Bioactive components in common beans (*Phaseolus vulgaris* L.)

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Abstract

The consumption of dry common beans (*Phaseolus vulgaris*) has been associated with a decrease risk for a wide variety of chronic and degenerative diseases such as cancer, obesity, diabetes and cardiovascular diseases. Beans are considered as a good source of high protein content, complex carbohydrates, dietary fiber and some vitamins and minerals. In addition to these nutritional components, common beans are rich in a variety of several phytochemicals with potential health benefits such as polyphenolic compounds, fiber, lectins and trypsin inhibitors, among others. Therefore, the scope of this chapter is to review the...
role of some bioactive compounds present in common beans (*Phaseolus vulgaris*) related with a substantial decrease in chronically-degenerative diseases.

**Introduction**

Based on the archeological, historical, linguistic and botanical evidences, the origin and domestication of common bean (*Phaseolus vulgaris*) has been established in America (1-3).

Dry common bean (*Phaseolus vulgaris* L) is a legume widely consumed throughout the world and it is recongized as the major source of dietary protein in many Latin-American and African countries (4). A large variability exists in common bean seeds; color and size are two important quality characteristics for the consumers. Seed size and weight depend on genetic variations, cultivar and environmental conditions (5). The seed color of beans is determined by the presence and concentration of flavonol glycosides, anthocyanins, and condensed tannins (proanthocyanidins) (6-10). Recently, common bean is gaining increasing attention as a functional or nutraceutical food, due to its rich variety of phytochemicals with potential health benefits such as fiber, polyphenolic compounds, lectins, unsaturated fatty acids, trypsin inhibitors, phytic acid, among others (11). Important biological activities have been described for fiber, polyphenolic compounds, lectins, trypsin inhibitors, and phytic acid from common beans like enhancement of the bifidogenic effect (12); antioxidant (13-15); antimutagenic (16, 17); anticarcinogenic (18) effects; as well as an antiproliferative effect on transformed cells (19).

**Polyphenols**

The seed color of beans is determined by the presence of polyphenolic compounds. The main polyphenolic compounds are flavonoids such as flavonol glycosides, anthocyanins, and condensed tannins (proanthocyanidins), however the most widely distributed group of flavonoids in beans includes proanthocyanidins (6, 9, 10, 16, 17, 20). Figure 1 shows the chemical structure of some polyphenolic compounds present in common beans (*Phaseolus vulgaris*). The presence of anthocyanins has only been reported in black and blue-violet colored beans (6, 10, 21). On the other hand, proanthocyanidins have been detected in different varieties of common bean (9.4-37.8 mg catechin equivalents per g), mainly in the seed coat (6, 9, 16, 20, 22); however, there is relatively little comprehensive research on the proanthocyanidin profile present in beans. Gu *et al.* (7, 8) identified heterogeneous B-type proanthocyanidins containing (epi)afzelechin as subunits in pinto beans by using electrospray ionization (ESI) mass spectrometry high-performance liquid chromatography. Aparicio-Fernández *et al.* (10), using also electrospray
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.

The biological activity of flavonoid compounds from beans has been reported in vitro as well as in vivo. For instance, the antioxidant activity has been evaluated using different methods and different common bean (Phaseolus vulgaris L) cultivars. Tsuda et al. (23) reported the antioxidant activity of trifluoroacetic acid (TFA)-ethanolic extract from red and black seed coat bean (Phaseolus vulgaris L), using the linoleic acid system and different pH conditions. For example the RPO (cyanidin 3-0-P-D-glucoside) extract showed strong antioxidant activity in the linoleic acid system at neutral condition (pH 7.01), while the RP1 (pelargonidin 3-0-P-D-glucoside) and the BP1 (delphinidin 3-0-P-D-glucoside) extracts exhibited no antioxidant activity at pH 7.0. However, RP1 and BP1 showed a strong antioxidant activity in acidic conditions (pH 3.0 and 5.0, respectively), suggesting that the antioxidant capacity is chemical-structure dependent. By using a fluorescence assay with liposomes and 3-[4-(6-phenyl)-1,3,5-hexatrienyl]phenylpropionic acid, Beninger and Hosfield (6) showed that pure flavonoid compounds such as anthocyanins, quercetin glycosides and protoanthocyanidins (condensed tannins), present in the seed coat methanol extract and tannin fractions from 10 colored genotypes of common bean Phaseolus vulgaris, all displayed antioxidant activity, while the highest activity was obtained with extracts rich in condensed tannins. Cardador-Martínez et al. (13) studied the antioxidant potential of a methanolic extract as well as the ethyl acetate/acetone and acetone fractions from common beans (Phaseolus Vulgaris cv. Flor de Mayo FM-38, red seed coat), using the β-carotene-linolate and the 1,1-diphenyl-2-picrylhydrazyl (DPPH) in vitro model systems. In this study, the antioxidant activity correlated with the polyphenolic content in a dose-dependent manner. On the other hand, using the oxygen radical absorbance capacity (ORAC) assay with fluorescein as the fluorescent probe and 2,2'-azobis(2-amidinopropane) dihydrochloride as a peroxyl radical generator, the antioxidant capacity of over 100 common food items and vegetables was examined, and among these, colored beans (black, navy, pinto, red kidney and small red) showed a high antioxidant capacity (15).

**Lectins**

Lectins are part of a major group of bioactive proteins found in almost all organisms, including plants, vertebrates, invertebrates, bacteria and virus, with
important biological activity (24). Lectins are glycoproteins and constitute a heterogeneous group of proteins, often resistant to proteolysis in the gastrointestinal tract and with the ability to agglutinate erythrocytes of some blood types in vitro (25). Lectin content in legumes is in the range of 5% to 20% (26-30). Lectin activity (LA) is commonly expressed as the maximal geometric dilution in which visible macroscopic hemagglutination is observed (HAU/g sample). Barampara and Simard (31) reported lectin content for four varieties of dry beans *Phaseolus vulgaris* L (A321, A410, Calima and Dore de Kirundo) cultivated in different regions, with hemagglutinin activity units (HAU) from 0.42 to 8.89 HAU/g (average 2.15 HAU/g). The authors suggested that variability in hemagglutinin activity can be influence by the variety as well as locality growing conditions. De Mejia *et al.* (20) studied the lectin content of five popular cultivars of common beans (*Phaseolus vulgaris* L) 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). Beans were cultivated at five different semi-arid highlands of Mexico (Aguascalientes, Chihuahua, Durango, Guanajuato and Jalisco) and the results
showed that Bayo Victoria and Durango beans had the highest LA, 2-3 fold content of LA reported for soy beans; the average LA was in the range 0.5 HAU/g to 3.1 HAU/g sample. Moreover, common beans (*Phaseolus vulgaris*) showed a significant higher lectin activity (8573 HAU/ mg protein) than tepary beans (*Phaseolus acutifolius*). Furthermore, there was no statistical differences among the cultivars of tepary beans tested (white: L-246-12, G-400-16, PI-246-22, L-246, L-173 and PI-319-443; black: L-242-45 and L-246-19; and brown: L-179), except for the L-173 white bean (5).

Lectins are known to be heat sensitivity, therefore different technological processes have been developed to inactive them, such as the traditional or home cooking, autoclaving, extrusion, toasting and microwave. Paredes-López (32) studied the LA and the thermal inactivation in two cultivars of *Phaseolus vulgaris*, wild variety Flor de Mayo FM-C and the genetically improved FM-RMC, resistant to the common mosaic virus and bean rust (*Uromyces phaseoli*). FM-RMC cultivar showed a higher level of LA than FM-C; however, the thermal hemagglutinin inactivation of the raw bean extracts showed a biphasic pattern for both cultivars. Carbonaro et al. (33) studied the *in vivo* protein digestibility and some antinutritional compounds (PHA and TI) of raw and cooked common bean (*Phaseolus vulgaris* L). The *in vivo* digestibility of proteins of raw common bean flour was 72.4% and not significantly improved after cooking and the HUA in the seed was almost completely abolished with thermal treatment (820 HUA to 3.2 HUA). Comparative effects of the extrusion cooking and conventional processing method on the hemagglutinin activity levels in *Vicia faba* and *Phaseolus vulgaris* variety Athro-purpurea was studied by Alonso et al. (34). According to their results, extrusion was the best method to abolish the hemagglutinating activity without modifying the protein content. On the other hand, microwave heating of common beans (*Phaseolus vulgaris*) failed to destroy hemoagglutins and trypsin inhibitors (35). Moreover, extrusion cooking reduced LA in common bean (*Phaseolus vulgaris* L. var. Pinto), as well as other antinutritional agents (phytic acid, condensed tannins, and trypsin, chymotrypsin, and α-amylase inhibitors). However, the protein content was not affected but improved the food intake and utilization by the animal model (rat) as they gained more weight during the experimental period (36).

On the other hand, the chemical modification of two fractions with agglutinating activity (F-I and F-II) isolated from *Phaseolus vulgaris* variety Jalo, showed that F-I fraction had a higher agglutinating activity and toxicity than F-II fraction. However, after the modification of some amino groups, like oxidation of tryptophan, both fractions lost their agglutinating activity and maintained their toxicity after modification amino groups. (37).

Important biological activities *in vitro* and *in vivo* have been described for the phytoemagglutinin (PHA) from common beans (*Phaseolus vulgaris*). For
instance, Jankovic and Kosanovic (38) used the PHA to detect alterations of urinary prostate-specific antigen (PSA) from benign prostatic hyperplasia (BPH) and prostate cancer (PCa) human samples. In this study, isoforms of urinary PSA from BPH and PCa showed different elution profiles from lectin-affinity columns (package with Phaseolus vulgaris erythroagglutinin and leukoagglutinin) as a result of molecular heterogeneity of PSA, suggesting that differences in the lectin reactivities between BPH-PSA and PCa-PSA may be of clinical importance in the evaluation of prostate health. Gonzalez de Mejia et al. (5) reported that PHA from common bean (Phaseolus vulgaris Flor de Mayo cultivar) and tepary beans (Phaseolus acutifolius, white: L-246-12, G-400-16, PI-246-22, L-246, L-173 and PI-319-443; black: L-242-45 and L-246-19; and brown: L-179 cultivars) inhibited the viability on rat epithelial cells (expressed as percent of cellularity) and it was significantly different among protein extracts from different bean cultivars. Common bean extract showed the lowest cytotoxicity (87.4% cellular viability), while the effect of tepary bean extracts on cellular viability was divided into two groups: L-242-45, G-400-16, L-179, and L-173 cultivars with intermediate cytotoxicity (53.5% to 59.7%) and L-246, PI-246-22, L-246-19, and L-246-12 cultivars with high toxicity (63.9%–76%). The relationship between lectin-cell binding and lectin toxicity was evaluated in a human colon cancer cell line CCL-220/Colo320DM and in a non-cancer human colon cell line CRL-1459/CCD-18Co (39). In this study, the human colon cancer cell line CCL-220/Colo320DM bound to agarose beads conjugated with the Phaseolus vulgaris leukoagglutinin (PHA-L), while the non-cancer human colon cell line CRL-1459/CCD-18Co did not. Moreover, the effect on cell viability was also higher in cancer cells than normal cells in a dose-response manner.

On the other hand, Welty et al. (40) developed and reported a novel histochemical assay using derivatized agarose beds (lectins from wheat germ agglutinin WGA, Phaseolus vulgaris agglutinin PHA and Lens culinaris agglutinin) to study the surface properties of various cell types (both malignant and their non-malignant counterparts), as well as a new fluorescence assay to detect lectin binding. The results showed that CCL-220 colon cancer line had more bound-specific lectins than CRL-1459 non-cancer colon cell line, whereas the qualitative and quantitative fluorescence assays correlated well with the bead assay. The results also showed that the fluorescence assay detected lower lectin-binding ligand levels than that of the bead assay, suggesting the use of this assay for initial screening studies to identify cells that are rich in surface binders receptors or ligands.

Alternatively, the incorporation of phytohemagglutinin (PHA) from raw kidney beans (Phaseolus vulgaris Processor cultivar) into the diet diminished markedly the growth of a murine non-Hodgkin lymphoma tumor in mouse, either as an intraperitoneal ascites tumor or as a solid subcutaneous tumor.
The reduced rate of growth occurred in a dose-dependent manner. It has been suggested that lectins have a competitive effect between the gut tissue undergoing hyperplasia and tumour development for nutrients (including polyamines) from a common body pool (40-44). The role of polyamines on tumour development was demonstrated by Bardocz et al. (45), where the number of Krebs II tumour cells recovered from ascitic fluid of mice fed with PHA diet was three times lower than the control animals, and there was an apparently inverse relationship between the total tumour cells count and the intracellular content of putrescine, spermidine and spermine.

**Trypsin inhibitors**

Although trypsin inhibitors (TI) in common beans (*Phaseolus vulgaris*) are protease inhibitors that are considered as antinutritional factors, to our knowledge there is no scientific evidence about their role in human health benefits. Most of the biological benefits are reported for other legumes such as soybean, lentil, and tepary beans (*Phaseolus acutifolius*).

The content of trypsin inhibitors in different cultivars of common bean (*Phaseolus vulgaris*) depends of the genotype, growing site and/or environmental conditions. For instance, Barampama and Simard (31) reported four varieties of dry beans, *Phaseolus vulgaris* (A321, A410, Calima and Dore de Kirundo), grown in four different areas of Burundi, Africa, in the range of 4.7 trypsin units inhibitor (TUI) to 27.8 TUI/mg dried bean with an average 15.2 TUI/mg dried bean, suggesting that variability can be influence by the variety as well as locality growing. Whereas, Sotelo et al. (46) 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 the cultivated beans did (21 TUI per mg). De Mejia et al., (20) 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 (*Phaseolus vulgaris* L) 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. (5) reported 27 TUI/mg for the Flor de Mayo cultivar. The authors attribute the differences to the effects of the genotype, growing region, or the use of different analytical methods. The antinutrient (raffinose oligosaccharides, tannins, phytic acid and trypsin inhibitors) composition and the *in vitro* protein digestibility of eight improved varieties of *Phaseolus vulgaris* grown in Ethiopia were determined by Shimelis and Rakshit (47). These authors found that the TI mean value was 28.68 TUI/mg, and the statistical analyses of data revealed that antinutritional factors and protein digestibility were influenced by variety (genotype).
Trypsin inhibitors, as other anti-nutritional factors in common beans, are heat sensitive and some different technological methods have been development to inactive them, such as the traditional or home cooking, autoclaving, extrusion, toasting and microwave. For example Sayeed and Njaa, (48) showed that the Bangladeshi home cooking on common beans (*Phaseolus vulgaris*) white navy pea, black turtle and Michigan small varieties) reduced the TUI/mg dry bean, whereas the mean percent inhibition was 23.4 ± 15.5 (range from 52.1 to 4.7 in white navy pea beans and black turtle beans, respectively). After cooking, the highest values were reduced to 7.1 and 3.5, respectively. The effect of cooking was greater when the original inhibition was high than when it was low. Similarly, Carbonaro et al. (33) reported that the thermal process of common beans (*Phaseolus vulgaris* L) decreased the TUI to negligible concentrations after cooking. Alonso et al. (34) compared the effect of extrusion cooking and conventional processing method on protein content and reduction of TI common bean *Phaseolus vulgaris* (Athro-purpurea variety); extrusion was the best method to abolish TUI (3.1 ± 0.24 to 0.43 ± 0.11 TUI mg/dry bean for raw seed and extrusion, respectively) without modifying protein content. Likewise, the extrusion cooking reduced the TUI in *Phaseolus vulgaris* L. Pinto variety 8.1 to 0.5 TUI/mg dry bean (36).

**Carbohydrates**

Carbohydrates constitute the main fraction of grain legumes, accounting up to 55-65% of the dry matter. Of these, starch and non- starch polysaccharides (dietary fiber) are the major constituents, with smaller but significant amounts of mono, di and oligosaccharides (49). These leguminous contain slow digested carbohydrates and high proportion of non-digested carbohydrates (NDC) that might be fermented in the large intestine. Non-digested carbohydrates reaching the colon include mainly resistant starch (RS), soluble and insoluble dietary fiber, and non digestible oligosaccharides (NDO) (50).

The NDC are associated with a low glycemic response, low serum cholesterol levels, and a decrease of colon cancer risk factors (51). The physiological effects of NDC from common beans may be related to colonic fermentation end products, short chain fatty acids (SCFA), such as acetic, propionic and butyric acids, and the content and distribution of SCFA are dependent on the microflora and the carbohydrate substrate at the intestinal tract (52, 53).

Not all of the RS is fermented at the same rate neither produce the same metabolites (54). The physicochemical properties of RS may be of major importance in determining the fermentation pattern. The main classification of RS has been proposed by Englyst *et al.* (55), based on the nature of the starch and on its environment in the food. RS type 1 (RS1) corresponds to physically inaccessible starches, entrapped in the cellular matrix in intact plant cells (56, 57). This kind of starch has been obtained from red kidney bean by boiling the
grain and after milling. The fact that these beans were boiled using a small amount of water (beans-water ratio 1:3, w/v), suggests that some of the RS may be partially ungelatinized starch (RS2), whose crystallinity makes them less susceptible to hydrolysis (55, 58, 50). RS3 includes retrograded starches, which may be formed in cooked foods that are kept at low or room temperature. The consequent reassociation of amylose leads to a semicrystalline structure resistant to hydrolysis, both \textit{in vitro} (59) and \textit{in vivo} (59, 60, 61). Red kidney beans that were autoclaved in excess of water produced retrograded starch, mainly retrograded amylose (50).

Intestinal microflora of rats fed with red kidney beans digests RS1 and RS2 more easily than RS3. Moreover, it also causes an increased in butyric acid concentration in the distal colon compared with diets containing higher proportion of soluble and insoluble dietary fiber and non-digestible oligosaccharides. It has been suggested that RS exerts a sparing effect on dietary fiber on fermentation in the colon, which means that bacteria prefer to ferment RS than to ferment fiber. This kind of bean yielded high percentages (18 %) of butyric acid in the rat caecum (50).

There is evidence to suggest that increased consumption of common beans could help to reduce mortality from colon cancer (62, 63).

In animal studies, consumption of pinto beans in the diet (59%) reduced azoxymethane-induced colon tumor incidence from 50% for the casein control to 24% for the pinto bean group. Fewer tumors per tumor bearing rat were observed in bean fed rats than in casein fed rat (1.0 \textit{vs} 2.5) (64). The dietary fiber present in beans seems to be a good candidate for the anticarcinogenic properties of dry beans, because bean dietary fiber is among the best known sources of insoluble fiber and contains more insoluble fiber than most cereals. Unlike oat bran, dry beans do not significantly increase fecal bile acid concentration. The poorly fermented fibers are good \textit{in vivo} dilutors and may decrease the concentration of carcinogens, pro-carcinogens and tumors promoters in the fecal stream, thus reducing access of these substances to the colonic mucosa (65). Resistant starch also increases fecal bulking and lowers fecal pH (66), factors that are usually considered as markers of healthy colonic mucosa (67).

In attempt to screen several beans cultivated in Mexico with chemoprotective activity against colon cancer, rats were fed a control diet or diets containing 0.43 g/Kg/day (per capita consumption) of colored beans (Negro 8025, Ayocote Morado, Pinto Zapata, and Ayocote Negro) and white-beige beans (Flor de Mayo Anita, Blanco Tlaxcala, and Marcela) 4 wk before, during (8 wk) and 10 wk after treatment with the carcinogen dimethylhydrazine (DMH, 21 mg/kg body weight, 8-weekly subcutaneous injections) and sacrificed at the end of the experimental period. Total tumor multiplicity was significantly lower in rats fed the Negro 8025 bean (1.0), Pinto Zapata bean (0.8) and
Ayocote Morado bean (1.1) diets than in rats fed the control diet (3.0) (Figure 2) (unpublished data).

Similarly, rats fed with diets containing black beans (75%) or navy beans (75%) and treated with the colonic carcinogen azoxymethane, showed a decreased total tumor incidence by 54% and 59%, respectively. Interestingly, the control group ate more, grew faster, and had a higher percent body fat than the rats fed the navy bean or the black bean diet (68).

Epidemiological data have consistently demonstrated a positive relation between increased body size (obesity) and colorectal malignancy. Obesity-induced insulin resistance leads to elevated levels of plasma insulin, glucose and fatty acids. Exposure of colonocytes to heightened concentrations of insulin may induce a mitogenic effect within these cells, producing hyperproliferation; whereas exposure to glucose and fatty acids may induce metabolic perturbations, alterations in cell signaling pathways and oxidative stress (69).

An animal study showed that rats fed with two bean diets (black or navy beans) had butyrate concentrations much greater in the colon contents than in the colon contents from rats fed control diet (68). In animals, diets containing

![Figure 2](image-url)

**Figure 2.** Effect of several bean diets cultivated in Mexico on DMH-induced colon tumors in rats. Male rats (5-6 weeks of age) were administered 0.43 g/Kg/day bean in powdered basal diet 4 weeks before, during (8 weeks) and 10 weeks after dosing with dimethylhydrazine (DMH, 21 mg/Kg, by subcutaneous injection) for 8 consecutive weeks and killed 22 weeks after the initial treatment. Colonic tumors are reported as the number of tumors in the entire group/number of rats at risk at termination of experiment.
high amounts of resistant starch produce significantly higher butyric acid concentration in the distal colon than in the proximal colon; therefore suggesting a greater benefit effect on this area. This is of great importance, because the majority of colonic cancer tumors occur in the distal part of the colon in both human subjects and experimentally induced rodent cancer models (50).

In tumor cell lines, butyrate causes cellular growth arrest (70) and apoptosis (71); regulates expression of proteins involved in cellular differentiation (72) and potentiates the transforming growth factor (TGF-beta) signaling and its tumor suppressor activity (73). In vivo, the resistant starch type 3 (RS3) decreased the number of proliferating cells of animals treated with the colonic carcinogen dimethyldihydrazine and enhanced apoptosis of damaged cells accompanied by changes in parameters of dedifferentiation in colonic mucosa. The results show that this effect is attributed to butyrate concentration in colon (74).

Although butyrate has been studied most extensively, other SCFA are present within the colon, including acetate (C2), propionate (C3), valerate (C5) and caproate (C6), and the relative amounts of each SCFA depend largely upon the type and amount of ingested fiber. Hangen and Bennink (68) demonstrated that rats fed with navy beans (75%) produce more propionate concentrations compare with control rats. On the other hand, it has been shown that propionate caused cell growth arrest and differentiation in human colon carcinoma cells. The magnitude of its effects was associated with a histone hyperacetylation. Hyperacetylation of histones disrupts ionic interactions with the adjacent DNA backbone, creating less densely packed chromatin, or euchromatin, and allowing transcription factors to activate specific gene (75). Butyrate effect on cell proliferation/differentiation may be linked to its ability to induce expression of cyclin D3 and p21 proteins (72).

Several studies indicate that the long-term consumption of a diet with a high glycemic load is a significant independent predictor of the risk of developing type 2 diabetes. More recently, evidence has been accumulating that a low-glycemic index (GI) diet might also protect against the development of obesity and therefore of diabetes (76). The glycemic index (GI) was introduced by Jenkins et al. (77) to express the rise of blood glucose after eating a meal against a standard blood glucose curve after glucose or white bread in the same subject. In this regard, beans have a low GI 20 related to glucose (78, 79, 80), whereas those of rice, whole meal bread and baked potatoes reach 50, 77 and 85, respectively (81). Low-GI diets improved adipocyte insulin-mediated glucose uptake in vitro and was found to be useful in normalizing diet-insulin responses of hyperinsulinaemic subjects (82, 83). The literature suggests that a 10% fall in the GI of a diet would result in a 30% increase in insulin sensitivity.

On the other hand, legumes are characterized by relatively high amylose content and the amylose-amylopectin ratio is an important factor that may
modulate glucose metabolism. Kabir et al. (84) demonstrated that incorporation of starches with different amylose:amylopectin rations (waxy cornstarch, 0.5:99.5%; mung beans, 32:68%) into a mixed meal, the meal with the highest amylopectin starch (waxy cornstarch) showed a higher glycemic response than that of the low amylopectin starch (mung beans). Moreover, the chronic consumption of high amylose foods normalized the insulin response of hyperinsulinemic subjects and even lowered glucose and insulin response curves of normal subjects (82, 85). Low GI starch diet increased maximal insulin stimulated glucose oxidation (percentage of basal values), indicating increased peripheral insulin action and glucose utilization (84).

In the other hand, Tovar et al. (86) demonstrated that the rate of hydrolysis of starch from black beans is markedly slower compared with white bread and tortilla, and this could be related with the RS contents. The RS and predict GI values for bean are higher than those in tortillas, this results can be explained by the crystalline structure exhibited by starch in legume seeds. Starch in leguminous seeds is entrapped in parenchyma cells and swells only partially during cooking. On the other hand, the alpha-amylase cannot easily penetrate within the gelatinized starch granules due to steric hindrance and the physical nature of the leguminous starch (56). These factors result in a restricted enzymatic hydrolysis and therefore a low digestion and absorption of ingested starch (87). Likewise, viscous soluble dietary fibers in beans have been suggested to slow not only digestion but also diffusion of digestion products like glucose.

In type 2 diabetic subjects ingestion of kidney beans resulted in a significantly lower glucose area compared to an ingestion of 50 g of glucose (88). Moreover, the antihyperglycemic effect of Phaseolus vulgaris has been also studied on healthy rabbits. After the intragastric administration of kidney bean (decoction), a 50% dextrose solution was infused subcutaneously. The beans caused a 20.8% decrease in area under glucose tolerance curve, while the drug (tolbutamide) produced a 16.1% decrease (89). The antidiabetic effects of beans could be explained by its fiber contents. In this regard, it is known that fiber slows carbohydrate absorption.

In experimental animals, the administration of blackgram fiber (30 % neutral detergent fiber) diet showed a significant increase in liver glycogen level and reduced hepatic gluconeogenesis (90). These data are consistent with the results obtained in our laboratory with different bean varieties cultivated in Mexico. In a sub-chronic study, Pinto Zapata bean incorporated into the diet (869 mg/kg doses) caused similar glucose levels between diabetic and normoglycemic (126 mg/dl) rats. In addition, the glucose-6-phosphatase enzymatic activity of diabetic rats treated with beans decreased significantly compared with the diabetic control group, suggesting that beans regulate hepatic gluconeogenesis (unpublished data).
Low-GI diets have been shown to reduce fasting triacylglycerol and non-esterified fatty acid concentrations (91, 92). In addition, these diets increase HDL-cholesterol and decrease total cholesterol, while improving *in vivo* and *in vitro* insulin-mediated glucose uptake. Prospective studies have demonstrated that low-GI carbohydrates improve insulin sensitivity in subjects with diabetes, obesity and cardiovascular disease (93).

On the other hand, the inclusion of 450 g baked beans into the daily diet of normocholesterolaemic men resulted in a significant reduction in the mean plasma cholesterol level within 1 week. In contrast, no reduction in plasma cholesterol was observed when 440 g spaghetti with tomato sauce was included in the daily diet of the same subjects for 2 more weeks (94).

The hypocholesterolemic effect of dietary fiber has been attributed to its ability to inhibit intestinal absorption of bile acids and neutral steroids, resulting in greater fecal bile acid and total steroids excretions (95). Buhman *et al.* (96) also demonstrated that feeding high viscous fiber (*Psyllium*) to rats enhanced the hepatic cholesterol 7α-hydroxylase mRNA level, fecal excretion of bile acid and total steroids. RS has the property of gelling and binding bile acids, thus increasing viscosity of intestinal contents and reducing absorption of bile acid from small intestine (97).

A regular intake of beans may contribute to lowering the plasma cholesterol level (98, 94, 99). This effect could be related with the production of SCFA. Propionic acid has a beneficial effect on lipid metabolism. Therefore, it has been proposed that propionate may lower plasma cholesterol concentration by inhibiting hepatic choles terogenesis. On the other hand, butyrate accelerated fecal steroid excretion and therefore decreases plasma cholesterol level (97). These results indicate that consumption of beans has a beneficial effect on lipids metabolism.

**Conclusion**

Common beans (*Phaseolus vulgaris*) have some bioactive components related with health benefits, such as polyphenols, lectins, and carbohydrates; however, there is still more to learn about the mechanism of those bioactive compounds on chronic-degenerative diseases. Undoubtedly, this area of research holds considerable potential on nutraceutical foods.

**References**


