71	3.78	57.01	12.1	17.41
Pink beans[1]	23.30	1.26	4.07	61.31	10.06	14.12
Pinto beans[1]	24.16	1.39	3.90	59.25	11.3	17.50
Small white beans[1]	23.91	1.34	4.25	58.39	11.71	28.20
Pérola, Carioca (beige)[2]	24.96	1.78	4.65	55.54	13.07	21.94
Madeira Island beans[3] (59 accessions)	18.55-29.69 mean: 23.27	0.57-2.86 mean: 1.65	3.64-5.67 mean: 4.57	53.09-67.56 mean: 59.64	6.45-16.65 mean: 10.87	-

Notes: DW = dry weight basis; FW = fresh weight basis.
Sources: adapted from: [1.] USDA-ARS database (2014) (data were converted to dry weight basis using mean moisture value); [2.] Delfino and Canniatti-Brazaca (2010), data already provided in dry weight%; and [3.] Gouveia et al. (2014), data mean and range
[4] Data converted from fresh weight to dry weight basis using given moisture level.
[5] Carbohydrate (by difference) = 100% - (crude protein% + crude fat% + ash% + moisture%)

23. Carioca bean grains have a cream background with tan stripes; Pérola is the most common carioca variety in Brazil. The cooking process affects mainly the fibre content of carioca beans (Pires et al., 2005).

24. Gouveia et al. (2014) evaluated the composition of 59 accessions of common bean varieties (52 Madeiran landraces, 5 standard and 2 commercial varieties) grown under the same field conditions in Madeira Island, minimizing the impact of the environmental factors. Regional common bean varieties exhibited great variability in the proximate parameters, presenting on average a better nutritional performance with highest protein and mineral contents compared to standard and commercial varieties.

2. Carbohydrates

25. Carbohydrates are monosaccharides and disaccharides (sugars), oligosaccharides and polysaccharides (starch, resistant starch, and non-starch). Carbohydrates content in beans are mainly composed of starch, with small amounts of monosaccharides and disaccharides. Of carbohydrates, 17 to 23% has been reported to be pectin, cellulose and hemicellulose (Shiga et al., 2009). The total starch content ranges from 23.4 to 64.3% (Jacinto-Hernández and Campos, 1993; Jacinto-Hernández et al., 2002; Gouveia et al., 2014).

26. Beans contain a high ratio of slowly digestible to readily digestible starch compared with other starchy foods. Most common beans contain 27 to 40% amylose, a linear polymer of α-1-4 glucose units (Hoover et al., 2010), whereas most other starchy vegetables contain 20 to 30% amylose. Beans also contain a substantial amount of resistant starch, considered as dietary fibre. Resistant starch resists digestion by amylase in the small intestine and progress to the large intestine for bacterial fermentation in the gut producing the short chain fatty acids, acetic, butyric and propionic acids (Chung et al., 2010). Dry beans contain a substantial amount of carbohydrates as raw fibre in the form of cellulose and hemicellulose (Geil and Anderson, 1994).

3. Protein

27. Mean protein content shown in Table 3 for some common bean types vary from 23.27 to 26.72% of the dry matter. Madeira Island types/varieties had a total protein mean content of 23.27 g/100 g with a range of 18.55 to 29.69 g/100 g (Gouveia et al., 2014). Bhatty et al. (2001) and Siddiq et al. (2010) reported a range of 20.43 to 23.62 g/100 g. Northern Portuguese beans and improved Ethiopian beans have reported total protein ranges of 17.96 to 27.45 g/100 g (Coelho et al., 2005) and 17.96 to 22.07 g/100 g (Shimelis and Rakshit, 2005), respectively. Rodiño et al. (2001; 2003) have shown mean protein content of Portuguese beans and Iberian Peninsula beans to be 30.7 g/100 g (Rodiño et al., 2001) and 31.4 g/100 g. Oliveira (2005) demonstrated that the black, white and pink varieties that were analysed have a protein content of 25% or more.

28. Table 4 presents the content of amino acids in common bean, based on elements collated from the USDA-ARS database (detailed by bean types, 2015), and Feedipedia database (Heuzé et al., 2013). The amino acid profile of common bean protein is characterized by its deficiency in sulphur amino acids (methionine and cystine) and tryptophan, with methionine considered as the limiting amino acid. The highest content is for the glutamic acid (Table 4).

Table 4. **Amino acid content (g/100 g, dry weight basis) of common beans**

Data source	USDA-ARS[1]							Feedi-pedia[2]
	Black beans	Cranberry (roman) beans	Kidney beans, all varieties	Navy beans	Pink beans	Pinto beans	Small white beans	
Moisture content per 100 g	11.02	12.39	11.75	12.1	10.06	11.33	11.71	10.90
Alanine	1.02	1.10	1.12	1.03	0.98	0.98	1.00	0.99
Arginine	1.50	1.63	1.65	1.16	1.44	1.24	1.48	1.59
Aspartic acid	2.94	3.18	3.23	2.96	2.82	2.56	2.89	2.65
Cystine	0.26	0.29	0.29	0.21	0.25	0.21	0.26	0.27
Glutamic acid	3.70	4.01	4.07	3.52	3.55	3.41	3.64	3.67
Glycine	0.95	1.03	1.04	0.91	0.91	0.90	0.93	0.97
Histidine	0.68	0.73	0.74	0.58	0.65	0.63	0.67	0.69
Isoleucine	1.07	1.16	1.18	1.08	1.03	0.98	1.06	1.09
Leucine	1.94	2.10	2.13	1.96	1.86	1.76	1.91	1.93
Lysine	1.67	1.80	1.83	1.46	1.60	1.53	1.64	1.61
Methionine	0.37	0.39	0.40	0.31	0.35	0.29	0.36	0.27
Phenylalanine	1.31	1.42	1.44	1.32	1.26	1.23	1.29	1.34
Proline	1.03	1.11	1.13	1.27	0.99	1.21	1.01	0.87
Serine	1.32	1.43	1.45	1.34	1.27	1.32	1.30	1.36
Threonine	1.02	1.11	1.12	0.81	0.98	0.91	1.01	1.04
Tryptophan	0.29	0.31	0.32	0.28	0.28	0.27	0.28	0.32
Tyrosine	0.68	0.74	0.75	0.55	0.66	0.48	0.67	0.84
Valine	1.27	1.38	1.40	1.41	1.22	1.13	1.25	1.24

Sources:[1] USDA-ARS (2015); [2] Heuzé et al. (2013)

[1] Data converted from fresh weight to dry weight basis using given moisture level.

[2] Data converted from % protein (average) to dry weight basis using given crude protein % dry matter.

29. The protein digestibility of raw beans varies from around 25 to 60%, and can be increased up to 93.2%, depending on the bean variety and cooking process (Batista et al., 2010; Kiers et al., 2000; Jacinto-Hernández and Campos, 1993; Jacinto-Hernández et al., 2002). Jacinto-Hernández and Campos (1993) showed that increases in protein digestibility following cooking was very variable, with some varieties showing 8-12% higher digestibility compared to raw beans, while others only improved digestibility by 3-4%.

30. The nutritional value of beans is increased by heat processing, especially under moist heat (Gallardo et al., 1974, cited by Poel et al., 1990). This is due to denaturation of anti-nutritional factors, such as trypsin inhibitors and phytic acid (Burns, 1987, cited by Poel et al., 1990), as well as to improved accessibility of bean proteins to enzymatic degradation (Romero and Ryan, 1978).

4. Lipids/Fatty acids

31. Beans contain only a small amount of lipids, with the majority of fatty acids being unsaturated (Anderson et al., 1999). Total fat/lipids content in some varieties of common beans is between 0.57 to 1.78 g/100 g of dry matter (Table 3). The content of total saturated, monounsaturated and polyunsaturated fatty acids in some types of common bean is presented in Table 5.

Table 5. **Fatty acid content (g/100 g, dry weight basis) in raw mature seeds**

Bean types	**Total saturated**	**Total monounsaturated**	**Total polyunsaturated**	**Moisture (% of raw seeds)**
Black	0.326	0.109	0.543	11.02
Black Turtle	0.206	0.069	0.344	11.00
Cranberry (roman)	0.277	0.093	0.462	12.39
Great Northern	0.318	0.047	0.426	10.70
Kidney, all types	0.106	0.056	0.403	11.75
Navy	0.149	0.113	0.767	12.10
Pink	0.263	0.088	0.438	10.06
Pinto	0.208	0.203	0.361	11.33
Red Kidney	0.136	0.072	0.517	11.75
Small White	0.268	0.090	0.448	11.71
White	0.194	0.066	0.323	11.32
Yellow	0.597	0.201	0.994	11.10

Source: adapted from USDA-ARS database (2014) (data were converted to dry weight basis using mean moisture value shown in the table).

5. Vitamins

32. Common beans in particular contain water-soluble B vitamins, such as thiamine (3.9 to 11.4 mg/kg dry matter), riboflavin (1.0 to 2.9 mg/kg), niacin (3.3 to 26.8 mg/kg), vitamin B_6 (0.4 to 5.7 mg/kg) and pantothenic acid (2.7 to 10.1 mg/kg) (Table 6). Common beans are also a prominent source of dietary folate - vitamin B_9 - (0.2 to 5.8 mg/kg) (Table 6) (Rychlik et al., 2007). Common beans contain only small amounts of vitamin C and because of the low level of lipids in beans, little to no fat-soluble vitamins (Geil and Anderson, 1994).

33. The vitamin content measured in common beans varies widely depending on commercial market classes, origin, environment and analytical methodology used for analysis (Table 6). Variation is greatest in folate (vitamin B_9) content (Rychlik et al., 2007).

34. Cooking, like other food treatments, introduces another source of direct and indirect variability. Commercial methods of preparation of canned beans can cause significant loss of water-soluble vitamins, whereas home cooked common beans seem to have less effect on nutrient retention (Augustin et al., 1981).

Table 6. **Vitamin composition (mg/kg, dry weight basis) of common beans**

Bean types	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
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

Sources: [1]Augustin et al. (1981); [2] Tiwari and Singh (2012); [3] Wang and Daun (2004).

6. Minerals

35. The bean ash is constituted by several minerals (Table 7). The mineral content depends on market class/variety and environmental conditions during cultivation. Regarding minerals occurring at higher quantities, ranges reported are 0.09-4.25 g/kg of the dry matter for calcium (Ca), 1.0-3.26 g/kg for magnesium (Mg), 2.30-8.42 g/kg for phosphorous (P) and 13.0-24.9 g/kg for potassium (K). A considerable variation in levels was also observed for minerals occurring at lower quantities in germplasm from different sources, as shown by Dwivedi et al. (2012).

36. Common beans accumulate different proportions of total seed minerals iron, zinc and manganese in the seed coat, embryo, and cotyledons. The highest amount of these minerals is stored in the cotyledons of mature seeds (Cvitanich et al., 2011). Iron and other constituents of the grain (phytate, tannins and fibre) are distributed differently in the hull and in the cotyledon. Food processing, such as baking and brewing, not only affect the bioavailability of iron, but also the factors that act as agonists or antagonists of mineral absorption (Lombardi-Boccia et al., 1995). Stripping significantly decreased the dialysability of iron, while cooking had the same influence on a coloured variety, but not on a white variety. The tannin-protein interaction may be the main cause of the difference in iron dialysability (Lombardi-Boccia et al., 1995). The effect of reheating beans on the iron content has also been studied. In whole bean, without broth, no changes were detected during cooking. In the case of beans with broth, insoluble iron increased in grains. Both soluble and insoluble iron decreased in the broth (Amaya et al., 1991).

Table 7. **Mineral composition of common beans**

Beans	**Calcium**	**Magnesium**	**Phosphorous**	**Potassium**	**Iron**	**Zinc**	**Copper**	**Manganese**
	(**g/Kg**, dry weight basis)				(**mg/Kg**, dry weight basis)			
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		
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		
Several Mexican varieties[6]	0.09-2.0	2.0	4.6		38.0-76.0	22.0-44.0		
Red mottled beans[7] (2 varieties)					76-81	33-34		
Madeira Island beans[8] (59 accessions)		1.0-1.8 mean: 1.5	3.0-7.5 mean: 5.0	13.0-24.9 mean: 18.9	41.0-100.0 mean: 60.1	22.0-50.0 mean: 30.1	5.0-14.0 mean: 10.1	0.009-0.021 mean: 0.015

Sources: [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); [6] Guzmán-Maldonado et al. (2002); [7] Blair et al. (2010); [8] Gouveia et al. (2014).

SECTION III – ANTI-NUTRIENTS, TOXICANTS AND OTHER CONSTITUENTS

A. Anti-nutrients and toxicants – General points

37. In spite of good nutritional quality, common beans contain some constituents having anti-nutritional effects. Thus, adverse effects may be induced by tannins, phytates, protease inhibitors, and lectins. Kidney beans have also been reported to contain toxic cyanogenic compounds (Cho et al., 2013), but only at trace levels having no health implications for the consumer.

B. Main anti-nutrients

1. Tannins

38. Tannins are colourless polyphenolic constituents of legumes (Reed, 1995). Levels reported in common bean varieties range from 10.1 to 44.2 mg catechin-equivalents per gram dry weight (De Mejía et al., 2003, Helbig et al., 2003; Cruz-Bravo et al., 2011). Beans differ in content of tannins, which affect quality as they are converted into pigments visible during dehydration and oxidation. Tannins also have the ability to interact with proteins, resulting in reduced protein and mineral digestibility (Junk-Knievel et al., 2008). Condensed tannins are present in the dietary fibre fraction and can be considered indigestible or poorly digestible (Bartolomé et al., 1995). Cooking does not destroy tannins, but they are partially removed with the cooking broth (Bressani and Elias, 1980). According to Ziena et al. (1991), less than 10% of total tannins are broken down during cooking, while about 50% are washed away in the cooking liquid.

2. Phytate/Phytic acid

39. Phytic acid (also known as inositol hexakisphosphate (IP6), inositol polyphosphate, or phytate when in salt form) chelates mineral nutrients including calcium, magnesium, potassium, iron, and zinc, rendering them unavailable to non-ruminant animals (NRC, 1998; Liener, 1994). Phytates are concentrated mostly in the cotyledons and embryo axes (up to 3% of total seed weight) of common bean (Kasim and Edwards, 1998; Blair et al., 2012) (Table 8). The negative effect on the bioavailability of minerals is associated with inositol penta- (IP5) and –hexa-phosphate (IP6). Phytates also interact with basic protein residues and can inhibit digestive enzymes such as pepsin, pancreatin and amylase (Agostini and Ida, 2006).

40. Phytate content in common beans varies due to genetic differences between varieties, and environmental factors such as growing conditions, agricultural practices and location. Commonly reported levels are in the range 2.6-25.1 mg/g dry weight (Stanley and Aguilera, 1985; Estévez et al., 1991; Burbano et al., 1999; Helbig et al., 2003; Diaz-Batalla et al., 2006; Oomah et al., 2008; Martin-Cabrejas et al., 2009; Martinez Meyer et al., 2013; Pedrosa et al., 2015; Carvalho et al., 2015). In beans, phytate phosphorus constitutes a major portion of the total phosphorus content and is found preferentially in the cotyledon (Deshpande et al., 1982), accounting for 57-81% of total phosphorus in navy, 68-72% in red kidney, 55-80% in Great Northern and 70% in California small white beans (Reddy, 2001). Low phytate bean germplasm have recently been developed (Campion et al., 2009). The proportion of phytate being IP5 and IP6, which are the most commonly detected inositol phosphate isomers, vary widely

in raw beans. IP6 is the most predominant isomer, constituting from 64% (in red kidney beans) to 98% (in pinto beans) of the total phytate content (Chen, 2004).

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

Table 8. **Phytic acid composition (mg/g) of common beans and its components**

Bean types	Whole[1, 2]	Cotyledon[1]	Dehulled[2]	Hull[2]
Black	10.4-29.3	36.1	17.09	1.91
Great Northern	5.0-27.0	32.6		
Pinto	6.1-23.8	25.6	11.48	1.30
Red	8.1-20.7	30.5	8.71	2.63
Red Kidney	12.0-26.3	34.7		
White	5.5-18.0	16.3	9.83	2.30

Sources: [1] Reddy (2001), [2] Calculated from Hu et al. (2006).

3. Trypsin inhibitors

42. Common beans contain trypsin inhibitors which inhibit the digestive action of the trypsin enzyme. Trypsin inhibitor activity (TI) in uncooked beans have been reported to be in the range 6.3-55.2 trypsin inhibited units (TIU)/mg (Dhurandhar and Chang, 1990; Estévez et al., 1991; Jacinto-Hernández and Campos, 1993; Sotelo et al., 1995; De Mejia et al., 2003, 2005; Morales-de Leon et al., 2007; Olmedilla-Alonso et al., 2013; Pedrosa et al., 2015). The level of TI in the common bean is not only dependent of bean genotype but also on the environmental conditions where it was cultivated (De Mejia et al., 2003, 2005). In cooked beans, trypsin inhibitor activity is much lower than in raw beans (Jacinto-Hernández and Campos, 1993; Jacinto-Hernández et al., 2002; Morales-de León et al., 2007).

4. Alpha-amylase inhibitors

43. Common beans are the legume with the highest amount of alpha-amylase inhibitors. Alpha-amylase inhibitors inhibit the digestive enzyme alpha-amylase resulting in reduced digestibility of certain carbohydrates. Various types of α-amylase inhibitors have been described in common bean (Ishimoto et al., 1995), including three different glycoprotein isoforms. Screening of 150 Brazilian bean varieties classified by colour revealed average values between 0.19 and 0.29 α-amylase inhibitor units per mg protein and a range between 0.09 and 0.40 α -amylase inhibitor units per mg protein (Table 9), with no correlation between inhibitory activity and seed coat colour (Lajolo et al., 1991).

Table 9. **α-Amylase Inhibitory Activity (AIU/mg protein) of common beans classified by bean colour**

Bean colour	Range	Average
Beige	0.14-0.40	0.26
Black	0.11-0.30	0.19
Brown	0.14-0.35	0.29
Dark brown	0.19-0.33	0.25
Light brown	0.09-0.32	0.20
Pale brown	0.16-0.40	0.29
Pink	0.16-0.28	0.21
Purple	0.17-0.22	0.19
Red	0.16-0.37	0.25
White	0.14-0.33	0.23

Note: AIU- α-amylase inhibitory unit value of 10 is defined as a 50% decrease in enzyme activity at 37°C/5 min after addition of 1% starch as substrate.

Source: Lajolo et al. (1991).

5. Lectins

44. Lectins are proteins that bind to carbohydrate-containing molecules and are found in a variety of foods, including legumes such as the common bean (Gupta, 1987). The biological activity of lectins has been reviewed (Grant, 1991). Levels reported vary with the methodology used to detect the lectins. Several investigators reported levels between non-detectable and around 10 haemagglutinating units (HU) per gram bean assayed with a method measuring heamagglutinating activity (Sotelo et al., 1995; De Mejía et al., 2003; 2005), whereas Burbano et al. (1999), Olmedilla-Alonso et al. (2013) and Pedrosa et al. (2015) reported 0.3-165 mg/g dry weight using an indirect ELISA assay for phytohaemagglutinin quantification. Lectins have been shown to have growth inhibitory properties and result in toxicity in animals. The heamagglutinating activity of lectins can be reduced by moist-heat treatment (Gupta, 1987), making proper cooking prior to consumption an important step in the safe consumption of common beans (Ogawa and Date, 2014). Several cases of human toxicity due to ingestion of raw or under-cooked beans have been reported (Cornell University, 2014).

C. Other constituents

1. Oligosacharides

45. Common bean varieties vary considerably in terms of their oligosaccharide content (Table 10), including the raffinose family oligosaccharides (RFOs). Thus, raffinose levels range from about non-detectable to 14.1 mg/g dry weight, stachyose from 0.9 to 63.8 mg/g and verbascose from non-detectable to a few mg/g, depending on the variety considered (Geil and Anderson, 1994; Weder et al., 1997; Burbano et al., 1999; Queiroz Kda et al., 2002; Diaz-Batalla et al., 2006; Campos-Vega et al., 2009; Cruz-Bravo et al., 2011; Kleintop et al., 2013; Olmedilla-Alonso et al., 2013; Slupski and Gebczynski, 2014; Pedrosa et al., 2015). Diaz-Batalla et al. (2006) noted that one out fourteen studied common bean varieties contained exceptionally high levels of verbascose (35.8 mg/g dry weight). RFOs are broken down by the enzyme

α-galactosidase which is not present in the lower gastrointestinal tract. As a result, RFOs are fermented by anaerobic bacteria in the gut, resulting in flatulence (Food Science: Res. and Tech./edit. Haghi, 2012). Soaking of dry beans prior to cooking is a common practice and has been shown to reduce the content of RFOs in common bean. The amount of raffinose + stachyose removed through soaking in Mexican common bean varieties was found to range from 7% to 60%, depending of the variety considered (Table 10).

Table 10. **Oligosaccharide content in Mexican common bean varieties**

Variety	**Dry grain**		**Soaked grain**	
	Raffinose	**Stachyose**	**Raffinose**	**Stachyose**
	Concentration (mg/g)			
Bayo Victoria	4.43	36.66	2.57	14.08
Azufrado Higuera	1.63	26.98	1.94	22.14
Flor de Durazno	2.20	31.33	1.61	16.48
Azufrado Peruano	2.06	34.27	1.73	20.41
Bayo Zacatecas	5.39	26.39	2.08	10.76
Azufrado Regional 87	1.72	23.32	1.82	20.32
Bayo Mecentral	6.16	9.43	3.36	8.03
Flor de Junio M.	5.38	28.06	3.78	18.75
Negro Otomí	3.87	26.76	2.45	16.36
Flor Mayo M38	3.94	26.50	3.74	24.48
Alubia	5.65	20.56	3.13	12.82
Negro Jamapa	7.04	35.22	6.00	24.76
Negro 8025	6.55	23.62	4.73	21.53

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

46. Other carbohydrates in common bean include pectic substances, arabinogalactans and xyloglucans (Reddy et al., 1984; Sathe and Salunkhe, 1984). Like RFOs, these sugars are hydrolysed by galactosidase, and are subject to anaerobic fermentation resulting in flatulence (Geil and Anderson, 1994).

2. Saponins

47. Saponins are secondary plant metabolites that exist in a wide variety of edible legumes (Shi et al., 2004; Guajardo-Flores et al., 2012; Calvert et al., 1981). In common bean, they are particularly found in the seed coat, the most abundant saponin in the extracts of black bean seed coats being soyasaponin Af (Chavez-Santoscoy et al., 2013).

3. Phenolics

48. The major phenolic compounds of beans are simple phenolic acids and flavonoids. Highest phenolic content are found in the dark, highly pigmented bean varieties, in particular in their seed coat or hulls (Oomah et al., 2005) that are rich in flavonols, flavonoids, anthocyanins and tannins. Seed coat polyphenols are partly responsible for the post-harvest seed darkening and hard-to-cook phenomenon in beans (Marles et al., 2008; Campos-Vega et al., 2012). A single gene seems to control post-harvest darkening. In pinto beans the slow-darkening trait is controlled by a recessive allele (Junk-Knievel et al., 2008). Total phenolic content (50-1104 mg/kg) and the spectrum of the various phenolic constituents vary widely among and within market classes of common bean, depending on genetic and environmental factors.

49. The most abundant simple phenolic compounds[2] in common beans are ferulic acid, sinapic acid, vanillic acid, caffeic acid, p-coumaric acid and p-hydroxybenzoic acid, but also syringic aicd, chlorogenic acid, gallic acid and vanillin have been reported (Espinosa-Alonso et al., 2006: Luthria and Pastor-Corrales, 2006; Xu and Chang, 2009).

50. Kaempferol, often occurring with O- and C_glycosidic linkages, is the most abundant flavonol in beans with red beans and pinto beans containing greater amounts (14-209 and 148 mg/kg, respectively) than black or grey beans (20 mg/kg) (Diaz-Batalla et al., 2006). 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).

51. Anthocyanins occurring in beans are simple, non-acylated anthocyanidins, usually containing glucose as the only sugar; however, malvidin 3-galactoside has been detected in black beans (Xu and Chang, 2009). Six different anthocyanidins have been detected in the (coloured) common bean but their relative percentage may differ among ecotypes and commercial market classes of beans. Several investigators reported delphinidin (49-81%) to predominate, with petunidin (4-32%), cyaniding (1-23%) and malvidin, (4-14%) occurring at intermediate level, and pelargonidin (0.4-6.5%) and peonidin (0.5-3.7%) less frequently (Choung, 2005; Espinosa-Alonso et al., 2006; Xu and Chang, 2009). However, López et al. (2013) reported cyanidin and pelargonidin as the major anthocyanidins in dark beans, where they were complemented with small amounts of acylateddelphinidin and pelargonidin 3-glucosides.

[2] Amounts will be influenced by chemical analytical methodology used.

SECTION IV - SUGGESTED CONSTITUENTS TO BE ANALYSED RELATED TO FOOD USE

A. Key products consumed by humans

52. Common bean is a staple food typically consumed after having been soaked in water and cooked or after having been canned. While beans can be milled and used to produce processed products, common bean is typically eaten as shelled beans (whole grain). For the purpose of compositional analysis, it is appropriate to analyse the whole grain once the shell has been removed.

B. Suggested analysis for food use of new varieties

53. In the context of the human diet, common bean can provide nutrients such as proteins, carbohydrates, dietary fibre and folate. Common bean may also contain the anti-nutrients such as phytic acid, trypsin inhibitor, α-amylase inhibitor and lectins. The suggested key nutritional and anti-nutritional parameters to be analysed are shown in Table 11.

Table 11. **Suggested constituents to be analysed for food use**

Constituent	**Whole grain**
Proximates	X
Dietary fibre	X
Amino acids	X
Phytic acid	X
Trypsin inhibitor	X
α-amylase inhibitor	X
Lectins	X
Vitamins[1]	X

Note: [1.] the B vitamins thiamine (B1), riboflavin (B2) and folate (B9) are suggested.

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

A. Key products consumed by animals

54. Although less common than its use in human food, common bean may be used in animal feed. While products from common bean may be used as feed, this document only addresses seeds, not green pods (snap beans or green beans), dry shelled pods, or stems.

55. The residue of packaging and processing of dried beans (including those from the genera Phaseolus) for human food may be added to animal diets. These may include broken, small, and cull beans, which may comprise all or part of plant protein products for animal diets (AAFCO, 2015).

B. Suggested analysis for feed use of new varieties

56. The suggested key nutritional and anti-nutritional parameters to be analysed in common bean for animal feed use are shown in Table 12.

Table 12. **Suggested Constituents to be analysed for feed use**

Constituent	**Whole grain**
Proximates	x
Fibre fractions[1]	x
Amino acids	x
Phytic acid	x
Trypsin Inhibitor	x
Lectins	x

Note: [1.] Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) should be substituted for crude fibre.

SECTION VI - REFERENCES

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