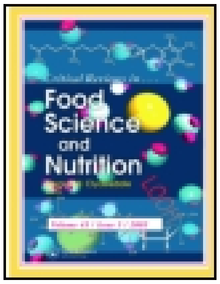

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Nutritional and Health Perspectives of Beans (Phaseolus vulgaris L.): An Overview

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ABSTRACT

Beans, the variants of Phaseolus vulagris , are nutritionally and economically important food crop in each part of the world. Besides providing nutrients such as multifaceted carbohydrates, elevated proteins, dietary fiber, minerals and vitamins, these also contain rich variety of polyphenolic compounds with prospective health benefits. This review mainly focuses the important nutritional aspects of beans as well as their contribution in decreasing the risks of chronically-degenerative diseases.

Keywords Beans, nutrients, antioxidant activity, CVD, diabetes mellitus, cancer

INTRODUCTION

There are about 20 leguminous species which are utilized as dry grains in substantial amounts for human nutrition. (Costa et al., 2006; Lin et al., 2008). In general, grain legumes are considered an essential source of nutrients and are also recognized as poor man's meat (Tharanathan and Mahadevamma, 2003), showing their importance for consumption in the third world countries where protein energy malnutrition often appear as major nutrition problem (Shimelis and Rakshit, 2005). Beans (*Phaseolus vulgaris*) are the member of the Leguminosae, family Phaseoleae, subfamily Papilionoideae (Bressani, 1993; Graham and Ranalli, 1997). Beans have been recognized to be domesticated and originated in America on the basis of chronological, archeological, botanical and linguistic evidences (Gepts and Dpbouk, 1991; Papa and Gepts, 2003; Papa et al., 2005) and now consumed in every part of this globe especially by the people of low income group in the developing countries (Shimelis and Rakshit, 2005). In some areas such as Maxico, south and central American and in Africian countries, these are being consumed as staple foods where per capita intake may extend upto 40 kg per year (Leterme, 2002; Luthria and Pastor-Corrales, 2006). Most oftenly, beans are mainly used as dry seeds but there is possibility of their use as green pods as well as green shelled seeds (Lin et al., 2008). The important classes of dry beans include, haricot beans (Shimelis and Rakshit, 2005), red kidney beans (Choung et al., 2003), black beans (Aparicio-Fernandez et al., 2006), Mexican beans (Hosfield et al., 2004), pinto beans, tirga beans (Amir et al., 2006), great northeren beans, navy beans and pink beans (Kelly et al., 2003; Luthria and Pastor-Corrales, 2006)

Nutritionally, beans are recognized as good source of proteins, which is 2-3 times that of cereal grains, (Siddiq et al., 2010). High dry matter content also contains high amounts of starch, dietary fiber, minerals and vitamins (Kutos et al., 2003; Costa et al., 2006). In addition to these, beans also contain rich variety of phytochemicals, antioxidant activity and an extensive array of flavonoids such as anthocyanins, flavonoids, proanthocyanidins, flavonols, phenolic acids and isoflavones (Beninger and Hosfield, 2003; Choung et al, 2003; Aparicio-Fernadez et al. 2005b; Lin et al., 2008; Granito et al., 2008). The utilization of beans has great association with many physiological and health benefits such as prevention of cardiovascular disease, obesity, diabetes mellitus and cancer (Jenkins, 2007; Chung et al., 2008). This paper envisage the role of beans and their nutrients in human nutrition, their potential health benefits as well as their association with substantial reduction of chronically-degenerative diseases.

BEANS CARBOHYDRATES

Carbohydrates are the major component of beans (*Phaseolus vulgaris*) found in variable amounts, accounting up to 50-60% of the dry matter (Vargas-Torres et al., 2004; Reynoso-Camacho et al., 2006; Ovando-Martinez et al., 2011). Starch and non-starch polysaccharides constitute the major components of these carbohydrates along with considerable amounts of carbohydrate derivates such as oligosaccharides also found (Bravo et al., 1998; Reynoso-Camacho et al., 2006). Carbohydrate contents of different beans varieties are shown in Table 1. Among all carbohydrates, starch is the major carbohydrate found in beans in different shapes and sizes (Table 2). Amylose and amylopectin are the two major forms of starch available in beans. Amylose is a linear molecule with molecular weight varying in the range of 70,000 to 200,000

Da whereas amylopectin is mainly branched and consist of main chains of α (1-4)-D-glucose as well as short chains of (1-6)-α-D-glucose linked branches with molecular weight greater than 2×10^7 Da.(Dona et al., 2010; Hoover et al., 2010). Beans starch can be degraded into oligodextrin and glucose by different enzymes such as α- and β-amylases (Tharanathan, 2002; Zhou et al., 2004). On the basis of their susceptibility to amylose and the rate of glucose release and its absorption in the gastrointestinal tract, starches are classified into several types such as slowly digestible starch (SDS), rapidly digestible starch (RDS) and non-digestible starch (NDS) or resistant starch (RS) (Englyst et al., 1992; Tharanathan and Mahadevamma, 2003; Zhang et al., 2006). The ingestion of rapidly digestible starch results in sudden rise in blood glucose level while slowly digestible starch is entirely digested in the small intestine but at comparatively slower rate than RDS. (Hoover and Ratnayake, 2002; Hoover et al., 2010). A non-digested carbohydrate (NDC) is the fraction of starch that resists hydrolysis by the amylopectic enzymes of the human beings and is referred to as resistant starch (Thompson, 2000). The resistant starch consist of insoluble and soluble dietary fiber as well as non-digestible oligosaccharides, that resist hydrolysis in the small intestine but are fermented by the colonic microflora in the large intestine at varying rates and metabolites (Henningson et al., 2001; Nugent, 2005). The fermentation of resistant starch from common beans results in the production of short chain fatty acids such as acetic, butyric and propionic acids whose concentration and distribution depends upon microflora as well as carbohydrate content in the intestine (Chung et al., 2008; Gidley et al. 2010). On the basis of its nature and environment in the food, the resistant starch can be classified into three main classes (Englyst et al., 1992). Resistant starch type-1(RS1) can not be physically accessed, mostly entrapped in the cellular matrix of the intact plant cell and can be obtained by boiling red kidney beans in a small amount of water after milling suggesting that some of the resistant starch might be partially ungelatinized (Chung et al., 2008). Resistant starch type-2 (RS2) is the starch whose crystallinity makes it less vulnerable to hydrolysis while Resistant starch type-3 (RS3) include retrograded starches formed by subsequent reassociation of the amylose resulting in crystalline structure resistant to hydrolysis, mostly in cooked foods kept at low temperatures (Englyst et al., 1992; Bello-Perez and Paredes-Lopez, 2009). The digestibility of beans starch is much lower than that of cereal starch. Comparative studies on four dry bean and maize starches after 6 hours digestion with porcine pancreatic α-amylase enzyme revealed extent of beans starch hydrolysis in the range from 26-35% as compared to 70% hydrolysis of maize starch (Hoover and Sosulski, 1985). Similarly, Socorro et al., (1989) also found percentage hydrolysis of wheat, corn, rice and black bean starches during 3 hours digestion period to be 75.2%, 74.4%, 75.5% and 49.5%, respectively. Different factors such as amylose/amylopectine ratio, molecular structure of amylopectin, amylose chain length, degree of crystallinity and size of granules might influence the digestibility of starch (Hoover and Sosulski, 1985; Tovar et al., 1992; Chung et al., 2008). High amylose content in beans starch resulting in higher resistant starch (Madhusudhan and Tharanathan, 1995; Tovar and Melito, 1996) as well as protein-starch interactions may account for decreased digestibility (Ovando-Martinez et al., 2011). In addition to this, high fiber content as well as antinutritional factors such as amylose inhibitors and phytate also significantly affect the rate and degree of starch digestibility (Tharanathan and Mahadevamma, 2003; Zhou et al., 2004).

Beans also contain considerable quantities of dietary fiber which consist of edible parts of plant analogous carbohydrates such as cellulose, hemicellulose, pectins, oligosaccharides and lignins, that resist digestion and absorption in the small intestine but are partially or completely fermented in the large intestine, thus imparting various physiological impacts with health implications (Hughes and Swanson, 1989; Hughes, 1991; Costa et al., 2006). Both types of dietary fiber viz soluble and insoluble fiber fractions are well characterized for these beans (Kutos et al., 2003; Shiga and Lajolo, 2006). The insoluble fiber consist of cellulose, hemicellulose, and lignin which primarily improve the movement of material through the digestive system thereby improving laxation while soluble fractions consists of oligosaccharides, glucans, and glactomanan gums that help in lowering blood cholesterol and regulating blood glucose levels (Guillon and Champ, 2002; Tungland and Meyer**,** 2002; Rodriguez et al., 2006). Presence of these fibers in beans is helpful in controlling slow release of carbohydrates during digestion process and is considered valuable in the management of different diseases (Rizkalla et al., 2002; Jenkins, 2007).

BEANS AS A SOURCE OF PROTEINS

Beans are an excellent source of dietary proteins that play an important role in human nutrition by complementing other foods such as wheat and other cereals (Butt and Batool, 2010). Using protein rich beans along with cereals offer best strategy to combat problem of protein malnutrition (Batista et al., 2011). These types of complementary food strategies are in practice in Latin America and Eastern Africa, Brazil and most parts of the Asia (Broughton et al., 2003; Siddiq et al., 2010). In contrast to the protein content of cereals, the protein content in beans is being equal to that of meat, ranging from 20-30% (Table 1) (Genovese and Lajolo, 2001; Costa et al., 2006). Globulins and albumins constitute the major protein fractions in pulse proteins while prolamin and glutelin exist as minor fractions (Adebowale et al., 2007). Contrary to other legume proteins, beans contain high amounts of glutelins (20-30%) versus (7-15%) in other legumes (Seena et al., 2005; Slupski, 2010). Globulins constitute the major fraction in beans proteins consisting of 50-70% of total proteins and are classified into 7S and 11S on the basis of their sedimentation coefficients (Tang and Sun, 2011a). Both 7S and 11S proteins are oligomeric in nature, but 7S proteins showing an ionic strength and pH dependent association-dessociation equilibria while 11S proteins being less susceptible to dissociation except at very low ionic strength and pH (Tang and Sun, 2011b). The 7S fraction also referred to as phaseolin, consisting of 40-50% of the total seed nitrogen whiles the 11S globulin fraction consisting of only 10%. Prolamin and the free amino acid pool are the other nitrogenous fractions of the beans consisting of 2-4% and 5-9%, respectively (Derbyshire et al., 1976; Ma and Bliss, 1978). Phaseolin is a glycoprotein containing neutral sugars mainly mannose and show pH dependent association-dessociation behavior between tetrameric, protomeric and polypeptide forms of the molecule (Tang et al., 2009; Yin et al, 2011). The oligomeric nature of phaseolin showed three polypeptide subunits; α, β, and γ with molecular weights of the subunits ranging from 43-53 kDa. These polypeptides differ in amino acid sequence, molecular weights, isoelectric point and degree of glycosylation (Tang 2008; Tang and Sun, 2011a, Rui et al., 2011). Like other legume proteins, beans proteins also contain greater amounts of essential amino acids including lysine that is deficient in cereal grains. Therefore, beans and cereal proteins are nutritionally complementary with respect to essential amino acids and the combined consumption of beans and cereals alleviates these mutual deficiencies ensuring a balanced diet (Broughton et al., 2003; Iqbal et al., 2006; Slupski, 2010). Essential amino acid composition of different fractions of beans proteins is shown in Table 3.

Digestibility of bean proteins

Unprocessed or untreated beans proteins are greatly resistant to proteolysis in the digestive tract of humans and monogastric animals (Liener and Thompson, 1980; Nielsen et al., 1991). The structural characteristics of different proteins such as presence of high β-sheet structures distinctive for 7S and 11S fractions may cause limited access of the proteolytic enzymes resulting in decreased digestibility (Deshpande and Damodaran, 1989; Yu, 2005). Similarly, other components in proteins such as carbohydrates (glycoproteins) also increase the resistance of proteins to hydrolysis (Deshpande and Nielsen, 1987; Genovese and Lajolo, 1996). In addition to this, improper storage of beans at high relative humidity also reduces the protein digestibility and biological utilization of beans amino acids (Marquez and Lajolo, 1981).

Raw phaseolin is highly resistant to both *in vitro* as well as *in vivo* digestion (Genovese and Lajolo, 1998; Montoya et al., 2006). The low susceptibility of phaseolin to proteolytic enzymes is attributed to glycosylation, rigid and compact structure rich in β-sheets as well as low hydrophilic potential of phaseolin limiting accessibility of the proteolytic enzymes (Deshpande and Damodaran, 1989; Nielsen, 1991). The innermost part of the raw phaseolin is more sensitive to proteolytic enzymes resulting in the generation of non-digestible fragments with molecular weights ranging from 22-33kDa (Jivotovskaya et al., 1996). The raw albumin and glutelin fractions of beans proteins also have low digestibility values ranging from 26-32% and 42%, respectively. (Genovese and Lajolo, 1998). The low digestibility of albumin is due to the presence of high number of disulfide bridges as well as 12% by weight of carbohydrates (Genovese and Lajolo, 1996).

Thermal treatment or excessive heat induces changes in the protein structure that may inactivate antinutritional factors thus increasing the digestibility and biological value of the beans proteins (Marquez and Lajolo, 1981; Nergiz and Gokgoz, 2007). Thermal treatment of phaseolin was reported to increase the rate of both in *vitro* and in *vivo* digestion by 82% and 90%, respectively. Thermal treatment mainly alters the tertiary and quaternary structures of the phaseolin without changing the secondary structure which results in 7-9 fold increase in the hydrophilic surfaces leading to high degree of hydrolysis (Nielsen, 1991; Montoya et al, 2010). There are variable effects of heat treatment on different phaseolin types. Montoya *et al.*, (2008) compared the effects of heat treatment on 43 different phaseolin types and found an increase in the digestibility values ranging from 56-96%, depending upon the phaseolin types. Heat treatment also increases the digestibility of albumin fractions. The digestibility of bean albumin is increased from 13-18% after heat treatment (Rocha et al., 2002; Moreno et al., 2005). There is no significant effect of heat treatment on bean glutelin fraction (Genovese and Lajolo, 1998). For bean legumin or 11S fraction, only α-polypeptides are degraded to some extent while β-polypeptides remain intact even after thermal treatment (Momma, 2006)

LIPID CONSTITUENTS IN BEANS

The lipid content in beans is approximately 2% (Table 1) with valuable composition of exogenic unsaturated fatty acids (Mabaleha and Yeboah, 2004). The major lipid components in beans are phospholipids and triacylglyerols, while minor amounts of diacylglycerols, hydrocarbons, steryl esters and hydrocarbons may also present. These lipids may also take the form of Phosphatidylcholine (PC), phosphatidylethanolamine (PE) and phosphatidylinositol (PI) in beans (Yoshida et al., 2005). Common beans are also considered an essential source of unsaturated fatty acids, comprising of 61% of the total fatty acids with palmitic, oleic and linoleic acids being the dominant fatty acids. Linolenic acid is dominant among unsaturated fatty acid consisting of 43.1% of the fatty acids in beans (Grela and Gunter, 1995). Kidney beans are rich source of poly unsaturated fatty acids consisting of 71.1g/100g while butter beans contain high amounts of saturated fatty acids consisting of 28.7g/100g (Ryan et al., 2007). The lipid content in Adzuki beans mainly consist of phospholipids, triglycerides, as well as steryl esters, hydrocarbons and diglyceroles, with linoleic, palmitic and linolenic acids in the range of 45%, 25%, and 21%, respectively (Yoshida et al., 2008). Saturated fatty acids such as stearic and palmitic acids primarily occupy *sn*-1- or *sn*-3-position whereas unsaturated fatty acid such as linoleic and linolenic acid mainly concentrate in the *sn*-2-position of the triaceylglycerol molecule while oleic acid is uniformly distributed in the sn-1,-2-or -3-position (Yoshida et al., 2005)

MINERALS AND VITAMINS IN BEANS

Beans are an essential source of micronutrients such as minerals and vitamins and considered superior to cereals as a source of micronutrients (Welch et al., 2000). Beans have the highest level of mineral contents than other legumes, and are an important source of iron, zinc, copper, phosphorous and aluminium while other minerals are also found in appreciable amounts

(Broughton et al., 2003; Shimelis and Rakshit, 2005). The level of iron is highest in beans with a range of 62.0-150 μg/g, which is mostly present in nonheme form (Elhardallon and Walker, 1992; Vadivel and Janardhanan, 2000). The levels of zinc, copper, phosphorus and aluminium in different beans varieties are found to be in the range of 10.1-109, 2.8-10.9, 15.8-64.6 and 6.7-14.4 μg/g, respectively (Ojijo et al., 2000; Cabrera et al., 2003; Wu et al., 2005).

Beans are also considered an important source of vitamins and variations in vitamin contents are observed in different classes of beans (Augustin et al., 2000). Beans are good source of folate, tocopherols, thiamine, riboflavin, niacin, biotin and pyridoximine (Broughton et al., 2003; Campos-Vega et al., 2010). Higher amount of folate (400-600 μg) in beans is sufficient to meet 95% of the daily requirement (Kadam and Salunkhe, 1989). Significant variations have been observed in the distribution of tocopherols in different bean cultivars with γ-tocopherols being the dominant followed by δ-tocopherols and very small amount of α- and β-tocopherols (Bauerfeind, 1980). Thiamine, riboflavin, niacin, vitamin B6 and folic acid content of raw beans are in the range of 0.81-1.32, 0.112-0.411, 0.85-3.21, 0.299-0.659 and 0.148-0.676 mg/100g, respectively (Augustin et al., 2000, Campos-Vega et al., 2010).

PHENOLIC COMPOUNDS IN BEANS

Phytochemicals of beans have a great potential as a functional and nutraceutical ingredient possessing both antioxidant and anticarcinogenic properties (Cardador-Martinez et al., 2002b; Dinelli et al., 2006). Phenolic compounds in beans may include variety of flavonoids such as such as anthocyanins, flavonol, proanthocyanoidins, tannins, glycosides as well as wide range of phenolic acids (Beninger and Hosfield 2003; Aparicio-Fernandez et al., 2005b).

Anthocyanins can be characterized only in black and blue-violet colored beans (Romani et al., 2004) while proanthocyanoidins exist in almost all varieties of beans (Guzman-Maldonado et al., 1998; De Mejia et al., 2003). The major amounts of these phenolic compounds reside in the seed coat while cotyledons may also contain these nutraceutical ingredients but only in small amounts (De Mejia et al., 1999). The level of total phenolics is influenced by both genetic and environmental factors (Elizabeth et al., 2007) and is responsible for color of the seed coat due to diversification and variability in the composition of procyanidins, flavonol glycosides and anthocyanidins (Feenstra, 1960).

Initial research work on the separation and extraction of phenolic compounds was started by Feenstra (1960) who primarily focusing on the anthocyanin pigments in the seed coat of dry beans, extracted four pigments such as delphinidin 3-glucoside, petunidin 3-glucoside, malvidin 3-glucoside and 3, 5 –diglucosides from black violet beans. Other researchers also isolated and characterized polyphenols such as anthocyanins, flavonols and tannins from different varieties of kidney beans (Stanton and Francis, 1966; Okita et al., 1972; Deshpande et al., 1982; Deshpande and Cheryan, 1987; Ariga and Hamano, 1990; Tsuda et al., 1994; Guzman-Maldonado et al., 1996; Takeoka et al., 1997; De Mejia et al., 1999). Variations in polyphenolic compounds were observed in different bean varieties. Pinto beans primarily contain kaempferol and its 3-O-glucosides, dark red kidney beans contain diglucosides of kaempferol and quercetin, black beans contain 3-O-glucosides of malvidin, petunidin and delphinidin while light red kidney beans containing traces of quercetin 3-O-glucoside and its malonates (Choung et al., 2003; Lin et al., 2008). Gu et al. (2003) identified heterogeneous B-type proanthocyanidins containing (epi) afzelechin subunit from pinto beans by utilizing electrospray ionization mass spectrometry high performance liquid chromatography. By using same technique, Aparicio-Fernandez et al. (2005b) also identified anthocyanins, flavanol monomers and flavanol oligomers from the seed coat of black jamapa bean. Dinelli et al. (2006) observed variations in the flavonoid content of the Italian beans, ranging from 0.19-0.84g/kg of seed weight with keempferol monoglucoside, kaempferol 3-O-glucoside and kaempferol 3-O-xylosylglucoside being the dominant contents. Luthria and Pastor-Corrales (2006) observed variations in the phenolic acid contents of different bean varieties, being in the range of 19.1-48.3 mg/g, with ferulic acid present at higher levels while *P*-coumaric acid and sinapic acid present at intermediate levels. Boateng et al. (2008) observed proanthocyanidins, gallic acid and flavonoids in different dry bean varieties to be in the range of 0.51-3.13, 3.42-7.21 and 0.61-0.84 mg/g, respectively. Similarly, Ocho-Anin et al. (2010) also evaluated different bioactive compounds such as anthcyanins, catechins, flavonoids, quercetin and tannins in common bean seeds. Recently, Akond et al. (2011) also observed variations in different varieties of common beans with total polyphenol content in the range of 5.87-14.14 mg/g while that of anthocyanins in the range of 0.05-0.47mg/g.

ANIOXIDANT AND ANTIMUTAGENIC ACTIVITY OF BEANS

Phenolic compounds in beans and other plants are gifted to act as antioxidants and antimutagenic agents, since they have the ability to restrain the development of initiating free radical species by chelating metal ions or inhibiting enzymes that are involved in the radical production process (Decker, 1995; Elizabeth et al., 2007). Phenolic compounds restrain the formation of superoxide anion as well as the production of reactive oxygen species by inhibiting key enzymes such as protein kinase, xanthine oxidase, lipoxygenase, cyclyoxygenase, Stransferase, glutathione and NADH oxidase (Cos et al., 1998; Oomah et al., 2010). Moreover, in aqueous and lipophilic phases, these compounds also serve as hydrogen donating radical scavengers (Jovanovic et al., 1994). In addition to this, phenolic compounds are also reported to act as antimutagenic agents by inhibiting the potential mutagens such as aflatoxins, nitroarenes and polycyclic aromatic hydrocarbons (De Mejia et al., 1999; Cardador-Martinez et al., 2002a)

The ability of flavanoids to complex with metal ions plays an important role in their antioxidant activity. There is a specific relationship between flavonod structures and their antioxidant activity as larger the number of hydroxyl groups in the flavanoid nucleus, the greater would be the antioxidant activity (Cao et al., 1997). Flavonoids in dry beans such as quercetins are all glycosylated at the 3-position which greatly reduces their metal complexing ability as the chelation of the 3-hydroxy-4-keto group is the strongest metal complexing group (Letan, 1966). The most imperative structural attribute for antioxidant activity is the B-ring ortho 3′, 4′-dihydroxy orientation. No antioxidant activity was observed in kaempferol 3-O-glucoside having a single B-4-hydroxyl substitution while antioxidant activity was observed in kaempferol 3-O-neohesperidosideing in a 1, 1-diphenly-2-picrylhydrazyl (DPPH) free radical assay (Gamez et al., 1998). A specific relationship also exist between flavonoid structure and their antimutagenic activities, as antimutagenic effect depends up on the position and number of phenoclic hydroxyl groups and blocking of these groups by acetylation or alkylation decreases antimutagenic actvities (Edenharder and Tang 1997; Elizabeth et al., 2007).

The antioxidant activity of flavonoid compounds from beans has been reported both *in vitro* as well as *in vivo* (Beninger and Hosfield 2003; Reynoso-Camacho et al.,2006). Different techniques have been used to evaluate the antioxidant activity from different bean cultivars.

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Tsuda et al (1994) used linoleic acid system at different pH conditions to access the antioxidant activity of triflouroacetic acid-ethanolic extract from black and red beans and observed that cyaniding 3-O-P-D-glucoside extract showed strong antioxidant activity at neutral condition while delphinidin 3-O-P-D-glucoside and pelargonidin 3-O-P-D-glucoside exhibited strong antioxidant activity in acidic conditions, confirming that antioxidant activity is chemical structure dependant. De Mejia et al. (1999) examined the antimutagenic effect of common beans extracts by utilizing *Salmonella typhimurium* and found that inhibitory effects of beans extracts against mutagenecity were dose-dependant. Cardador-Martinez et al. (2002b) studied the antioxidant potential of methanolic, acetone and ethyl acetate/acetone extracts from common beans by utilizing β-carotene-linoleate and 1, 1-diphenyl-2-picrylhydrazyl (DPPH) *in vitro* method system and observed antioxidant activity to be correlated with polyphenolic content in a dose dependant manner. Beninger and Hosfield (2003) evaluated anthocyanins, quercetin glycosides and protoanthocyanidins utilizing fluorescence assay with liposome and 3-[4-(6-phenyl)-1, 3, 5-hexatrienyl] phenylpropionic acid from colored genotypes of common beans and observed high antioxidant activity in all genotypes. In another study, colored beans such as red, black and navy beans showed high antioxidant activity among more than hundred common food items and vegetables when these were evaluated by utilizing oxygen radical absorbance capacity (ORAC) assay (Wu et al., 2004). Similarly, different beans cultivators were also found to exhibit antioxidant activity of 10-46% inhibition of lipid peroxidation in the linoleate and DPPH model systems (Oomah et al., 2005). Elizabeth et al. (2007) evaluated antioxidant and antimutagenic activities of colored bean cultivators and found a high correlation between total phenolic content and antioxidant and antimutagenic activities. Granito et al. (2008) observed that post-harvest storage of beans at low temperatures and humidity preserves their antioxidant activity while thermal processing and fermentation decrease the antioxidant activity of beans. Sreeramulu et al. (2009) found a significant correlation between total phenolic compounds and antioxidant activity of different legumes including common beans. Recently, Akond et al. (2011) also observed variations in different beans genotypes and found that genotypes with high phenolic compounds exhibited high antioxidant activity.

HEALTH BENEFITS OF BEANS

The consumption of beans have received increased attention because of their beneficial physiological effects in the prevention and control of broad range of chronic and degenerative diseases such as obesity, cardiovascular diseases, diabetes and cancer (Daiz-Batalla et al., 2006; Jenkins, 2007; Chung et al., 2008). The inclusion of half a cup (130g) of beans and other legumes in the diet several times in a week is recommended good for health, by the Dietary Guidelines for Americans (2005), the total recommendation per week being 3½ cups. The role of beans in the prevention and control of different diseases is summarized below:

Cardiovascular diseases

Metabolic syndrome is the group of metabolic conditions associated with the risks of cardiovascular diseases, elevated serum triglyerides and LDL cholesterol, low HDL cholesterol, central adiposity, high serum glucose and high blood pressure (Pi-Sunyer, 2004; Finley et al., 2007). Consumption of beans in the diet is considered beneficial for healthy individuals as well as those preconditioned for metabolic syndrome by lowering serum total cholesterol and LDL cholesterol (Anderson and Major, 2002). The mechanism of the prevention of the cardiovascular diseases is depicted in Figure 1. Resistant starch (RS) and dietary fiber content of beans are mainly responsible in the management of metabolic syndrome by delaying the degree of glucose as fuels, changing fat utilization and controlling appetite through increased satiety, thus lowering the risk of cardiovascular diseases (Anderson et al., 2002; Park et al., 2004). Fermentation of fiber as well as resistant starch by bacteria in the large intestine results in the generation of specific short chain fatty acids (SCFA), propionate being the dominant, which alter metabolic pathways resulting in reduced serum cholesterol (Venter et al., 1990; Pereira et al., 2003). Thus, increased production of SCFA by fermentation of resistant starch is an underlying reason for the protective benefits by the consumption of dry beans (Finley et al., 2007). The cholesterol lowering effect of dietary fiber has been ascribed to its ability to restrain the intestinal absorption of neutral steroids and bile acids and total steroid excretions (Moundras et al., 1997). Hypocholesterolemic effect can also be achieved by regular ingestion of beans that reduce the rely on animal proteins by replacing it through plant proteins (Marcello, 2006). In addition to this, beans α-amylase inhibitor is known to have anti-obesity effect as α-amylase inhibitory action to starch digestion causes energy restriction resulting in mobilization of body fat reserves (Obiro et al., 2008).

Several epidemiological and clinical studies have shown positive effects of beans consumption in lowering the risk of coronary heart diseases and cardiovascular diseases (Finley et al., 2007; Winham and Hutchins, 2007). In an epidemiological trial, men and women consuming four times or more legumes per week decreased their risks of coronary heart diseases and cardiovascular diseases up to 22% and 11%, respectively, as compared to those with once serving per week (Flight and Clifton, 2006). A 1% decline in serum total cholesterol reduces the risk of coronary heart disease by 2% while each 1% decline in serum LDL cholesterol decreases the risk to about 1% (Winham and Hutchins, 2007). In a clinical trial, Anderson et al. (1990) investigated that utilization of 275 g of navy beans by hypercholesterolemic patients for three weeks decreased serum cholesterol and LDL cholesterol upto 19% and 24%, respectively; while in 2^{nd} trial, 24% reduction was observed in both total cholesterol and LDL cholesterol under metabolic ward conditions with similar diet. Shutler et al. (1989) also investigated that consumption of baked beans by hypercholesterolemic patients for two weeks reduced total cholesterol and LDL cholesterol by 12% and 15%, respectively. Similarly, Bazzano et al. (2001) investigated that consumption of at least ¾ cups of cooked beans resulted in 38% decreased risk of myocardial infarction. In another study, hypercholesterolemic men were given half a cup daily intake of baked beans for a period of eight weeks which resulted in reductions of serum LDL cholesterol and total cholesterol by 5% and 6%, respectively (Winham and Hutchins, 2007). Similarly, Finley et al. (2007) also observed significant decline in serum total cholesterol and LDL cholesterol in healthy individuals who were given 130g daily intake of dried, cooked pinto beans, concluding that consumption of beans four times per week decrease the risk of heart diseases by 20%. Recently, Maruyama et al. (2008) also observed that azuki bean juice supplementation to young women resulted in decreased triglycerides concentrations preventing hypercholesterolemia.

Diabetes Mellitus:

The consumption of whole-grain foods such as beans and other legumes have a protective role, not only in the development of diabetes, but these are also considered beneficial in the management of people suffering from type-2 diabetes mellitus (Figure 1) (Venn and Mann, 2004). Epidemiological studies show that consumption of three or more servings of whole-grain foods per week reduces the risk of diabetes mellitus by 20-35%, as compared to less consumption (Campos-Vega et al., 2010).

The reduced digestibility of beans carbohydrates due to presence of viscous soluble dietary fiber and high amylose and resistant starch contents together with production of short chain fatty acids prevent elevated glucose levels, thus ultimately resulting in reduced insulinimic and glycemic responses (Zhou *et al*., 2004; Campos-Vega et al., 2010). Due to the slow release of carbohydrates, beans are considered as low glycemic index (GI) foods (Chung et al., 2008). Beans have a glycemic index of 20 as compared to baked potatoes, whole meal bread and rice with (GI) of 85, 77 and 50, respectively (Noriega et al., 2000; Foster-Powell et al., 2002).

Several studies indicate that consumption of low glycemic index foods is useful in the reduction of diabetes mellitus and obesity (Rizkalla et al., 2002; Jenkins, 2007). It has been observed that a fall of 10% in the glycemic index of a diet results in 30% increase in insulin sensitivity (Foster-Powell et al., 2002). Frost et al. (1998) found low glycemic index diets to be beneficial in normalizing the diet-insulin responses of hyperinsulininaemic individuals by improving adipocyte insulin-mediated glucose up take *in vitro*. In another study, low glycemic index starch diets were found to increase glucose oxidation indicating enhanced peripheral insulin action as well as glucose utilization (Kabir et al., 1998). High amylose content in beans is considered an important factor to affect glucose metabolism. In an experiment, starches with different amylose: amylopectin ratios were introduced in a mixed meals and meal with higher amylose starch showed higher glycemic response (Behall and Howe, 1995). Tovar et al. (2003) observed decreased rate of starch hydrolysis from black beans resulting in low glycemic index. Another study pertaining to antihyperglycemic effect of beans in healthy rats revealed 20.8% decrease in the area under glucose tolerance curve by kidney beans compared with 16.1% of the standard drug (Roman-Ramos et al., 1995). Similarly, Villegas et al. (2008) reported that consumption of beans and other legumes is inversely associated with the risk of type-2 diabetes mellitus in large Chinese population. In another study, Tang et al. (2008) compared the pharmacological activity annotations of traditional medicinal agents and legumes and found that many components of legumes including beans are associated with ameliorating type-2 diabetes mellitus.

Cancer

Oxidative stress leading to extracellular modification of macromolecules as well as reactive oxygen species inducing protein disruption, lipid peroxidation and DNA cross linking are the chief causes of chronic degenerative diseases, particularly cancer (Pietta, 2000; Pizzimenti et al., 2010). The incidence of cancer could be reduced by changing the dietary pattern. There is significant evidence suggesting links between diet rich in beans with reduced risk of numerous types of cancer (Cardador-Martinez et al., 2006; Patterson et al., 2009). Epidemiological studies suggest that consumptions of beans reduce the incidence of colon, breast and prostate cancer. Correa (1981) examined data from 41 countries and found that countries with larger utilization of beans had lower morbidity due to breast, colon and prostate cancer. Sing and Fraser (1998) found that beans consumption more than 2 times per week is associated with 47% reduced risk of colon cancer as compared to consumption less than once per week. Similarly, Kolonel et al. (2000) also found an inverse relationship between beans consumption and prostate cancer.

The investigations of epidemiological studies regarding consumption of beans with reduced risk of cancer were confirmed by animal studies. Hughes et al. (1997) compared the effects of beans and casein consumptions in rats and found that beans consumption reduced azomethane-induced total tumor incidence by 50% compared to 24% by casein-fed rats. They also observed only 1 tumor in rats fed into beans compared to 2.5 tumors in casein-fed rats. In a similar study, Hangen and Bennik (2003) found that diets fed to rats containing black beans resulted in decrease of total tumor incidence and adenocarcinoma incidence by 54% and 75%, respectively, while that of navy beans by 59% and 44%, respectively. Recently, Thompson et al. (2009) found that feeding cooked bean powder to laboratory rats resulted in 67% reduction in mammary carcinogenesis as well as decrease in number of cancer tumors per animal.

The anticarcinogenic activity of beans is related to the presence of resistant starch, soluble and insoluble dietary fiber, phenolic compounds as well as other microconstituents such as phytic acid, protease inhibitors and saponins (Hangen and Bennink, 2003; Patterson et al., 2009). The detailed mechanism of cancer prevention is depicted in Figure 2. The fermentation of resistant starch results in the production of short chain fatty acids principally butyrate that have protective effect against colon cancer as majority of tumors develop in the distal colon. Butyrate has been reported to induce apoptosis, growth arrest and differentiation in colon cancer cell lines (Gamet et al., 1992; Barnard and Warvick, 1993). Moreover, butyrate also exerts its effects through histone hyperacetylation and down regulation of epidermal growth factor receptor (McBain et al., 1993; Archer et al., 1998). In addition to this, slow digestion of beans starch results in reduced glycemic index attenuating the postprandial insulin response resulting in reduction of colon cancer as hyperinsulinemia and hyperglycemia are reported to increase the risk of colon cancer (Giovannucci, 1995; Jenkins et al., 2002,). Beans also contain phenolic compounds that reveal antimutagenic, anticarcinogenic and antioxidant activities (Aparicio-Fernandez et al., 2005a; Cardador-Martinez et al., 2006). These compounds have the ability to inhibit mutagenic agents such as nitrosamines, hydrocarbons, mycotoxins and polycyclic aromatic hydrocarbons by inhibiting activation enzymes, stimulating detoxification enzymes as well as through intonation of metabolic commencement of mutagens (Williams et al., 2002; Sabater et al., 2003). The anticarcinogeic and antimutagenic activity of beans is due to different mechanisms such as interactions between phenolic compounds with ultimate toxicants or mutagens, inhibition of metabolism to the ultimate mutagen as well as scavenging activities of phenolics (De Flora, 1998; De Mejia et al., 1999; Cardador-Martinez et al., 2002a). Dry beans contain phytate which are also expected to have role in the inhibition of colon cancer (Harland and Morris, 1995). Beans also contain saponins which have been found to restrain the growth of aberrant crypt foci in the colon (Koratkar and Rao, 1997). Similarly, protease inhibitors in beans, particularly chymotrypsin inhibitors are also reported to have a role in restraining cancer (Kennedy, 1994).

CONCLUSION

Beans are an important source of nutritional components as well as polyphenolic compounds with potential health benefits and antioxidant activity. The association of beans consumption with reduced risk of chronic diseases such as cardiovascular diseases, obesity, diabetes and

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cancer could be an exceptionally cost effectual approach for improving health. Because of their nutritional and health promoting properties, the development of bean based functional foods products as well as nutraceuticals needs to be promoted.

REFERENCES

Abdelwhab, N. M., Azim, A., Nour, A. M. and Fageer, A. S. M. (2009). The nutritive and functional properties of dry bean (*Phaseolus vulgaris*) as affected by gamma irradiation. *Pak. J. Nutr*. **8** (11): 1739-1742.

Adebowale, Y. A., Adeyemi, I. A., Oshodi, A. A., and Niranjan, K. (2007). Isolation, fractionation and characterization of proteins from Mucuna bean. *Food Chem*. **104**: 287-299.

Akond, G. M., Khandaker, L., Berthold, J., Gates, L., Peters, K., Delong, H., and Hossain, K. (2011). Anthocyanin, total polyphenols and antioxidant activity of common bean. *Am. J. Food Technol.* **6(5)**: 385-394.

Amir, Y., Haenni, A. L., and Youyou, A. (2006). Differences in the biochemical composition of dry legumes cultivated in north Algeria. *Electron. J. Environ. Agric. Food Chem*. **5**(3): 1411-1418.

Anderson, J. W., Story, L., Sieling, B., Chen, W. L., Petro, M. S., and Story, J. (1990). Hypocholesterolemic effects of bean intake for hypercholesterolemic men. *Am. J. Clin. Nutr.* **40**:1146-55.

Anderson, J. W., Gustafson, N. J., Spencer, D. B., Tietyen, J., and Bryant, C.A. (2002). Serum lipid response of hypercholesterolemic men to single and divided doses of canned beans. *Am. J. Clin. Nutr*. **51**:1013–1019.

Anderson, J.W. and Major, A.W. (2002). Pulses and lipaemia, short- and long-term effects: potential in the prevention of cardiovascular disease. *Br. J. Nutr*. **88**: 263–271.

Aparicio-Fernandez, X., Manzo-Bonilla, L., and Loarca-Pina, G. F. (2005a). Comparision of antimutagenic activity of phenolic compounds in newly harvested and stored common beans *Phaseolus vulgaris* against Aflatoxin $B_{1.}$ *J. Food Sci*. **70**: 73-78.

Aparicio-Fernandez, X., Yousef, G. G., Loarca-Pina, G., Gonzalez de Mejia, E., and Lila, M. A. (2005b). Characterization of polyphenolics in the seed coat of black jamapa bean (*Phaseolus vulgaris* L.). *J. Agric. Food Chem*. **53**: 4615-4622.

Aparicio-Fernadez, X., Garica-Gasca, T., Yousef, G. G., Lila, M. A., Gonzales de Mejia, E., and Loarca-Pina, G. (2006). Chemopreventive activity of polyphenolics from black jamapa bean (*Phaseolus vulgaris* L.) on HeLa and HaCaT cells. *J. Agric. Food Chem*. **54**: 2116–2122.

Archer, S., Meng, S. F., Wu, J., Johnson, J. and Tang, R. (1998). Butyrate inhibits colon carcinoma cell growth through two distinct pathways. *Surgery* **124**: 248–253.

Ariga, T., and Hamano, M. (1990). Radical scavenging action and its mode in procyanidins B-1 and B-3 from adzuki beans to peroxyl radicals. *Agric. Biol. Chem.* **54**:2499–2504.

Augustin, J., Beck, C. B., Kalbfleish, G., Kagel, L. C. and Matthews, R. H. (2000). Variation in the vitamin and mineral content of raw and cooked commercial *Phaseolus vulgaris* classes. *J. Food Sci*. **46**: 1701–1706.

Barnard, J. A., and Warwick, G. (1993). Butyrate rapidly induces growth inhibition and differentiation in HT-29 cells. *Cell Growth Differ*. **4**: 495–501.

Batista, K. A., Prudencio, S. H., and Fernandes, K. F. (2011). Wheat bread enrichment with hard-to-cook bean extruded flour: Nutritional and acceptance evaluation. *J. Food Sci*. **76**(1): 108-113.

Bauerfeind, J. C. (1980). Tocopherols in foods. **In** *Vitamin E: A* Comprehensive Treatise (L.J. Machin, ed.) pp. 91–169, Marcel Dekker, New York.

Bazzano, L. H. J., Ogden, L. G., Loria, C., Vupputuri, S., Myers, L., and Whelton, P. K. (2001). Legume consumption and risk of coronary heart disease in US men and women: NHANES I Epidemiologic Follow-up Study. *Archives Int. Med*. **161**: 2573–2578.

Boateng, J., Verghese, M., Walker, L. T., and Ogutu, S. (2008). Effect of processing on antioxidant contents in selecteddry beans (*Phaseolus* spp. L.). *LWT- Food Sci. Technol.* **41**: 1541-1547.

McBain, J. A., Eastman, A., Nobel. C. S., and Mueller, G. C. (1993). Apoptotic death in adenocarcinoma cell lines induced by butyrate and other histone deacetylase inhibitors. *Biochem. Pharmacol*. **53**: 1357–1368.

Behall, K. M., and Howe, J. C. (1995). Effect of long-term consumption of amylose vs amylopectin starch on metabolic variables in human subjects. *Am. J. Clin. Nutr.* **61**: 334-40.

Bello-Perez, L. A., and Paredes-Lopez, O. (2009). Starches of some food crops, changes during processing and their nutraceutical potential. *Food Eng. Rev*. **1**: 50–65.

Beninger, C. W. and Hosfield, G. L. (2003). Antioxidant activity of extracts, condensed tannin fractions, and pure flavonoids from *Phaseolus vulgaris* L. seed coat color genotypes. *J. Agric. Food Chem.* **51**: 7879-7883.

Berrios, J. J., Swanson, B. J., and Chaong, W. A. (1999). Physico-chemical characterization of stored black beans (*Phaseolus vulgaris* L.). *Food Res. Int*. 669-676.

Bhushan, R., and Pant, N. (1986). Composition of globulins from *Phaseolus vulgaris*, Vigna mungo and V. radiata. *Transaction Ind. Soc. Desert Technol.* **11:** 129–132.

Bravo, L., Siddhurahu, P., and Saura-Calixto, F. (1998). Effect of various processing methods on the in vitro starch digestibility and resistant starch content of Indian pulses. *J. Agric. Food Chem*. **46**: 4667-4674.

Bressani, R. (1993). Grain quality of common beans. *Food Rev. Int.* **9**(2): 237-297.

Broughton, W. J., Hernandez G, Blair, M, Beebe, S., Gepts, P, and Vanderleyden, J. (2003). Beans (Phaseolus spp.)-model food legumes. *Plant and Soil* **252**: 55-128.

Butt, M. S, and Batool, R. (2010). Nutritional and functional properties of some promising legume protein isolates. *Pak. J. Nut*. **9**(4): 373-379.

Cabrera, C., Lloris, F., Gimez, R., Olalla, M., and Lez, M. C. (2003). Mineral content in legumes and nuts: Contribution to the Spanish dietary intake. *Sci. Total Environ*. **308**: 1–14.

Campos-Vega., R., Loarca-Pina, G., and Oomah, B. D. (2010). Minor components of pulses and their potential impact on human health. *Food Res. Int*. **43**: 461-582.

Cao, G., Sofic, E.; and Prior, R. L. (1997). Antioxidant and prooxidant behavior of flavonoids: Structure-activity relationships. *Free Radical Biochem. Med.* **22**: 749-760.

Cardador-Martınez, A., Castano-Tostado, E., and Loarca-Pina, G. (2002a) Antimutagenic activity of natural phenolic compounds present in the common bean (*Phaseolus vulgaris*) against aflatoxin B1. *Food Addit. Cont.* **19**(1): 62–69.

Cardador-Martiänez, A., Loarca-Pina, G., and Oomah, B. D., (2002b). Antioxidant activity in common beans (*Phaseolus vulgaris* L.). *J. Agric. Food Chem.* **50**: 6975-6980.

Cardador-Martinez, A., Albores,A., Bah, B., Calderon-Salinas, V., Castano-Tostado, E., Guevara-Gonzalez, R. Shimada-Miyasaka, A., and Lorca-Pina, G. (2006). Relationship among antimutagenic, antioxidant and enzymatic activities of methonolic extract from common beans (*Phaseolus Vulgaris* L). *Plant Food Hum. Nutr*. **61**: 161-168.

Choung, M. G., Choi, B. R., An, Y. N., Chu, Y.H., and Cho, Y. S. (2003). Anthocyanin profile of Korean cultivated kidney bean (*Phaseolus vulgaris* L.). *J. Agric. Food Chem*. **51**: 7040–7043.

Chung, H. J., Liu, Q., Pauls, K. P., Fan, M. Z., and Yada, R. (2008). In vitro starch digestibility, expected glycemic index and some physicochemical properties of starch and flour from common bean (*Phaseolus vulgaris* L.) varieties grown in Canada. *Food Res. Int.* **41**: 869–875.

Correa, P. (1981). Epidemiological correlations between diet and cancer frequency. *Cancer Res* **41**: 3685–3689.

Cos, P., Ying, L., Calomme, M., Hu, J. P., Cimanga, K., and Van Poel, B. (1998). Structure–activity relationship and classification of flavonoids as inhibitors of xanthine oxidase and superoxide scavengers. *J. Nat. Prod*. **61**: 71–76.

Costa, G. E. A., Queiroz-Monici, K. S., Reis, S. M. P. M., and Oliveira, A. C. (2006). Chemical composition, dietary fibre and resistant starch contents of raw and cooked pea, common bean, chickpea and lentil legumes. *Food Chem*. **94**:327–330.

Daiz-Batalla, L., Jack, M. W., George, C. F., Fahey, J., Edurdo, C. T., and Octavio, P. L. (2006). Chemical components with health implications in wild and cultivated mexican common bean seeds (*Phaseolus vulgaris* L.). *J. Agric. Food Chem.* **54**: 2045-2052.

Decker, E. A. (1995). The role of phenolic, conjugated linoleic acid, carnosine and pyrroloquinoline as nonessential dietary antioxidants. *Nutr. Rev.* **53**: 49–58.

De Flora, S. (1998) Mechanisms of inhibitors of mutagenesis and carcinogenesis. *Mut. Res*. **402**(1–2): 151–158.

De Mejıa, E. G., Castano-Tostado, E., and Loarca-Pina, G. (1999). Antimutagenic effects of natural phenolic compounds in beans. *Mut. Res*. **441**: 1–9.

De Mejia, E., Guzman-Maldonado, S. H., Acosta-Gallegos, J. A., Reynoso-Cmacho, R., Ramirez-Rodriguez, E., Pons-Hernandez, J. L., Gonzalez-Chavira, M. M., Castellanos, J. Z., and Nelly, J. D. (2003). Effect of cultivar and growing location on the trypsin inhibitors, tannins and lectins of common beans (*Phaseolus Vulgaris* L.) grown in semiarid highlands of Mexico. *J. Agric. Food Chem*. **51**: 5962-5966.

Derbyshire, E., Wright, D. J., and Boulter, D. (1976). Legumin and vicilin, storage proteins of legume seeds. *Phytochem*. **15**: 3–24.

Deshpande, S. S., and Cheryan, M. (1987). Determination of phenolic compounds of dry beans using vanillin, redox and precipitation assays. *J. Food Sci.* **52**(2): 332-334.

Deshpande, S. S., and Damodaran, S. (1989). Structure–digestibility relationship of legume 7S proteins. *J. Food Sci*. **54**: 108–113.

Deshpande, S. S., Sathe, S. K., Cornforth, D. P., and Salunkhe, D. K. (1982). Effect of dehulling on functional properties of dry bean (*Phaseolus vulgaris* L.) flours. *Cereal Chem.* **59**: 396–401.

Deshpande, S. S., and Nielsen, S. (1987). In vitro enzymatic hydrolysis of phaseolin, the major storage protein of *Phaseolus vulgaris* L. *J. Food Sci.* **52**: 1326–1329.

Dietary guidelines for Americans (2005). Department of Health and Human Services (HHS) and the Department of Agriculture (USDA); Publ. no.: Home and Garden Bulletin No. 232; US Government Printing Office, Washington, DC.

Dinelli, G., Bonetti, A., Minelli, M., Marotti, I., Catizone, P., and Mazzanti, A. (2006). Content of flavonols in Italian bean (*Phaseolus vulgaris* L.) ecotypes. *Food Chem*. **99**(1): 105-114.

Dona, A. C., Pages, G., Gilbert, R. G., and Kuchel, W. (2010). Digestion of starch: In vivo and in vitro models used to characterize oligosaccharide or glucose release. *Carb. Polym.* **80**(3), 599–617.

Edenharder, R., and Tang, X. (1997). Inhibition of mutagenicity of 2-nitrofluorene, 3-nitrofluorene and 1-nitropyrene by flavonoids, coumarins, quinones and other phenolic compounds. *Food Chem.Toxicol.* **35**: 357–372.

Elhardallon, S. B., and Walker, A. F. (1992). Binding of iron by three starchy legumes in the presence of iron alone, with calcium or with calcium, zinc, magnesium and copper. *J. Food Sci. Nutr*. **43**: 61–68.

Elizabeth, R. N., Annete, H., Francisco, G. R., Javier, I. F., Graciela, Z., and Alberto, G. J. (2007). Antioxidant and antimutagenic activity of phenolic compounds in three different colour groups of common bean cultivars (*Phaseolus vulgaris*). *Food Chem*. **103**: 521-527.

 ACCEPTED MANUSCRIPT

Englyst, H. N., Kingman, S. M., and Cummings, J. H. (1992). Classification and measurement of nutritionally important starch fractions. *Eur. J. Clin. Nutr.* **46**:33-50.

Feenstra, W. J. (1960). Biochemical aspects of seed coat color inheritance in *Phaseolus vulgaris* L. *Med. Landbouwhogeschool Wageningen*. **60**: 1–53.

Finley, J. W., Burrell, J. B., and Reeves, P. G. (2007). Pinto bean consumption changes SCFA profiles in fecal fermentations, bacterial populations of the lower bowel, and lipid profiles in blood of humans. *J. Nutr*. **137**: 2391–2398.

Flight, I., and Clifton, P. (2006). Cereal grains and legumes in the prevention of coronary heart disease and stroke: A review of the literature. *Eur. J. Clin. Nutr*. **60**: 1145–1159.

Foster-Powell, K., Holt, S. H., Brand-Miller, J. C. (2002). International table of glycemic index and glycemic load values. *Am. J. Clin. Nutr*. **76**: 5-56.

Frost, G. S., Keogh, B. E., Smith, D., Leeds, A. R., and Dornhorst, A. (1998). Reduced adipocyte insulin sensitivity in Caucasian and Asian subjects with coronary heart disease. *Diabet. Med*. **15**: 1003-9.

Gamet, L, Daviaud, D., Denispouxviel, C., Remesy, C., and Murat J.C. (1992). Effects of short-chain fatty acids on growth and differentiation of the human colon cancer cell line HT-29. *Int. J. Cancer* **52**: 286–289.

Gamez, E. J. C., Luyengi, L., Lee, S. K., Zhu, L., Zhou, B., Fong, H. H. S., Pezzuto, J. M., and Kinghorn, A. D. (1998) Antioxidant flavonoid glycosides from *Daphniphyllum calycinum*. *J. Nat. Prod.* ***61:*** 706-708.

Genovese, M. I., and Lajolo, F. M. (1996). Effect of bean (*Phaseolus vulgaris*) albumins on phaseolin in vitro digestibility, role of trypsin inhibitors. *J. Food Biochem.* **20**: 275–294.

Genovese, M. I., and Lajolo, F. M. (1998). Influence of naturally acid-soluble proteins from beans (*Phaseolus vulgaris* L.) on in vitro digestibility determination. *Food Chem.* **62**: 315–323.

Genovese, M. I., and Lajolo, F. M. (2001). Atividade inibito ria de tripsina do feijao (*Phaseolus vulgaris* L.): avaliacao crıtica dos metodos de determinacao. Archivos *Latinoamericanos de Nutricao*. **51**(4): 386–394.

Gepts, P., and Dpbouk, D. (1991). Origin, domestication, and evolution of the common bean (*Phaseolus vulgaris* L.). Common beans: Research for Crop Improvement, Van Schoonhoven, A. and Voyset, O. (Eds), Wallingford, England: CAB International. Pp:7-53.

Gidley, M. J., Hanashiro, I., Hani, N. M., Hill, S. E., Huber, A., and Jane, J. L. (2010). Reliable measurements of the size distributions of starch molecules in solution: Current dilemmas and recommendations. *Carb. Polym.* **79**: 255–261.

Giovannucci, E. (1995). Insulin and colon cancer. *Cancer Causes Control* **6**: 164–179.

Graham, P. H., and Ranalli, P. (1997). Common bean (*Phaseolus vulgaris* L.). *Field crops Res*. **53**: 131-146.

Granito, M., Palolini, M., and Perez, S. (2008). Polyphenols and antioxidant activity of *Phaseolus vulgaris* stored under extreme conditions and processed. *LWT* **41**: 994-999.

Grela, E. R., and Gunter, K. D. (1995). Fatty acid composition and tocopherol content of some legume seeds. *Animal Feed Sci. Technol.* **52**: 325–331.

Gu, L., Kelm, M. A., Hammerstone, J. F., Beecher, G., Holden, J., Haytowitz, D., and Prior, R. L. (2003). Screening of foods containing proanthocyanidins and their structural characterization using LC-MS/MS and thyolitic degradation. *J. Agric. Food Chem.* **51**: 7513-7521.

Guillon, F., and Champ, M. M. J. (2002). Carbohydrate fractions of legumes: Uses in human nutrition and potential for health. *Brit. J. Nutr.* **88**(3): 293–306.

Guzel, D., and Sedat, S. (2011). Effect of cooking methods on selected physicochemical and nutritional properties of barlotto bean, chickpea, faba bean, and white kidney bean. *J Food Sci. Technol.* **Doi 10.1007/s13197-011-0260-0.**

Guzman-Maldonado, G. H., Castellanos, J., De Mejıa, E. G. (1996). Relationship between theoretical and experimentally detected tannin content of common bean *Phaseolus vulgaris* L. *Food Chem.* **55**: 333–335.

Guzman-Maldonado, S. H., and Paredes-Lopez, O. (1998). Functional products of plants indigeneous of Latin America: amaranth, quinoa, common beans and botanicals. **In**: *Functional Foods. Bichemical and Processing Aspects*; Mazza G. (Eds). Thechnomic. Lancaster, PA. Pp: 39-328.

Hangen, L. A., and Bennink, M. R. (2003) Consumption of black beans and navy beans (*Phaseolus vulgaris*) reduced axozymethane-induced colon cancer in rats. *Nutr. Cancer.* **44**: 60-65

Harland, B. F., and Morris, E. R. (1995). Phytate: a good or a bad food component? *Nutr. Res.* **15**: 733–754.

Henningson, A.. M., Nyman, E. M., and Bjorck, I. M. (2001). Content of short-chain fatty acids in the hindgut of rats fed processed bean (*Phaseolus vulgaris*) flours varying in distribution and content of indigestible carbohydrates. *Br. J. Nutr*. **86**: 379-89.

Hoover, R., and Ratnayake, W. S. (2002). Starch characteristics of black bean, chick pea, lentil, navy bean and pinto bean cultivars grown in Canada. *Food Chem*. **78**: 489–498.

Hoover, R., Hughes, T., Chung, H. J., and Liu, Q. (2010). Composition, molecular structure, properties, and modification of pulse starches: A review. *Food Res. Int.* **43**(399): 413.

Hoover, R., and Sosulski, F. W. (1985). A comparative study of the effect of acetylation on starches of *Phaseolus vulgaris* biotypes. *Starch*. **37**: 397–403.

Hosfield, G. L., Varner, G. V., Uebersax, M. A., and Kelly, J. D. (2004). Registration of 'Merlot' small red bean. *Crop Sci.* **44**: 351–352.

Hughes, J. S. (1991). Potential contribution of dry bean dietary fiber to health. *Food Tech*. **45**(9): 122-126.

Hughes, J. S., Ganthavorn, C., and Wilson-Sanders, S. (1997) Dry beans inhibit azoxymethane-induced colon carcinogenesis in F344 rats. *J. Nutr.* **127**: 2328-2333.

Hughes, J. S., and Swanson, B. G. (1989). Soluble and insoluble dietary fiber in cooked common bean *(Phaseolus vulgaris)* seeds. *Food Microstruc.* **8**: 15-21.

Iqbal, A., Khalil, I. A., Ateeq, N., and Khan, M. S. (2006). Nutritional quality of important food legumes. *Food Chem.* **97**: 331–335.

Jenkins, A. L. (2007). The glycemic index: Looking back 25 years. *Cereal Foods World*. **52**: 50–53.

Jenkins, D. J., Kendall, C. W., Augustin, L. S., Franceschi, S., Hamidi, M., Marchie A., Jenkins, A. L., Axelsen, M. (2002). Glycemic index: overview of implications in health and disease. *Am. J. Clin Nutr*. **76**: 266-273.

Jivotovskaya, A., Senyuk, V., Rotari, V., Horstmann, C., and Vaintraub, I. (1996). Proteolysis of phaseolin in relation to its structure. *J. Agric. Food Chem*. **44**: 3768–3772.

Jovanovic, S. V., Steenken, S., Tosic, M., Marjanovic, B., and Simic, M. G. (1994). Flavonoids as antioxidants. *J. Am. Chem. Soc.* **116**: 4846–4851.

Kabir M., Rizkalla S. W., Champ M., Luo J., Boillot J., Bruzzo F., and Slama G. (1998). Dietary amylose-amylopectin starch content affects glucose and lipid metabolism in adipocytes of normal and diabetic rats. *J. Nutr.* **128**: 35-43

Kadam, S. S., and Salunkhe, D. K. (1989). Minerals and vitamins. **In** D. K. Salunkhe (Ed.), Handbook of world food legumes pp. 117–121. Boca Raton: CRC Press.

Kelly, J. D., Hosfield, G. L., Varner, G. V., Uebersax, M. A., Ender, M., and Taylor, J. (2003). Registration of ‘Seahawk’ navy bean. *Crop Sci*. **43**: 2307–2308.

Kennedy, A.R. (1994). Prevention of carcinogenesis by protease inhibitors. *Cancer Res.* **54**: 999–1005.

Kolonel, L. N., Hankin, J. H., Whittemore, A. S., Wu, A. H., Gallagher, R. P., Wilkens, L. R., John, E. M., Howe, G. R., Dreon, D. M., West, D. W., and Paffenbarger, R. S. (2000) Vegetables, fruits, legumes and prostate cancer: A multiethnic case-control study. *Cancer Epidem. Biomark. Prevention.* **9**: 795-804

Koratkar, R., and Rao, A. V. (1997). Effect of soy bean saponins on azoxymethane-induced preneoplastic lesions in the colon of mice. *Nutr. Cancer* **27**: 206–209.

Kutos, T., Golob, T., Kac, M., and Plestenjak, A. (2003). Dietary fibre content of dry and processed beans. *Food Chem.* **80**: 231–235.

Letan, A. (1966) The relation of structure to antioxidant activity of quercetin and some of its derivatives. I. Primary activity. *J. Food Sci.*, **31**: 518-23.

Leterme, P., and Munoz, L. C. (2002). Factors influencing pulse consumption in Latin America. *Br. J. Nutr.* **88** (3): 251–254.

Liener, I., and Thompson, R. (1980) In vitro and in vivo studies of the digestibility of the major storage protein of the navy bean Phaseolus vulgaris. *Plant Foods Hum. Nutr.* **30**: 13–25.

Lin, L. Z., Harnly, J. M., Pastor-Corrales, M. S., and Luthria, D. L. (2008). The polyphenolic profiles of common beans (*Phaseolus vulgaris* L.). *Food Chem.* **107**: 399-410.

Luthria, D. L., and Pastor-Corrales, M. A. (2006). Phenolic acids content of fifteen dry edible bean (*Phaseolus vulgaris* L.) varieties. *J. Food Comp. Anal.* **19**: 205-211.

Ma, Y., and Bliss, F. A. (1978). Seed proteins of common bean. *Crop Sci.* **17**: 431–437.

Mabaleha, M. B., and Yeboah, S.O. (2004). Characterization and compositional studies of the oils from some legume cultivars, *Phaseolus vulgaris*, grown in Southern Africa. *J. Am. Oil Chem. Soc.* **81**: 361–364.

Madhusudhan, B., and Tharanathan, R. N. (1995). Legume and cereal starch—why differences in digestibility? Part I. Isolation and composition of legume (green gram and Bengal gram) starches. *Staerke*. **47**: 165–171.

Marcello, D. (2006). Grain legume proteins and nutraceutical properties. *Fitoterpia*. **77**: 67-82.

Marquez, U., and Lajolo, F. (1981). Composition and digestibility of albumin, globulins, and glutelins from *Phaseolus vulgaris*. *J. Sci. Food Agric.* **53**: 235–242.

Maruyama, C., Araki, R., Kawamura, M., Kondo, N., Kigawa, M., and Kawai, Y. (2008). Azuki bean juice lowers serum triglyceride concentrations in healthy young women. *J. Clin. Biochem. Nutr.* **43**: 19–25.

Marzo, F., Alonso, R., Urdaneta, E., Arricibita, F. J., and Ibanez, F. (2002). Nutritional quality of extruted kidney bean (*Phaseolus vulgaris* L. var. Pinto) and its effects on growth and skeletal muscle nitrogen fractions in rats. *J. Animal Sci.* **80**: 875–879.

Momma, M. (2006). A pepsin-resistant 20 kDa protein found in red kidney bean (*Phaseolus vulgaris* L.) identified as basic subunit of legumin. Note. *Biosci. Biotech. Biochem.* **70**: 1–4.

Montoya, C. A., Alles, J. P., Beebe, S., and Leterme, P. (2010). Phaseolin diversity as a possible strategy to improve the nutritional value of common beans (*Phaseolus vulgaris*). *Food Res. Int.* **43**: 443–449

Montoya, C. A., Gomez, A. S., Lalles, J. P., Souffrant, W. B., Beebe, S., and Leterme, P. (2008a). In vitro and in vivo protein hydrolysis of beans (*Phaseolus vulgaris*) genetically modified to express different phaseolin types. *Food Chem.* **106**: 1225–1233.

Montoya, C. A., Lalles, J. P., Beebe, S., Montagne, L., Souffrant, W. B., and Leterme, P. (2006). Influence of the Phaseolus vulgaris phaseolin level of incorporation, type and thermal treatment on gut characteristics in rats. *Br. J. Nutr.* **95**: 116–123.

Montoya, C. A., Leterme, P., Victoria, N. F., Toro, O., Souffrant, W. B., and Beebe, S. (2008b). The susceptibility of phaseolin to in vitro proteolysis is highly variable across *Phaseolus vulgaris* bean varieties. *J. Agric. Food Chem.* **56**: 2183–2191.

Moreno, F. J., Maldonado, B. M., Wellne, N., and Mills, E. N. (2005). Thermostability and in vitro digestibility of a purified major allergen 2S albumin from white sesame seeds (*Sesamun indicum* L). *Biochimica Biophysica Acta.* **1752**, 142–153.

Moundras, C., Behr, S. R., Remesy, C., and Demigne, C. (1997). Fecal losses of sterols and bile acids induced by feeding rats guar gum are due to greater pool size and liver bile acid secretion. *J. Nutr.* **127**: 1068-76.

Nergiz, C., and Gokgoz, E. (2007) Effects of traditional cooking methods on some antinutrients and in vitro protein digestibility of dry bean varieties (*Phaseolus vulgaris* L.) grown in Turkey. *Int. J. Food Sci. Technol.* **42**:868–873.

Nielsen, S. S. (1991). Digestibility of legume proteins. *Food Technol.* **45**: 112–118.

Noriega, E., Rivera, L., and Peralta, E. (2000). Glycaemic and insulinaemic indices of Mexican foods high in complex carbohydrates. *Diabet. Nutr. Metab.* **13**: 13-9

Nugent, A.P. (2005) Health properties of resistant starch. *Nutr Bull*. **30**:27–54.

Obiro, W. C., Tao, Z., and Bo, J. (2008). The nutraceutical role of the *Phaseolus vulgaris* α-amylase inhibitor. *Br. J. Nutr*. **100**: 1-12.

Ocho-Anin, A. A. L., Kouakou, T. H., Brou, K. D., Kouadio, Y. J., and Gnakri D. (2010). Evaluation of bioactive components in seeds of *Phaseolus vulgaris* L. (fabaceae) cultivated in Cote d'Ivoire O. *J. Appl. Biosci*. **31**: 1928 – 1934.

Ojijo, N. K. O., Kimura, T., and Koazei, H. (2000). Composition, soaking and softening characteristics of some Kenyan beans (*Phaseolus vulgaris* L.). *Food Sci. Tech, Res.* **6**(I): 12-18.

Okita, C., Kazuko, S., Kazuko, Y., and Hamaguchi, Y. (1972). Anthocyanins of *Phaseolus vulgaris*, cv. KurodaneKinugasa. *Eiyo To Shokuryo* **25**: 427–430.

Oomah, B. D., Corbe, A., and Balasubramanian, P. (2010). Antioxidant and anti-inflammatory activities of beans (*Phaseolus vulgaris* L.) hulls. *J. Agric. Food Chem.* **58**: 8225-8230.

Oomah, B. D., Cardador-Martınez, A., and Loarca-Pina, G. (2005). Phenolics and antioxidative activities in common beans (*Phaseolus vulgaris* L). *J. Sci. Food Agric.* **85**: 935–942.

Ovando-Martinez, M., Luis, A., Bello-Pereza, L. A., Whitney, K., Osorio-Diaz, P., Senay Simsek, S. (2011). Starch characteristics of bean (*Phaseolus vulgaris* L.) grown in different localities. *Carboh. Polym.* **85** : 54–64

Papa, R., Acosta, J., Delgado-Salinas, A.., and Gepts, P. (2005). A genome-wide analysis of differentiation between wild and domesticated *Phaseolus vulgaris* from Mesoamerica. *Theor. Appl. Genet.* **111**: 1147–1158.

Papa, R., and Gepts, P. (2003). Asymmetry of gene flow and differential geographical structure of molecular diversity in wild and domesticated common bean (*Phaseolus vulgaris* L.) from Mesoamerica. *Theor. Appl. Genet.* **106**: 239–250.

Park, O. J., Kang, N. E., Chang, M. J., and Kim, W. K. (2004). Resistant starch supplementation influences blood lipid concentrations and glucose control in overweight subjects. *J. Nutr. Sci. Vitaminol.* **50**:93–9.

Patterson, C. A., Maskus, H., and Dupasquier, C. (2009). Pulse Crops for health. *Cereals Foods World* **54**: 108-113.

Pereira, D. I. A., McCartney, A. L., and Gibson, G. R. (2003). An in vitro study of the probiotic potential of a bile-salt-hydrolyzing lactobacillus fermentum strain, and determination of its cholesterol-lowering properties. *Appl. Environ. Microbiol.* **69**:4743–52.

Pietta, P. G. (2000). Flavonoids as antioxidants. *J. Nat. Prod*. **63**: 1035–1042.

Pi-Sunyer, F. X. (2004). Pathophysiology and long-term management of the metabolic syndrome. *Obes Res*.**12**:174–180.

Pizzimenti, S., Toaldo, C., Pettazzoni, P., Dianzani, M. U., and Barrera, G. (2010). The "two faced" effects of reactive oxygen species and lipid peroxidation product 4-Hydroxynonenal in the hall marks of cancer. *Cancers* **2**(2): 338-363.

Reynoso-Camacho, R., Ramos-Gomez, M., and Loarca-Pina, G. (2006). Bioactive components in common beans (*Phaseolus vulgaris* L.). *Advances Agric. Food Biotechnol.* 217-236.

Rizkalla, S. W., Bellisle, F., and Slama, G. (2002). Health benefits of low glycaemic index foods, such as pulses, in diabetic patients and healthy individuals. *Brit. J. Nutr.* **88**: 255–262.

Rocha, M. C. P., Genovese, M. I.,and Lajalo, F. M. 2002. Albumins from the bean *Phaselous Vulgaris*: effect of heat treatment. *J. Food Biochem.* **26**: 191–208.

 ACCEPTED MANUSCRIPT

Rodriguez, R., Jimenez, A., Fernandez-Bolanos, J., Guillen, R., and Heredia, A. (2006). Dietary fibre from vegetable products as a source of functional ingredients. *Trends in Food Sci. Technol*. **17**: 3–15.

Roman-Ramos, R., Flores-Saenz, F. J., Alarcon, A. (1995). Anti-hyperglycemic effect of some edible plants. *J. Ethnopharmacol.* **48**: 25-32.

Romani, A., Vignolini, P., Galardi, C., Mulinacci, N., Benedettelli, S., and Heimler, D. (2004). Germplasm characterization of Zolfino landraces (*Phaseolus Vulgaris* L.) by flavonoid content. *J. Agric. Food Chem*. **52**: 3838-3842.

Rui, X. I., Boye, J. I., Ribereau, S., Simpson, B. K., and Prasher, S.O. (2011). Comparative study of the composition and thermal properties of protein isolates prepared from nine *Phaseolus vulgaris* legume varieties, *Food Res. Int.* doi:**10.1016/j.foodres.2011.01.008**

Ryan, E., Galvin, K., O'Connor, T. P., Maguire, A. R., and O'Brien, N. M. (2007). Phytosterol, squalene, tocopherol content and fatty acid profile of selected seeds, grains, and legumes. *Plant Foods Hum. Nutr*. **62**: 85–91.

Sabater, V. M., Kuilman-Wahls, M. E. M., and Fink-Gremmels. J. (2003) Inhibition of aflatoxin B1 mutagenicity by cyclopiazonic acid in the presence of human liver preparations. *Toxicol Lett.* **143**: 291–299.

Sai-Ut, S., Ketnawa, S., Chaiwut, P., and Rawdkuen, S. (2009). Biochemical and functional properties of proteins from red kidney, navy and adzuki beans. *As. J. Food Agric. Ind.* **2**(04), 493-504

Sathe, S. K., and Salunke, D. K. (1981). Isolation partial characterization and modification of the great northern bean (Phaseolus vulgaris L.) starch. *J. Food Sci.* **46**: 617–621.

Seena, S., Sridhar, K. R., and Bajia, B. (2005). Biochemical and biological evaluation of ANF unconventional legume, Canavalia maritima of coastal sand dunes of India. *Trop. Subtrop. Agroecosys.* **5**: 1–14.

Shiga, T. M., and Lajolo, F. M. (2006). Cell wall polysaccharides of common beans (*Phaseolus vulgaris* L.)—Composition and structure. *Carbohydrate Polymers*. **63**: 1–12.

Shimelis, E. A., and Rakshit S. K. (2005). Proximate composition and physico-chemical properties of improved dry bean (*Phaseolus vulgaris L.*) varieties grown in Ethiopia. *LWT*. **38**: 331–338.

Shutler, S. M., Bircher, G. M., Tredger, J. A., Morgan, L. M., Walker, A. F., Low, A. G. (1989). The effect of daily baked bean (*Phaseolus vulgaris)* consumption on the plasma lipid levels of young, normocholesterolemic men. *Br. J. Nutr*. **61**:257-65.

Siddiq, M., Ravi, R., and Dolan, K. D. (2010). Physical and Functional Characteristics of Selected Dry Bean (*Phaseolus vulgaris* L.) flour. *LWT-Food Sci Technol.* **43**: 232-237.

 ACCEPTED MANUSCRIPT

Singh, P. N., and Fraser, G. E. (1998) Dietary risk factors for colon cancer in a low-risk population. *Am. J. Epidemiol.* **148**: 761-774.

Slupski, J. (2010). Effect of cooking and sterilization on the composition of amino acids on immature seeds of flageolet beans (*Phaseolus vulgaris* L.) cultivars. *Food Chem*. **121**: 1171-1176.

Socorro, M., Levy-Benshimol, A., and Tovar, J. (1989). In vitro digestibility of cereals and legumes (*Phaseolus vulgaris*) starches by bovine pancreas and human pancreatic a-amylase. *Starch* **41**: 69–71.

Sreeramulu, D., Reddy, C. V. K., and Raghunath, M. (2009). Antioxidant activity of commonly consumed cereals, millet and legumes in India. *Ind. J. Biochem Biophy*. **46**: 112-115.

Stanton, W. R., and Francis, B. J. (1966). Ecological significanceof anthocyaninsin the seed coats of the Phaseoleae. *Nature*. **211**: 970–971.

Takeoka, G. R., Lan, T. D., Gerhard, H. F., Rosalind, Y. W., Leslie, A. H., Richard, H. E., and Jose, D. J. B. (1997). Characterization of black bean (*Phaseolus vulgaris* L.) anthocyanins. *J. Agric. Food Chem*. **45**: 3395-3400.

Tang, C. H. (2008). Thermal denaturation and gelation of vicilin-rich protein isolates from three *Phaseolus* legumes: A comparative study. *LWT-Food Sci. Technol.* **41**: 1380-1388.

Tang, G. Y., Li, X. J., and Zhang, H. Y. (2008). Antidiabetic components contained in vegetables and legumes. *Molecules*. **13**: 1189–1194.

Tang, C. H., Sun, X., and Yin, S. W. (2009). Physicochemical, functional and structural properties of vicilin-rich protein isolate from three *Phaseolus* legumes: Effect of heat treatment. *Food Hydrocolloids*. **23**: 1771-1778.

Tang, C. H., and Sun, X. (2011a). Structure-physicochemical function relationships of 7S globulins (vicilins) from red bean (*Phaseolus anglaris*) with different polypeptide constituents. *Food Hydrocolloids.* **25**: 536-544.

Tang, C. H., and Sun, X. (2011b). A comparative study of physicochemical and conformational properties in three vicilins from *Phaseolus* legumes: Implications for the structure-function relationship. *Food Hydrocolloids*. **25**: 315-324

Tharanathan, R. N. (2002). Food derived carbohydrates—structural complexity and functional diversity. *Crit. Rev. Biotechnol*. **22**: 65–84.

Tharanathan, R. N., and Mahadevamma, S. (2003). Grain legumes-a boon to human nutrition. *Trends Food Sci. Technol.* **14**: 507-518.

Thompson, D. B. (2000). Strategies for the manufacture of resistant starch. *Trends Food Sci. Technol*. **11**: 245–253.

Thompson, M. D., Brick, M. A, McGinley, J. N. and Thompson, H. J. (2009). Chemical composition and mammary cancer inhibitory activity of dry beans. *Crop Sci*. **49**: 179-186.

Tovar, J., Granfeldt, Y., and Bjorck, I. M. (1992). Effect of processing on blood glucose and insulin responses to starch in legumes. *J. Agric. Food Chem.* **40**: 1846–1851

Tovar, J., and Melito, C. (1996). Steam cooking and dry heating produce resistant starch in legumes. *J. Agric. Food Chem.* **441**: 2642–2645.

Tovar, J., Sayago-Ayerdi, S. G., Penalver, C., Paredes-Lopez, O., Bello-Perez, L. A. (2003). In vitro starch hydrolysis index and predicted glycemic index of corn tortilla, black beans (*Phaseolus vulgaris* L.), and Mexican taco. *Cereal Chem.* **80**: 533-535.

Tsuda, T., Ohshima, K., Kawakishi, S., and Osawa T. (1994). Antioxidative pigments isolated from the seeds of *Phaseolus vulgaris* L. *J. Agric. Food Chem.* **42**: 248-251.

Tungland, B., and Meyer, D. (2002). Non-digestible oligo- and polysaccharides (dietary fiber): Their physiology and role in human health and food. *Comprehen. Rev. Food Sci. Food Safety*. **1**(3): 90–109.

Vadivel, V., and Janardhanan, K. (2000). Nutritional and anti-nutritional composition of velvet bean: An under-utilized food legume in South India. *Int. J. Food Sci. Nutr*. **51**: 279–287.

Vargas-Torres, A., Osorio-Dıaz, P., Islas-Hern!andez, J. J, Tovar, J., Paredes-Lopez, O., and Bello-Perez, L. A. (2004). Starch digestibility of five cooked black bean (*Phaseolus vulgaris* L.) varieties. *J. Food Comp. Anal.* **17**: 605–612

Venn, B. J., and Mann, J. I. (2004). Cereal grains, legumes and diabetes. *Eur. J. Clin. Nutr.* **58**: 1443–1461.

Venter, C. S., Vorster, H. H., and Cummins, J. H. (1990). Effects of dietary propionate on carbohydrate and lipid metabolism in healthy volunteers. *Am. J. Gastroenterol*. **85**:549–53.

Villegas, R., Gao, Y. T., Yang, G., Li, H. L., Elasy, T. A., and Zheng, W. (2008). Legume and soy food intake and the incidence of type 2 diabetes in the Shanghai Women’s Health Study. *Am. J. Clin. Nutr.* **87**: 162–167.

Welch, R. M., House, W. A., Beebe S. and Cheng, Z. (2000) Genetic selection for enhanced bioavailable levels of iron in bean (*Phaseolus vulgaris* L.) seeds. *J. Agric. Food Chem.* **48**: 3576–3580.

Winham, D. M. and Hutchins, M. H. (2007). Baked beans consumption reduces serum cholesterol in hypercholesterolemic adults. *Nutr. Res.* **27**: 380-386.

Williams, G. M., Iatropoulos, M. J., and Jeffrey, A. M. (2002) Anticarcinogenicity of monocyclic phenolic compounds. *Eur. J. Cancer Prev.* **11**(*Suppl*. 2): 101–107.

Wu, X. L., Beecher G. R., Holden J. M., Haytowitz D. B., Gebhardt S. E., adn Prior R. L. (2004). Lipophilic and hydrophilic antioxidant capacities of common foods in the United States. *J. Agric. Food Chem.* **52**: 4026-4037.

Wu, X. F., James, R., and Anderson, A. K. (2005) Mineral contents in seed coat and canning quality of selected cultivars of dark red kidney beans (*Phaseolus vulgaris* L.). *J. Food Process Preserv.* **29**:63–74

Yin, S. W., Tang, C. H., Wen, Q. B., and Yang, X .Q. (2011). Conformational and Thermal properties of phaseolin, the major storage protein of red kidney bean (*Phaseolus vulgaris* L.). *J. Sci. Food Agric.* **91:**94-99.

Yoshida, H., Nozaki, K., Hanashiro, I., Yagi, F., Ito, H., and Honma, M. (2003). Structure and physicochemical properties of starches from kidney bean seeds at immature, premature and mature stages of development. *Carbohydrate Res.* **38**: 463–469.

Yoshida, H., Tomiyama, Y., and Mizushina, Y. (2005). Characterization in the fatty acid distributions of Triacylglycerols and phospholipids in kidney beans *Phaseolus vulgaris* L.). *J. Food Lipids.* **12**: 169-180.

Yoshida, H., Tomiyama, Y., Yoshida, N., Saiki, M., and Mizushina, Y. (2008). Lipid classes, fatty acid compositions and triacylglycerol molecular species from adzuki beans. *J. Food Lipids*. **15**: 343–355.

Yu, P. (2005). Protein secondary structures (a-helix and b-sheet) at a cellular level and protein fractions in relation to rumen degradation behaviours of protein: A new approach. *Br. J. Nutr.* **94**: 655–665.

Zhang, G., Ao, Z., and Hamaker, B. R. (2006). Slow digestion property of native cereal starches. *Biomacromol.* **7**: 3252–3258.

Zhou, Y., Hoover, R., and Liu, Q. (2004). Relationship between a-amylase degradation and the structure and physicochemical properties of legume starches. *Carbohydrate Polymers.* **57**: 299–317.

Table 1 Composition of beans

Source	*Carbohydrates*	*Proteins*	*Lipids*	*Ash*	**References:**
Haricot bean varities	56.53-61.56	17.95-22.07	0.66-1.02	2.83-4.26	Shimelis and Rakshit, 2005
Red Kidney bean	53.2	25.3	2	3.3	Ojijo et al., 2000
Tirga bean	51.5	26.8	2.1	4.8	Amir *et al.*,2006
Common bean	58.14	23.80	1.40	5.58	Abdelwhab et al., 2009
Common bean	54.3-59.9	20.9-22.1	2.49-2.52	3.80-4	Costa et al., 2006
White kidney beans	59.62	25.63	1.44	3.55	Guzel and Sedat, 2011
Pinto bean	57.3	30.1	1.8	4.9	Amir et al., 2006,
Black beans	67.83-68.09	25.66-25.93	1.52-1.59	4.65-44.71	Berrios et al., 1999
Red Haricot	50.4	27.1	2.8	4.1	Ojijo et al., 2000
Navy beans	54.30	18.15	2.63	4.14	Sai-Ut et al., 2009

Table 2 Size and shape of starch granules in beans

Source	*Diameter (range)* Length (μm)	*Width (μm)*	*Shape*	**Reference:**
Black bean	7.5-55.5	6.5-37.5	Round, oval, spherical	Hoover and Sosulski, 1985; Hoover and Ratnayake, 2002; Zhou et al., 2004
Kidney bean	15.5-60.5	16.1-42.5	Round, oval, elliptical	Hoover and Sosulski, 1985; Yoshida et al., 2003
Navy bean	14.0-28.5	14.2-32.0	Elliptical, oval, round	Hoover and Ratnayake, 2002
Northern bean	12.0-62.0	12.2-40.0	Irregular, oval, round	Sathe and Salunke, 1981; Hoover and Sosulski, 1985
Pinto bean	10.5-42.5	6.0-32.0	Irregular, oval, round	Hoover and Ratnayake, 2002; Zhou et al., 2004

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Table.3 Essential amino acid composition (mg/g) of the total and different protein fractions of beans

	Leu	***Lys***	***Phen***	***Arg***	***Val***	***Isleu***	***Thr***	***His***	***Met***	**References**
Total Proteins	95	76	65	63	57	48	47	30	12	Montoya et al., 2008a
Albumin	66	109	40	65	49	43	74	35	10	Ma and Bliss, 1978
Glutelin	114	81	54	61	66	62	46	35	20	Ma and Bliss, 1978
Phaseolin (7S)	83	64	31	53	59	43	30	32	9	Montoya et al., 2008b
Prolamin	101	59	74	71	79	57	39	24	16	Derbyshire et al., 1976
11S	87	78	36	48	70	49	49	30	15	Marzo et al., 2002

Leu-Leucine, **Lys**-Lysine, **Phen**-Phenylalanine, **Arg**-Arginine, **Isleu**-Isoleucine, **His**-Histidine, **Met**-Methionine

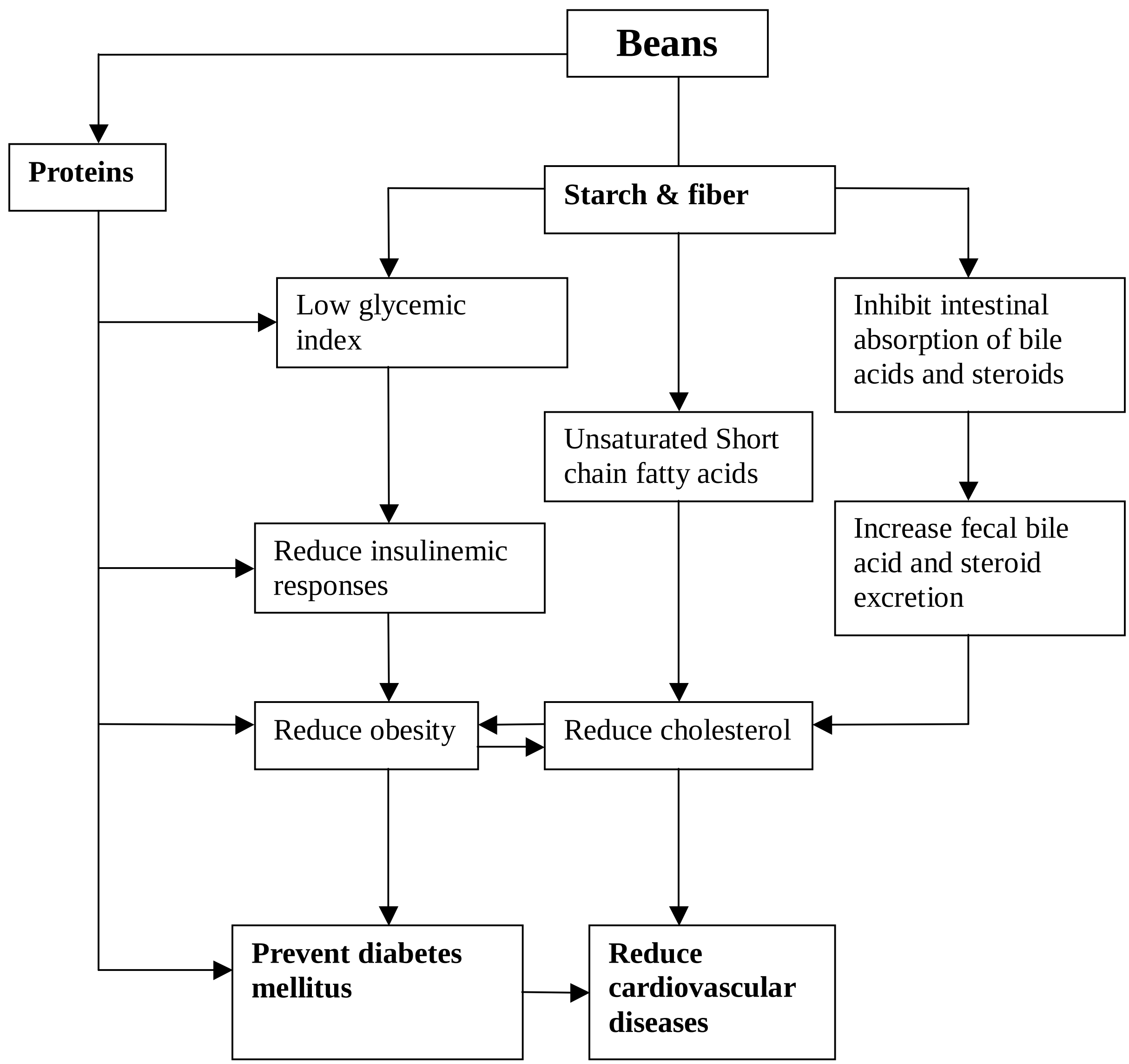

Figure 1 Mechanisms involving reduction of cardiovascular diseases, obesity and diabetes mellitus by beans

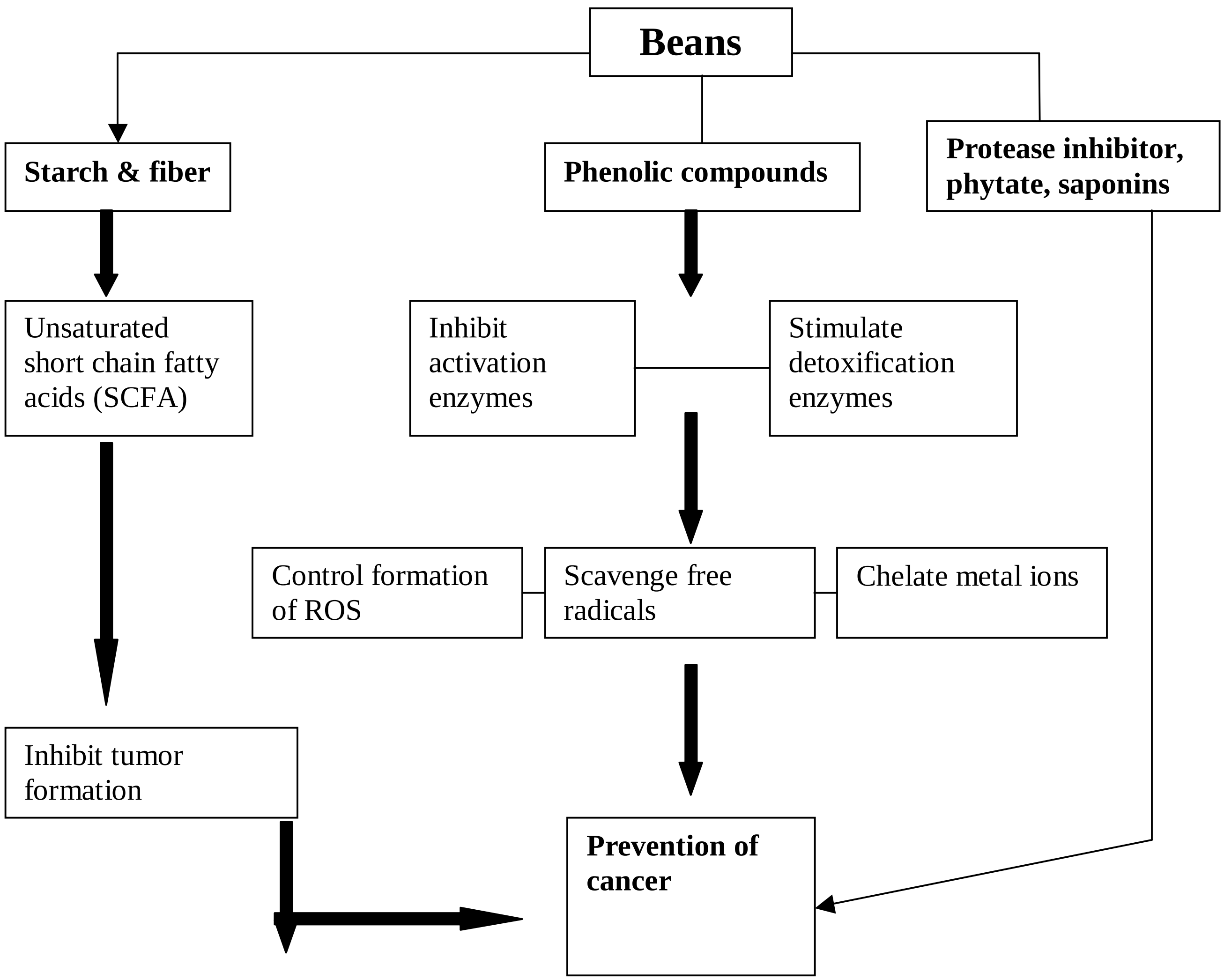

Figure 2 Mechanisms involving prevention of cancer by beans

