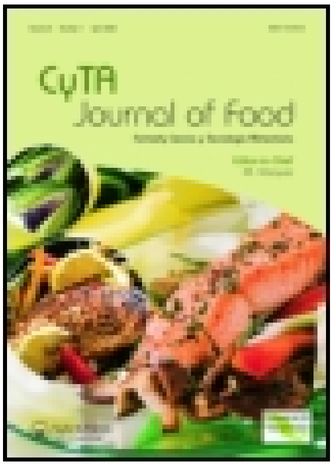

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Bean seeds: leading nutraceutical source for human health

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REVIEW

Bean seeds: leading nutraceutical source for human health

Semillas del frijol: fuente líder de nutracéuticos para la salud humana

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Phaseolus is the most important food legume for human consumption in the world. Its seeds consist mainly of carbohydrates and are a good source of nitrogen and protein. It also contains calcium, magnesium, potassium, phosphorus, copper, iron, zinc, manganese and sulfur. This legume is rich in bioactive components such as enzyme inhibitors, lectins, phytates, oligosaccharides and phenolics, which exhibit metabolic roles in humans and animals. Among the observed biological activities are the antioxidant capacity, the reduction of cholesterol and reduction of low-density lipoproteins, thus *Phaseolus* has a protective effect against cardiovascular diseases. Also it has shown favourable effects against cancer because of the antimutagenic and antiproliferative properties of their phenolics, lectins and protease inhibitors. Additionally, it has showed effects on obesity and diabetes due to its content of resistant starch and α-amylase inhibitor. Here we present a review of the beneficial properties of beans as a nutraceutical food.

Keywords: beans; cancer; cardiovascular disease; diabetes; obesity; *Phaseolus*

Phaseolus es la leguminosa más importante para consumo humano en el mundo. Sus semillas se componen principalmente de hidratos de carbono y son una buena fuente de nitrógeno y proteínas. También contiene calcio, magnesio, potasio, fósforo, cobre, hierro, zinc, manganeso y azufre. Esta leguminosa es rica en componentes bioactivos como inhibidores de enzimas, lectinas, fitatos, oligosacáridos y compuestos fenólicos, que exhiben funciones metabólicas en humanos y animales. Entre las actividades biológicas observadas están la capacidad antioxidante, la reducción de colesterol y la reducción de lipoproteínas de baja densidad, por lo que tiene efecto protector contra enfermedades cardiovasculares. *Phaseolus* ha mostrado efectos favorables contra el cáncer debido a las propiedades antimutagénicas y antiproliferativas de sus compuestos fenólicos, lectinas e inhibidores de la proteasa. Adicionalmente, ha mostrado efectos sobre obesidad y diabetes debido a su contenido de almidón resistente e inhibidor de α-amilasa. Aquí se presenta una revisión de las propiedades benéficas del frijol como alimento nutracéutico.

Palabras clave: cáncer; enfermedad cardiovascular; diabetes; frijol; obesidad; *Phaseolus*

1. Introduction

Numerous species of *Phaseolus* are cultivated all over the world (Table 1). They are cultivated primarily for their grains (beans), which are harvested when mature and marketed as dry products. They are generally known as pulses in the industry and commerce (Delgado-Salinas, 2012). Archeological studies reveal that beans from *Phaseolus* originated in the Americas, and in Mexico there have been discoveries of *Phaseolus vulgaris* dating from to 9000 years ago (Reyes-Rivas, Padilla-Berna, Pérez-Veyna, & López-Jáquez, 2008). The main five domesticated species are the common bean (*Phaseolus vulgaris* L.), the lima bean (*Phaseolus lunatus*), the runner bean (*Phaseolus coccineus*), the tepary bean (*Phaseolus acutifolius*), and the year bean (*Phaseolus polyanthus*) (Gepts, 2001).

Twenty-three million tons of *Phaseolus* plants and over 12 million tons of dry beans are produced worldwide. This crop is produced under a diversity of systems and environments in all regions: Asia (45.75%), the Americas (34.17%), Africa (17.56%), Europe (2.29%) and Oceania (0.24%). For the 2001–2011 period, the largest production of cultivation was Brazil (16%), followed by India (15.9%), Myanmar (10.5%), China (8.9%), Mexico (5.8%) and USA (5.6%) (FAOSTAT, 2013; Secretaría de Economía, 2012). The dry common bean, or *Phaseolus vulgaris* L., is the most important edible legume for direct consumption in the world. There are many variations with regard to growth patterns, seed characteristics, maturation and adaptation, accounting for more than 40,000 varieties (Schneider, 2002). Among the highest consumers of beans are Brazil (19.7%), India (19.7%), Mexico (7.7%), the United States (6.6%), Tanzania (2.7%), and Uganda (2.7%) (FAOSTAT, 2013). In Latin America, beans are considered traditional nourishment, but in Africa beans are grown primarily for subsistence, and the Great Lakes region has the highest consumption per capita in the world (Jones, 2011).

However, beans are more than a foodstuff since they are rich in many other compounds and have beneficial effects on human health. This review presents a description of the chemical composition of beans emphasizing their nutraceutical properties against important human diseases.

2. Chemical composition

Dry beans are said to be a fine source of nitrogen and protein (20–30%). One portion (90 g or a ½ cup of cooked beans) provides 7 to 8 g of protein, nearly 15% of the recommended dietary intake of protein for a 70 kg adult (Paredes, Becerra, & Tay, 2009). Sulfur-

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Table 1. Main *Phaseolus* species.

Tabla 1. Principales especies de *Phaseolus*.

Family *Leguminoseae*		
Tribe: *Phaseolac*		Subfamily: *Papilionoidene*
Generous: *Phaseolus*		Subtribe: *Phascolinae*
Phaseolus acutifolius	*Phaseolus jaliscanus*	*Phaseolus parvulus*
Phaseolus albescens	*Phaseolus juquilensis*	*Phaseolus pauciflorus*
Phaseolus albiflorus	*Phaseolus laxiflorus*	*Phaseolus pedicellatus*
Phaseolus albinervus	*Phaseolus leptostachyus*	*Phaseolus perplexus*
Phaseolus altimontanus	*Phaseolus lignosus*	*Phaseolus persistentus*
Phaseolus amblysepalus	*Phaseolus lunatus*	*Phaseolus plagiocylix*
Phaseolus angularis	*Phaseolus macrolepis*	*Phaseolus pluriflorus*
Phaseolus angustissimus	*Phaseolus maculatifolius*	*Phaseolus polyanthus*
Phaseolus augusti	*Phaseolus maculatus*	*Phaseolus polymorphus*
Phaseolus bolivianus	*Phaseolus macvaughii*	*Phaseolus polystachios*
Phaseolus campanulatus	*Phaseolus magnilobatus*	*Phaseolus reticulatus*
Phaseolus carteri	*Phaseolus marechalii*	*Phaseolus rotundatus*
Phaseolus chiapasanus	*Phaseolus micranthus*	*Phaseolus salicifolius*
Phaseolus coccineus	*Phaseolus microcarpus*	*Phaseolus sonorensis*
Phaseolus costaricensis	*Phaseolus mollis*	*Phaseolus talamancensis*
Phaseolus dasycarpus	*Phaseolus mungo*	*Phaseolus tenellus*
Phaseolus dumosus	*Phaseolus neglectus*	*Phaseolus texensis*
Phaseolus esperanzae	*Phaseolus nelsonii*	*Phaseolus tuerckheimii*
Phaseolus esquincensis	*Phaseolus nodosus*	*Phaseolus vulgaris*
Phaseolus filiformis	*Phaseolus novoleonensis*	*Phaseolus xanthotrichus*
Phaseolus glabellus	*Phaseolus oaxacanus*	*Phaseolus xolocotzii*
Phaseolus gladiolatu	*Phaseolus oligospermus*	*Phaseolus zimapanensis*
Phaseolus grayanus	*Phaseolus pachyrrhizoides*	*Phaseolus sp. SH-2010*
Phaseolus hintonii	*Phaseolus parvifolius*	*Phaseolus sp. XHJ-2009*

Note: Reyes-Rivas et al. (2008); NCBI.

containing amino acids are the most limiting (Bressani, Elias, & Navarrete, 1961). Values for histidine, isoleucine, lysine, phenylalanine, threonine, and valine are slightly variable between species and arginine can be detected in some variations. The wild species show higher levels of amino acids than domesticated crops (Baldi & Salamini, 1973). The digestibility of beans proteins is about 79%; the amino acid score is 0.78 and protein digestibility between 0.57–0.68 (FAO/WHO, 1991).

Beans mostly contain carbohydrates (55–65% on dry weight). Of these, the polysaccharide derivative and non-derivative of starch (dietary fibre) are the primary components, with minor but significant amounts of mono-, di- and oligosaccharides. Beans contain slow digestion carbohydrates and a high proportion of non-digestible carbohydrates, which can be fermented in the large intestine. Non-digested carbohydrates that reach the colon include resistant starch, soluble and insoluble dietetic fibre and non-digestible oligosaccharides (Reynoso-Camacho, Ramos-Gómez, & Loarca-Pina, 2006).

Calcium, magnesium and potassium are the major cations in common beans. There is greater availability of calcium than magnesium or potassium. Average mineral concentrations for copper (18 mg/kg), iron (60 mg/kg), manganese (23 mg/kg), zinc (29 mg/kg) and sulfur (234 mg/kg) are higher in wild genotypes. However, although some studies have shown considerable variation between wild beans and modern cultivars, it seems that domestication does not affect the concentration of iron and zinc in the seed (Paredes et al., 2009). Both these minerals found in common beans are important for the populations of Latin America and Africa (Muhamba-Tryphone & Nchimbi-Msolla, 2010). Pressure-cooking and pre-soaking in water affect the retention of iron and zinc in cooked seeds, which should be complemented with the stock in which they

Table 2. Nutritional components of different types of beans.

Tabla 2. Componentes nutrimentales de diferentes tipos de frijol.

Component	*P. vulgaris*	*P. mungo*	*P. lunatus*	*P. angularis*
Water (g/100 g)	12.10	9.05	10.17	13.44
Energy (kcal)	337	347	338	329
Carbohydrates (%)	69.11	68.85	70.55	72.67
Protein (%)	25.40	26.23	23.89	22.95
Fat (%)	1.70	1.26	0.768	0.612
Ash (%)	3.78	3.66	4.79	3.77
Fibre (%)	17.4	17.92	21.15	14.67
Sugars (%)	4.41	7.25	9.46	–
Starch (%)	37.42	–	–	–
Saturated fatty acids (%)	0.193	0.382	0.179	0.221
Monounsaturated fatty acids (%)	0.145	0.177	0.069	0.058
Polyunsaturated fatty acids (%)	0.993	0.422	0.344	0.131
Calcium (mg)	167	145	90.17	76.25
Cooper (mg)	0.949	–	–	–
Iron (mg)	6.24	7.41	8.36	5.75
Magnesium (mg)	199	208	249	147
Manganese (mg)	1.613	–	–	–
Phosphorus (mg)	463	403	428	440
Potassium (mg)	1348	1370	1919	1449
Sodium (mg)	5.69	16.49	20.04	5.78
Zinc (mg)	4.15	2.95	3.15	5.82
Vitamin A (IU)	0	114	–	17
Thiamine (mg)	0.882	0.683	0.564	0.526
Riboflavin (mg)	0.186	0.256	0.225	0.254
Niacin (mg)	2.489	2.475	1.711	3.038
Pantothenic acid (mg)	0.846	–	–	–
Vitamin C (mg)	–	5.28	–	0
Folate total (mg)	0.414	0.687	0.440	0.718
Vitamin B6 (mg)	0.487	0.420	0.570	0.405
Choline total (mg)	99.4	–	–	–
Betaine (mg)	0.113	–	–	–
Tocopherol total (mg)	2.5	0.56	0.80	–

Note: All values are given per 100 g of raw seed on dry basis. *Values for minerals and vitamins higher than 0.1 mg. Data marked as (–) were not available (USDA, 2011).

are cooked (Carvalho et al., 2012). Table 2 shows the nutritional composition of different types of beans.

Raw beans contain several antinutritional components that may limit their consumption. The adverse effects include growth inhibition, low nitrogen balance, decreased intestinal absorption of sugars and amino acids, and an altered immune response. Among the antinutritional substances are phenolics trypsin inhibitors, lectins, phytates and non-digestible oligosaccharides (Valle-Vega & Lucas-Florentino, 2000). However, paradoxically, low concentrations of some antinutritional factors exhibit nutraceutical effects.

Beans require relatively long cooking to soften the tissues, be palatable and reduce antinutritional factors. During cooking, several physicochemical changes occurring in the dietary fibre cause solubilization and degradation of pectic polysaccharides. Such changes can improve the hypocholesterolemic or glycemic response during intestinal transit. Complex changes have been observed in dietary fibre due to thermal processing of beans, which depends on the cultivar and the processing method (Tiwari, Gowen, & McKenna, 2011). Phytic acid is reduced after the process of steeping, germination and heat, which promotes increased extractability and mineral bioavailability (Carvalho et al., 2012). Extrusion cooking is a processing method widely used to improve the nutritional value of legumes; mainly in order to decrease heat labile antinutritional compounds. The protein content does not appear to be affected by this treatment (Marzolo, Amigo, & Nervi, 1993).

Lectins can bind to intestinal epithelium and interfere with the absorption of nutrients. Bean lectins are inactivated by cooking for at least 15 mins at atmospheric pressure or under pressure for 7.5 mins (Lajolo & Genovese, 2002). It has been found that neither dry heat nor conventional microwave ovens are effective in destroying common bean lectins (González de Mejía & Prisecaru, 2005). Temperature is also an important factor for phenolic stability. It should be noted that the processes of soaking, mashing or cooking could affect the content of phenolic compounds in beans (Rocha-Guzmán et al., 2013).

3. Beans and chronic degenerative diseases

Chronic diseases can be defined as disorders which last for a long time and progress slowly such as heart disease, infarcts, cancer, pulmonary diseases and diabetes. These diseases are the main causes of mortality in the world, accountable for 63% of deaths (WHO, 2013). Bean consumption has been related to numerous health benefits, such as a decrease in cholesterol levels and cardiac diseases. Beans also offer some protection against cancer, diabetes and obesity, because of their antioxidant, antimutagenic and antiproliferative properties is shown in Table 3 (Campos-Vega, Loarca-Piña, & Oomah, 2010; Paredes et al., 2009).

3.1. Antioxidant and anti-inflammatory effects

Antioxidants, such as flavonoids, phenolic acids, total phenolic compounds and tannins can terminate oxidative chain reactions by eliminating free radical intermediaries and inhibiting other oxidation reactions (Jeon, Han, Lee, Hong, & Yim, 2012; Paredes et al., 2009). Bean seed colour is determined by the presence of phenolic compounds, principally flavonoids, such as flavonol glycosides, anthocyanins and condensed tannins (proanthocyanidins). However, the most widespread flavonoid group in beans are proanthocyanidins (Reynoso-Camacho et al., 2006).

The Wight (adzuki bean) (*Phaseolus angularis*) is used in traditional Asian medicine for infections, edema and inflammation of the joints, appendix, kidneys and bladder. Ethanolic extracts of *Phaseolus angularis* can suppress prostaglandin E2 and nitric oxide release in lipopolysaccharide (LPS) induced macrophages in a dose-dependent way, with inhibition of nuclear factor NF-κB and activator protein (AP)-1 response (Yu et al., 2011). Also, the extract of this bean has an inhibitor effect on malonaldehyde formation.

The seeds of *Phaseolus calcaratus* Roxburgh (PHCR) have been used as herb remedies because of their anti-inflammatory potential. Extracts obtained from this bean suppress nitric oxide production, iNOS and COX-2 expression, and TNF-α and IL-6 secretion almost completely in LPS-stimulated cells. In addition, the extract which contained more phenolic compounds with antioxidant potential against DPPH and hydroxyl radicals, exhibited anti-inflammatory potential on LPS-stimulated macrophages through down regulation of ERK/p38 and NF-κB mediated signaling pathways (Fang et al., 2011).

3.2. Hypolipidemic effect

Dyslipidemias are an important risk factor for coronary artery disease. Insulin resistance, a consequence of increased triglyceride and low-density lipoprotein cholesterol (LDL-C) in plasma and decreased high-density lipoprotein cholesterol (HDL-C), is an important risk factor for peripheral vascular disease, stroke and coronary artery disease (Jellinger et al., 2012).

Dietetic fibre can be defined as a heterogeneous group of non-digestible compounds, including fibre (soluble and insoluble), resistant starch and oligosaccharides, such as raffinose, estachyose and mullein, among others. The common bean (*Phaseolus vulgaris* L.) mostly consumed in Latin America has a high fibre content (Cruz-Bravo et al., 2011). Levels of Cholesterol 7-α-hydroxylase on rats fed with a pancreatin resistant fraction prepared from kintoki beans (*Phaseolus vulgaris*) were significantly higher compared to those of rats on a cellulose diet. It also increased intestinal content viscosity and decreased bile acid absorption in the small intestine (Han et al., 2004). It has been shown that long-term feeding with beans decreases cholesterol and low-density lipoprotein (LDL) serum levels in humans, so it seems likely that it can offer protection against cardiovascular diseases (Marzolo et al., 1993). The fibre isolated from *Phaseolus mungo* showed a neutral detergent residue (NDR). It has significant cholesterol lowering activity and increased bile acid excretion in faeces (Thomas, Leelamma, & Kurup, 1983).

3.3. Effects on obesity and diabetes

Hyperglycemia in type 2 diabetes mellitus (DM2) correlates with endothelial dysfunction and an increase in the intima-media thickness, as well as with a greater prevalence of atherosclerotic plaques. This is related to an increase in oxidative stress with platelet activation, thrombin production and low-density lipoprotein oxidation which increase the risk of cardiovascular diseases related to DM2 (Barrett & Udani, 2011). The oral administration of a *Phaseolus vulgaris* ethanolic extract (200 mg/kg of body weight) for 45 days to streptozotocin-induced diabetic rats significantly decreased tiobarbituric acid and hydroperoxide reactive substances. The extract caused a significant increase in reduced glutathione, superoxide dismutase, catalase, glutathione

Table 3. Beans antinutritional factors and their nutraceutic effects.

Tabla 3. Factores antinutrícios del frijol y sus efectos nutracéuticos.

Phytochemical	Antinutritional effects	Beneficial effects	References
Lectins	Weight loss or reduce weight gain, atrophy of certain organs, fatty liver and other histological injuries. They are able to survive passage through the gastrointestinal tract.	Appetite lowering effect, cholecystokinin and glucagon-like peptides secretion. Effects on cellular regulation (agglutination or cellular aggregation); apoptosis induction/cell cycle interruption; down regulation of telomerase activity and angiogenesis inhibition. Oral administration of low doses of lectins may have beneficial effects on the efficiency of digestion and intestinal absorption, immune response and bacterial flora. Target diseases: Obesity, cancer, and immune system.	Carai et al. (2009), Ferriz-Martínez et al. (2010) and references therein García-Gasca et al. (2012)
α-amylase inhibitor and glycosidase inhibitors.	Interfere with starch and complex carbohydrate breakdown reducing digestibility	Hypoglycemic effect. Postprandial response to insulin lowering effect. Target diseases: being overweight, obesity, diabetes	Celleno et al. (2007), Obiro et al. (2008), Carai et al. (2009), Preuss (2009)
Protease inhibitors	Proteolytic activity inhibition of proteases. Interfere with protein digestion or absorption and utilization of amino acids and other nutrients.	Effect on proteolytic enzymes, cell proliferation and survival, invasion metastasis. Target diseases: Cancer, HIV	Castro-Guillén et al. (2010) and references therein García-Gasca et al. (2012) Chan et al. (2013)
Flavonoids: flavonol glycosides, anthocyanins and condensed tannins.	Tannins antinutritional effects relate to the decrease in food intake, the formation of complexes with proteins in the diet and other food components, inhibition of digestive enzymes, the increase in the excretion of endogenous protein.	Oxidation inhibition. Suppression of prostaglandin E2, nitric oxide release, and TNF-α and IL-6 secretion. Inhibition of nuclear factor NF-κB and activator protein (AP)-1 response. Increase in GSH, SOD, catalase, GPx, and GST. Target diseases: obesity, diabetes, cancer	Gupta (1987) Venkateswaran & Pari (2002) Reynoso-Camacho et al., (2006), Paredes, Becerra, & Tay (2009) Fang et al. (2011) Yu et al. (2011)
Fibre (soluble and insoluble), resistant starch and oligosaccharides.	The main cause of flatulence in common beans are resistant starch, oligosaccharides raffinose family and dietary fibre components.	Cholesterol, triglyceride and LDL lowering activity; increased bile acid excretion in faeces. Target diseases: hypercholesterolemia, cardiovascular diseases, cancer, diabetes, constipation	Marzolo et al. (1993) Han et al. (2004) Reynoso-Camacho et al. (2007) Vergara-Castañeda et al. (2010)
Phytates	Interaction with proteins; inhibition of digestive enzymes and chelation of dietary minerals. Decreasing essential element bioavailability, such as calcium, iron, magnesium and zinc.	Induction of cell differentiation. Target diseases: cardiovascular diseases, cancer	Kigel (1999) Campos-Vega et al. (2010) and references therein Martínez Meyer, Rojas, Santanen, & Stoddard (2013)

peroxidase, and glutathione-S-transferase in the liver and kidneys. The extract was more effective than glibenclamide in diminishing glucose levels (Venkateswaran & Pari, 2002).

The *in vivo* effect of a supplemented diet with black bean flour on rats with streptozotocin-induced diabetes was evaluated. The treated group showed significantly decreased glucose (22.8%), triglyceride (21.9%), total cholesterol (29.9%) and LDL (56.1%) levels. Before diabetes induction, the bean flour diet did not have a protective effect on glucose levels, but showed a decrease in total cholesterol (47.5%) and LDL (56.1%) levels. The treated group showed inhibition of TNF-α and IL-1β elevation, compared to the diabetic control group (Hernández-Saavedra et al., 2013).

Starch in beans is slowly digested and attenuates postprandial response to insulin (Feregrino-Pérez et al., 2008; Hangen & Bennink, 2002). The α-amylase inhibitor isoform 1 (α-AI1) has been extracted and used in diverse commercial products against obesity and diabetes in humans (Barrett & Udani, 2011; Celleno, Tolaini, D'Amore, Perricone, & Preuss, 2007; Obiro, Zhang, & Jiang, 2008). Epidemiological studies have linked bean consumption with a lowered risk of being overweight or obese. In US adults, bean consumers presented 23% lower risk of obesity, and lower systolic blood pressure. Studies of Brazilian adults indicate that a regular diet including beans correlates with a lower risk of being overweight and obese, both in men (−13%) and women (−14%) (Nilsson, Johansson, Ekström, & Björck, 2013). In addition, there is evidence that a bean extract used by humans lowers body weight, percentage of fat and waist and hip circumference (Preuss, 2009).

P. vulgaris extract, prepared to contain α-amylase inhibitors and phytohemagglutinin, was compared to a standard medication with metformin in adult male Wistar rats. It was observed that *P. vulgaris* extracts reduced postprandial glycemia in a similar way as metformin. The proposed mechanism of action comprises the union of phytohemagglutinin to gastric epithelial cells and to the small and large intestine brush border membrane, which causes cholecystokinin and glucagon-like peptides secretion, two hormones that have an important role in digestive processes and central control of appetite. The treatment with the cholecystokinin receptor antagonist type A (CCKA), lorglumide, blocked the lowering effect of the *P. vulgaris* extract over food ingestion in rats, suggesting the *P. vulgaris* appetite lowering effect (Carai et al., 2009).

3.4. Beans and cancer

Epidemiological studies have found that beans and legumes consumption relates to a lower risk of breast cancer (Velie et al., 2003). The Four-Corners Breast Cancer Study informed a relationship between bean consumption and lower risk of breast cancer. It showed that breast cancer incidence among Hispanic women, who ate native Mexican diet (characterized by a high consumption of pulses, such as beans), was two thirds the incidence of breast cancer among Caucasian non-Hispanic women, whose diet was characterized by an elevated intake of meat, sugar and processed foods (Murtaugh et al., 2005).

Other epidemiological and preclinical studies evaluating colon and prostate cancer have provided additional evidence about an inverse relationship between bean consumption and cancer development (Monroe et al., 2003; Thompson et al., 2012). Colorectal cancer is the second principal cause of death related to cancer in developed countries. Studies for its detection have not diminished the incidence or the mortality of this disease, so the interest has focused on preventive strategies focused on life style interventions (Derry, Raina, Agarwal, & Agarwal, 2013). Epidemiological evidence suggests a protective effect of dietary fibre against colorectal cancer. It has been reported that rats with induced colon cancer and fed with pinto, black and white beans developed four times fewer tumours compared to rats not fed with beans (Reynoso-Camacho et al., 2007).

Black and Bayo cultivars of common beans contain fermentable substrates with a non-digestible fraction that prevents early and advanced development of colon cancer through gene modulation and apoptosis, proliferation, cell cycle interruption and inflammation related proteins (Cruz-Bravo et al., 2011). The cooked Bayo Madero variety of *Phaseolus vulgaris* L. and its non-digestible fraction suppressed aberrant foci formation in distal intestinal crypts and reduced β-glucuronidase activity in fecal, cecal and colonic content, on early stages of azoxymethane-induced colon cancer in rats (Vergara-Castañeda et al., 2010).

A combination of resistant starch and fermentable fibres causes high concentrations of short chain fatty acids in the distal colon. Butyrate has physiological relevance for the colonic epithelium because it enforces normal mucosa proliferation, and it has been demonstrated that it induces growth interruption, apoptosis and differentiation of diverse cellular lines of colon cancer. Besides, it can exert its effect through hystone hyperacetylation, up regulation of p21WAF1 and down regulation of epidermal growth factor receptor (Campos-Vega et al., 2009; Feregrino-Pérez et al., 2008; Hangen & Bennink, 2002). Human intestinal flora fermentation products of the non-digestible fraction of cooked beans inhibited HT-29 cell growth and modulated apoptosis-related protein expression, cell cycle interruption and proliferation, as well as morphologic changes associated to apoptosis (Campos-Vega et al., 2012).

On the other hand, it is known that proteolysis is part of the complete process of cancer development, progression and metastasis. It affects extracellular matrix degradation, causes changes in adhesion, migration, invasion and chemical modification of the environment, including growth factor production. Protease inhibitors (PI) are proteins that regulate the hydrolytic activity of proteolytic enzymes. The balance between proteases and PI is necessary for cellular homeostasis, so, if this balance is broken, pathologic processes such as cancer are likely to develop (Castro-Guillén, García-Gasca, & Blanco-Labra, 2010). A PI found in the protein fraction of tepary bean seeds (*Phaseolus acutifolius*) could affect transformed 3T3/*v-mos* fibroblasts' proliferation and metastasis, and affect cellular survival and proliferation, and restore partially adhesion patterns of the transformed fibroblasts (García-Gasca, Garcia-Cruz, Hernández-Rivera, López-Martínez, Castañeda-Cuevas, Yllescas-Gasca, Rodríguez-Mendez, Mendiola-Olaya, Castro-Guillen, & Blanco-Labra, 2012; Osman, Reid, & Weber, 2003). Another PI of *Phaseolus vulgaris* seeds inhibited MCF-7 breast cancer cells' proliferation and showed slight inhibition of proliferation of hepatoma HepG2 cells and embryonic hepatic cells WRL68 (Chan, Zhang, & Ng, 2013).

Bean lectins are proteins or glycoproteins that possess at least one non-catalytic domain which reversibly bind to mono- or oligo-saccharides. These proteins have demonstrated antitumour, immunomodulatory, antimycotic, antibacterial and anti-HIV activities (Sharma, Ng, Wong, & Lin, 2009). Binding between lectins and cellular surface molecules or by their cellular internalization implies varied important signals for cellular regulation, such as agglutination or cellular aggregation; apoptosis induction or cell cycle interruption; down regulation of telomerase activity and angiogenesis inhibition (Ferriz-Martínez, Torres-Arteaga, Blanco-Labra, & García-Casca, 2010). Lectins of *P. vulgaris* and *P. acutifolius* exhibit differential cytotoxic effect over diverse cancer type cells by apoptosis induction (Chan, Wong, Fang, Pan, & Ng, 2012; García-Gasca et al., 2012; Valadez-Vega et al., 2011).

4. Concluding remarks

Modern life-styles induce people to change eating habits by increasing high caloric density food intake. High glycemic index and high fat foods, mainly from processed and simple sugar derived products, increase risks of chronic diseases. Intake of pulses, particularly beans, has been diminishing during the last few years. Scientific evidence shows that this vegetal food group is not only important due its nutritional contribution, but also because its consumption is related to a lower risk of developing important chronic non-transmissible diseases. *Phaseolus* has several beneficial biological activities in humans, as an antioxidant source, cholesterol- and low-density lipoprotein-lowering properties, antimutagenic and anticancer effects as well as effects on cardiovascular disease, diabetes and obesity. It is important to make efforts to increase consumption of beans and take advantage of the benefits. Ongoing research of several groups worldwide will continue to explain the biological mechanisms by which beans carry out all those properties and others. On the other hand, beans could be a good source of nutraceuticals for human supplementation, mainly compounds that disappear with cooking conditions but exhibit important biological activity.

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