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Nutritional and Bioactive Compounds of Soybean: Benefits on Human Health

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1. Introduction

The soybean (*Glycine Max.* (L) Merrill) is a leguminous which originated from China and has been cultivated in this country for around five thousand years. It was considered for centuries the staple food of the countries of East Asia. In the West, its introduction was made experimentally in the Europe in 15th century. In the USA the first reports of cultivation of soybean date from 1765. Unlike East Asia, the USA soybean was initially cultivated as forage plant being used as a source of edible oil starting at 1915. A major technological progress for the use of soybean meal as protein source in nutrition was made in 1917, when Osborne and Mendel demonstrated that unheated soybean meal presents nutritional quality lower than that of heated soybean meal. Thus, the finding of the nutritional value of soybean meal as a feed for animal nutrition, coupled with growing demand for vegetable oils allowed the deployment of many industries for the processing of soybeans in the USA (Müller, 1981).

In Brazil, the introduction of soybeans occurred in Bahia state, in 1882 (Bonetti, 1981). But the first statistics showing the use of soybean for grain production are from 1941. In this same year, the first soybean processing industry in the country was installed in Rio Grande do Sul (Teixeira, 2003). However, only from the 1960, soybean crop became important in the country, initially in the South where it showed better adaptation because of the similarity with regions of cultivation in southern United States. From the 70's, the soybean crop has evolved significantly in the cultivation states, not only in the south, but also in the middle western of Brazil. With the development of new cultivars adapted to different agro-climatic regions of the country, Brazil has become the second largest soybean producer in the world. Advances in new technologies for increased acceptability of soy proteins as human food occurred as result of protein deficiency worldwide, after the World War II. Since the 1950's, USA and Canadian public research institutions worked on the development of soybean cultivars for human food use for export, mainly to Japan. In 1999, there were 16 breeding programs in public institutions working on soybean for human consumption (food-type). By

1998, dozens of cultivars had been launched specifically for the production of Tofu, Edamame and Natto. In the domestic market, only from mid-1980 genetic breeding became important in reducing the beany flavor, which is the factor that contributes more to low acceptability of soybeans as food.

In the 70s Brazil implemented a series of government programs for the introduction of a soybean beverage in school lunches, but this product was not well accepted because of its unpleasant taste resulting from the use of an inappropriate processing technology and inappropriate soybean cultivars. This led to the failure of this initiative and the deactivation of almost all programs, which reduced for a long time the possibility of using soybeans for human consumption.

The lack of a cultivar more suited to Western market has an explanation in the evolution of the low acceptability of soybean grown in Brazil, as well as in the USA. Soybean was initially grown as a forage plant, then as grain for oil extraction and only in 1960 as a source of protein meal. The development of flavored cultivars, more suited to the Western palate, was never a priority. Hence, the lack of cultivars adapted for this purpose. The cultivars used until this time point had undesirable taste and odor called beany flavor. The beany flavor derives from the formation of hydroperoxides as a result of the degradation of polyunsaturated fatty acids resulted from the action of lipoxygenases enzymes. The heat inactivation of lipoxygenases during the processing of soybean has been used in the food industry to reduce the beany flavor. Several treatments are recommended; however, they promote denaturation of proteins, altering their functional properties. This fact, coupled with the inefficiency of the thermal treatment to completely eliminate the beany flavor encouraged several groups of researchers in the country and abroad to find instead a genetic solution to the problem.

Mindful of the need to adjust the taste of soybean to the Western consumer, testing began in Brazil in 1982, in partnership with foreign researchers, in order to identify soybean genotypes that have a lower beany flavor. So, productive cultivars without lipoxygenase and very low levels of other related compounds to beany flavor have been developed. Research conducted at the *Universidade Federal de Viçosa*, Brazil, has led to the development of five cultivars devoided of lipoxygenases in the seeds, and also considered as productive cultivars (Cultivars UFVTN 101, UFVTN 102, UFVTN 103, UFVNT 104 and UFVTN 105). These cultivars are currently being recommended for planting in the state of Minas Gerais.

Other aspects relating to quality of soybean, of great relevance for the food industry, subject of genetic improvement, are: higher content and quality of protein, lower oligosaccharides content (stachyose, raffinose and verbascose), higher contents of isoflavones, oleic acid and lower levels of linolenic acid, and absence of inhibitors of protease and lectins (Moreira, 1999). Several cultivars that meet these characteristics are now under development, among them, some derived of UFVTN 105, that besides their absence of lipoxygenases, may contain either high protein (UFVTN 105 AP), low-linolenic acid (UFVTNC 106) or high protein content, and lack of KTI and lectin (UFVTNK 107).

Another improvement program for creation of cultivars destined to human feeding has been developed by *Empresa Brasileira de Pesquisa Agropecuária - Soja (EMBRAPA Soja)* since 1987. With the aimed of searching for cultivars with more suitable characteristics for food processing, such as good appearance (clear integument and hilum) and mild flavor, among others, *EMBRAPA Soja* released the following cultivars: BRS 155, which features low content of trypsin inhibitor; BRS 213, which does not contain lipoxygenase enzymes; BRS 216, which has grains of small size, suitable for the production of sprouts and natto; BRS 257, which does not contain lipoxygenase; BRS 267, which has a higher sugar content, and BRS 258, destined to the organic system.

In the private sector the company *Naturalle Agro Mercantil Ltda* works in the commercialization of special soybean for human consumption and aimed for export. Several cultivars (NT2; NT4, NT10, NT12, among others) with differentiated characteristics of grain size, with clear colors of integument and hilum, and high levels of protein have been already developed.

Traditionally, soybean is not consumed raw. Studies have shown the importance of using appropriate techniques of preparation, preservation and improvement of their nutritional and sensory characteristics. Traditional methods of preparation of soybean for human consumption include germination, cooking, roasting, and fermenting, in order to inactivate thermolabile antinutrients e.g. trypsin and chymotrypsin inhibitors and lectins (Reinwald et al., 2010).

Regarding heat treatment, there is not a recommendation of the best time and temperature to be applied to the grains in order to inactivate and, or reduce their phytochemicals which have antinutritional effects, in detriment of those with functional or beneficial effects. Adequate levels of urease activity have been demonstrated in soybeans subjected to a temperature of 98 °C for 30 minutes under humid heat, 60 °C for 42 hours, 150 °C for 30 minutes and 121 °C for 15 minutes under dry heat indicating denaturation of trypsin inhibitor (Machado et al., 2008). Moreover, the temperature of 150 °C for 30 minutes promotes the dephosphorylation of phytic acid, reducing the concentrations of inositol pentaphosphate and hexa, which have anti-nutritional action, without affecting the concentration of inositol triphosphate and tetra, which are phytochemicals with antioxidant properties (Andrade et al., 2010).

As soybean consumption increases in the Western diet, it is more common to find foods containing soy components rather than whole soy. Soy flour is the soy products less refined, however it is the industrialized most important soy product, since it is used to enrich foods, and for manufacturing textured, concentrated and isolated proteins. The incorporation of soy flour to replace wheat flour in formulation of bakery products increases the nutritional value of these products, especially the levels of protein, lipids, fiber and minerals when compared to conventional product (Dantas et al., 2009). The acceptance of formulations using mixed flours of wheat and soybeans suggests that the use of soy flour, obtained from cultivars without lipoxygenase, minimizes the unpleasant sensory problems which are characteristics of soybean (Dantas et al., 2010).

The use of soybean for human consumption in the form of integral flour is a nutritional and technological advantage, since it presents greater contents of total dietary fiber and iron than soybean hull-less flour (Carvalho, 2009).

2. Chemical composition and nutritional value of soybean

In general, soybean cultivars have approximately 8% bark, 90% cotyledon, which contains the highest percentage of proteins and lipids, and 2% hypocotyledon. The soybean chemical composition and its structural parts vary according to cultivar, growing season, geographic location and environmental stress (Ciabotti et al., 2006).

Protein is the major constituent of the soybean (30 to 50 g/100g), followed by carbohydrates (20 to 35 g/100g) and lipids (15 to 25 g/100g) (Carvalho et al., 2011; Esteves et al., 2010; Felix & Canniatti-Brazaca, 2008; Machado et al., 2008; Martino et al., 2007; Oliveira et al., 2007; U.S. Department of Agriculture, 2009). However, commercially, carbohydrates are less important than the proteins and lipids (Liu, 1997). There is an inverse relationship between the protein content and, contents of lipid and carbohydrate, thus the cultivars with greater protein content present a lower contents of lipids and carbohydrates (Table 17.1).

Compounds	BRS 133 ^a	BRS 258 ^b	OCEPAR-19 ^c	UFV-116 ^d	UFVTN 105AP ^e	USDA ^f
Protein	37.4	42.3	41.1	39.4	46.2	39.9
Lipid	21.4	22.7	24.6	20.8	19.9	21.4
Ash	4.9	4.8	4.7	6.6	5.3	5.2
Insoluble dietary fiber	23.2	23.0	0.7	0.8	9.1	nd
Soluble dietary fiber	2.8	2.8	1.7	1.3	1.5	nd
Total dietary fiber	26.0	25.8	2.3	2.1	10.5	9.9
Total carbohydrates	36.3	30.1	28.0	23	13.8	32.3
Linoleic (18:2)	5.6	5.6	5.5	5.5	5.8	9.9
α -Linolenic (18:3)	0.9	0.7	0.8	0.8	0.7	1.3

nd: not determined; a Soybean with low protein content and with hull; b Soybean with high protein content and with hull (Paucar-Menacho et al., 2010); c Conventional soybean with hull thermally treated 80 °C for 20 minutes; d Soybean without LOX 2 and 3, hull-less, thermally treated 80 °C for 20 minutes (Esteves et al., 2010); e Soybean with high protein content without LOXs, with hull, thermally treated 150 °C for 30 minutes (Andrade et al., 2010); f Conventional soybean (U.S. Department of Agriculture, 2009).

Table 17.1. Chemical composition of conventional and genetically improved soybeans (g/100g).

The main soluble carbohydrate of immature soybean is glucose. With the maturation of the grain, this sugar disappears, predominating non-reducing sugars such as sucrose, raffinose and stachyose (Paula, 2007). Most of the complex polysaccharides and oligosaccharides of the grain are composed of fibers, which are located mainly in cell walls and interstitial material of the shell (86%). The cell wall of soybean contains about 30% pectin, 50% hemicellulose and 20% cellulose. The grain also contains approximately 1% starch (Liu, 1997).

Soybean presents a high lipid content and is good source of essential fatty acids. In some soybean cultivars it has been observed they contain approximately 63% polyunsaturated fatty acid, 55% linoleic acid and 8% linolenic acid; 21.5% monounsaturated fatty acid (oleic acid), and 15% fatty acids saturated, 11% palmitic acid and 4% stearic acid (Esteves et al., 2010). The linoleic acids ($\omega 6$) and linolenic ($\omega 3$) found in soybean are considered essential and are easily oxidized due to the presence of unsaturations. These fatty acids compete with the enzymes involved in the reactions of desaturation and chain elongation. Although these enzymes have a greater affinity for $\omega 3$ acids, the conversion of alpha-linolenic acid to polyunsaturated fatty acid of long chain is strongly influenced by levels of linoleic acid in the diet. Thus, the ratio between daily intake of foods rich in $\omega 6$ and $\omega 3$, such as soybeans, is very important in human nutrition (Martin et al., 2006).

The lipid fraction of grain contains vitamin E isomers, α -tocopherol (42.0 to 291.0 mg/100g), γ -tocopherol (79.0 to 252.0 mg/100g) and δ -tocopherol (27.0 to 89.0 mg/100g) (Andrade, 2010; Baumgartner et al., 2010); and small amounts of vitamin K (47 mcg/100g) and vitamin A (1.0 mcg/100g). There is also the presence of water soluble vitamins such as vitamin C (6.0 mg/100g), folates (375.0 mcg/100g), thiamin (0.9 mg/100 g), riboflavin (0.3 mg/100 g), pyridoxine (0.5 mg/100g), niacin (2.1 mg/100 g) (Lebiedzinska & Szefer, 2006; U.S. Department of Agriculture, 2009).

2.1 Soy proteins

Soybean is the legume that presents the highest protein content and thus contributes to the supply of essential amino acids and nitrogen to human and animals (Liu, 1997). The major components of soy proteins are storage proteins known as β -conglycinin (7S) and glycinin

(11S), which represents 65% to 80% of total seed proteins. In addition, soybean contains are several inhibitors de proteases, lectins and enzymes (such as lipoxygenase and urease). Storage proteins can be classified according to their rate of sedimentation during centrifugation, as 2S, 7S, 11S, and 15S (Table 17.2). S means Svedberg unit, which is a unit of sedimentation rate computed as the rate of sedimentation per unit field of centrifugation strength (Wang & De Mejia, 2005).

Ultrafiltration protein fraction ^b	Percent in extractable protein	Proteins in the fraction
2S	20%	Kunitz trypsin inhibitors; Bowman-Birk trypsin inhibitors; Cytochrome C; AL1 and AL3- Conglycinin
7S	33%	β -Conglycinin; γ -Conglycinin; α -Amylase; Lipoxygenase; Hemagglutinins (or lectins); Soybean vacuolar protein P34
11S	33%	Pure protein: glycinin
15S	10%	Pure protein: polymer of glycinin

^a Adapted by: Wang et al.,(2005); ^b S = Svedberg unit. A unit of sedimentation rate computed as the rate of sedimentation per unit field of centrifugation strength.

Table 17.2. Soybean protein classification ^a

Soy proteins have high nutritional value and high concentration of lysine. This feature is important because of the its possible use in diets based on cereals, which are poor in lysine. In conventional cultivars sulfur amino acids are limiting, being methionine the most limiting one, followed by cystine and threonine (Liu, 1997). However, some genetically improved cultivars, such as the Brazilian cultivars BRS 133, BRS 258, OCEPAR-19, UFVTN 105 AP and UFV116, do not present this limitation (Carvalho, 2009; Esteves et al., 2010; Paucar-Menacho et al., 2010). In these cultivars, the breeding provided a qualitatively and quantitatively better balance of essential amino acids.

Genetic breeding is able of improve the profile of amino acids of soybean. However, the genetically improved cultivars may still present deficiencies of essential amino acids. By comparing the content of essential amino acids of soybean cultivars, with hull and hull-less (Table 17.3) with the standard of nutritional recommendations of FAO/WHO (2007), it was observed chemical scores above 1 for most of the essential amino acids. However, the cultivar UFVNT 105 AP was deficient in valine. Therefore, the development of new cultivars that meet the recommendations of essential amino acids is necessary.

The antigenic proteins, glycinin and β -conglycinin, may cause transient hypersensitivity reactions in the intestinal mucosa, especially in recently weaned animals, causing changes in the morphology of the intestinal mucosa with shortening of the villous and increased of the crypt depth. As a result, there may be a reduction in the number of mature enterocytes in villous, reduced villous height and increased of the crypt depth and thickness of inner and outer muscle, with consequent reduction of the digestive and absorptive capacity in the gut (Andrade et al., 2010; Caruso & Demonte, 2005). However, fermentation can decrease soy immunoreactivity and can be optimized to develop nutritious hypoallergenic soy products. However, the clinical relevance of these findings needs to be determined by human challenge studies (Song et al., 2008).

Amino acid	BRS 133 ^a	BRS 258 ^b	OCEPAR-19 ^c	UFV-116 ^d	UFVTN 105AP ^e
<i>Indispensable</i>					
Cystine	0.72	0.71	0.62	0.72	0.66
Histidine	0.98	1.16	1.34	1.34	1.08
Isoleucine	1.66	1.90	2.32	2.66	1.97
Leucine	2.83	3.17	4.03	4.26	3.31
Lysine	2.30	2.58	2.94	3.25	2.77
Methionine	0.46	0.43	0.93	0.99	0.55
Phenylalanine	1.80	2.06	2.66	3.1	2.22
Threonine	1.47	1.56	1.99	2.2	1.77
Tryptophan	nd	nd	0.86	0.73	0.59
Tyrosine	1.33	1.43	1.76	1.99	1.54
Valine	1.68	1.82	2.32	2.55	2.03
<i>Total of indispensable</i>	15.24	16.82	21.77	23.79	18.49
<i>Dispensable</i>					
Alanine	1.61	1.81	2.21	2.36	1.92
Arginine	3.25	3.98	3.78	4.35	3.25
Aspartic acid	4.34	4.90	5.62	6.24	5.11
Glutamic acid	6.93	8.02	9.28	10.51	7.87
Glycine	1.91	2.09	2.03	2.24	1.88
Proline	1.86	2.11	2.51	2.64	2.38
Serine	2.27	2.55	2.44	2.51	2.35
<i>Total of dispensable</i>	22.17	25.48	27.87	30.85	24.66
<i>Total of amino acids</i>	37.41	42.30	49.64	54.64	43.15

nd: not determined; a Soybean with low protein content and with hull; b Soybean with high protein content and with hull (Paucar-Menacho et al., 2010); c Conventional soybean with hull thermally treated 80 °C for 20 minutes; d Soybean without LOX 2 and 3, hull-less, thermally treated 80 °C for 20 minutes (Esteves et al., 2010); e Soybean with high protein content without LOXs, with hull, thermally treated 150 °C for 30 minutes (Andrade et al., 2010)

Table 17.3. Amino acids composition of conventional and genetically improved soybeans (g/100g)

β -Conglycinin is a trimer with a molecular weight (MW) of about 180 kDa. It is composed of 3 subunits, α (63 kDa), α' (67kDa) and β (48kDa) (Apweiler et al., 2004; Liu, 1997; Nielsen, 1996). These subunits share a large degree of amino acid homologies. Furthermore, β -conglycinins with different subunit composition have also been identified. It is likely that the trimers are composed of randomly assembled mixture of subunits (Nielsen, 1996). Glycinin, on the other hand, is a hexamer with MW of about 320 to 375 kDa and with 5 major subunits, G1, G2, G3, G4, and G5. Each subunit consists of 2 polypeptide chains, an acidic chain (about 40 kDa) and a basic chain (about 20 kDa), joined by a single intra-chain disulphide bond. G1, G2, and G3 can be grouped as they share about 90% sequence

homologies. Similarity, G4 and G5 share about 90% sequence homologies. However, sequence homologies between these 2 groups (G1, G2, G3 and G4, G5) are only about 50% (Nielsen, 1996).

Whole soybean contains about 7-9% of protease inhibitors that are in the grain cotyledon (Brandon & Friedman, 2002; Esteves et al., 2010; Penha et al., 2007). There are two types of inhibitors: the Kunitz trypsin (KTI), and trypsin inhibitor and chymotrypsin Browman-Birk (BBI) (Miura et al., 2005; Monteiro et al., 2004; Monteiro et al., 2003). Although cultivars without protease inhibitors already exist (Barros et al., 2008), heat treatment alone is able to inactivate them, improving its nutritional value (Miura et al., 2005). These compounds can be removed with heat treatment of the grain and genetic breeding, without prejudice the quality of protein (Andrade et al., 2010; Machado et al., 2008).

Lectins are widely distributed in plants and animals and are present in greater quantities in grain legumes and grasses. They are proteins that do not interact with the immune system, but are able to recognize specific sites on molecules and bind reversibly to carbohydrates without altering covalent structure of the glycosidic links of sites (Silva & Silva, 2000). The lectins can interfere in the metabolism of animals and man. Some lectins, in contrast to other proteins, are resistant to enzymatic hydrolysis in the digestive tract and are recovered intact and still biologically active in animal feces. Since they are not inactivated by the action of enzymes of the digestive tract, these lectins can react with the gut epithelial cells causing complications to those who consume them. The lectins have the ability to bind to specific receptors in the intestinal epithelium, and this interaction interferes in the absorption and utilization of nutrients, causing poor performance in developing animals (Ritt, 2005). Soybean lectins are tetrameric protein with a molecular weight of 110-120 kDa constituted by four subunits of 30 kDa each. The natural content of lectin in soybean ranged from 2.10 to 5.68 mg/g (Gu et al., 2010; Paucar-Menacho et al., 2010), however this content can be reduced during the heat treatment. It has been observed that soybean thermally treated for 25 minutes showed no hemagglutinating activity and its analysis through sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) confirmed the absence of lectins. However, activities of trypsin inhibition and urease were detected (Machado et al., 2008). Thus, lectins demonstrated larger sensibility to heating than trypsin inhibitors and urease.

Some proteins, such as lipoxygenase and urease, have enzyme activity. Lipoxygenases (LOX 1, 2 and 3) are enzymes belonging to a group of nonheme iron containing proteins widely distributed in soybean, representing up to 2% of soybean seed protein (Loiseau et al., 2001). They catalyze the oxidation of polyunsaturated fatty acids such as linoleic (18:2) and α -linolenic (18:3) to produce unsaturated fatty acid hydroperoxides (Liavonchanka & Feussner, 2006). Those hydroperoxides are further decomposed into volatile compounds such as hexanal aldehyde and other carbonyl compounds that are responsible for the beany flavors. With the genetic breeding, cultivars have been developed without lipoxygenase in order to decrease the production of beany flavor. The reduction of beany flavor also may occur in function of processing, since lipoxygenase is an enzyme thermolabile.

Urease is an enzyme thermolabile which correlates directly with levels of phytochemicals with antinutritional action presents in foods. Therefore, with the inactivation of the enzyme urease possibly some phytochemicals with anti-nutritional effect such as trypsin inhibitors and lipoxygenases, could be destroyed (Wiriyaumpaiwong et al., 2004). The analysis of urease is used as an indication that the thermal process was sufficient to inactivate phytochemicals with anti-nutritional effect present in soybean. The analysis of activity ureatic is a good indicator of adequate heat processing when it is between the cut points

from 0.01 to 0.30 (Mendes, 2004; Runho, 2009). It has been demonstrated that two soybeans cultivars presented urease activity of 2.39 and 2.86, however, after subjected to 15 minutes in an autoclave, the urease activity in this cultivars was reduced to 0.10 and 0.12 (Machado et al., 2008).

2.2 Other soybean components

Soybean contains other compounds, among them isoflavones, oxalate, phytic acid and bioactive peptides, which act in different ways in the human body. Isoflavones are a subclass of a large group called flavonoids. Because of its estrogenic activity, are also known as phytoestrogens (Cederroth & Nef, 2009). In soybean there are basically three types of isoflavones that are normally present in four different isoforms: glucosides (daidzin, genistin and glycitin); acetylglucosides (acetyl daidzin, acetylgenistin and acetylglycitin); malonylglucosides (malonyl daidzin, malonylgenistin and malonylglycitin) and structure unconjugated aglycone (daidzein, genistein and glycitein) (Kao et al., 2007; Pereira & Oliveira, 2002). Soybean is the main source of isoflavones (genistein, daidzein and glycitein), and its concentration range from 1.45 to 4.59 mg/g (Table 17.4) Traditional fermented products (miso, tempeh) contain high concentrations of aglycone forms, genistein and daidzein, resulting from the enzymatic action of β -glucosidase, while non-fermented products such as dried beans, aqueous extracts of soybeans, soy flour and tofu, contain high concentrations of the glucosides, genistin and daidzin (Wang & Murphy, 1994).

The majority of species in the Leguminosae family contain oxalate in one or more of their tissues. The greater concentrations of oxalate in soybean are found in the mature seeds (Ilarslan et al., 2001; Nakata, 2003). The oxalate content of some plants is known to vary by genotype of soybean and possibly within cultivars under different growth conditions. Some Brazilian soybean cultivars, such as UFV-116 and OCEPAR-19 present oxalate content of 0.38 and 0.20 mg/100g, respectively (Esteves et al., 2010). Absorbed oxalate cannot be metabolized by humans and is excreted in the urine. In humans, high urinary oxalate increases the risk of calcium oxalate (CaOx) kidney stones because CaOx is poorly soluble in the urine. Saturated oxalate in solution binds to Ca to form crystals that aggregate, often becoming large enough to block the urinary stream (Massey et al., 1993).

The phytic acid, also known as phytate, inositol hexaphosphate (IP⁶), myo-inositol, myo-inositol and inositol phosphate, is the main form of phosphorus stocks in soybean who is essential for germination of the grain (Domínguez et al., 2002) (Table 17.5).

During processing, storage, fermentation, germination and digestion of grains and seeds, IP⁶ may be partly dephosphorylated to produce compounds as pentaphosphate (IP⁵), tetraphosphate (IP⁴), triphosphate (IP³) and possibly inositol diphosphate (IP²) and monophosphate (IP¹), by action of endogenous phytases (Chiplonkar & Agte, 2005; Domínguez et al., 2002) (Table 17.5). Only IP⁶ and IP⁵ exert a negative effect on the bioavailability of minerals. The other compounds formed such as IP⁴ and IP³ has low capacity to bind to the minerals or complexes formed are more soluble. Furthermore, these compounds may have antioxidant properties (Andrade et al., 2010; Domínguez et al., 2002; Martino et al., 2007).

During gastrointestinal digestion or food processing of proteins, small bioactive peptides can be released. Food-derived peptides commonly contain 2 to 9 amino acids (Kitts & Weiler, 2003). However, this range may be extended to 20 or more amino acid units (Korhonen & Pihlanto, 2003). Numerous biologically active peptides have been identified in foods, and may act as regulatory compounds with hormone-like activities. Soybean is a

potential source of bioactive peptides which play an important role in physiological activities, particularly those related to the prevention of chronic diseases. Peptides with other biological activities, such as opioid agonistic and antagonistic, antioxidative, anticancer, and immunomodulatory actions have also been identified in soybean (Wang & De Mejia, 2005).

Types	Isoforms	BRS 133 ^a	BRS 258 ^b	OCEPAR-19 ^c	UFV-116 ^d	UFVTN 105AP ^e
Glucosides	Daidzin	424.6	147.1	237.5	74.5	308.6
	Genistin	361.2	230.9	382.0	325.5	498.1
	Glycitin	10.4	60.2	59.0	70.0	106.4
Malonyl	Daidzin	131.6	575.6	211.0	59.5	395.1
	Genistin	1007.5	729.6	263.0	213.5	526.2
	Glycitin	419.6	226.4	27.5	33.0	38.5
Acetyl	Daidzin	nf	nf	32.0	nf	227.8
	Genistin	nf	nf	40.5	28.5	233.9
	Glycitin	nf	nf	nf	nf	99.9
Aglycones	Daidzein	109.8	76.9	112.0	26.5	143.3
	Genistein	144	154.1	124	86.5	34.5
	Glycitein	13.1	23.0	10.5	nf	9.1
Total Isoflavones		2621.8	2223.8	149.09	917.5	2621.4

nf: not found; a Soybean with low protein content and with hull; b Soybean with high protein content and with hull (Paucar-Menacho et al., 2010); c Conventional soybean with hull thermally treated 80 °C for 20 minutes; d Soybean without LOX 2 and 3, hull-less, thermally treated 80 °C for 20 minutes (Esteves et al., 2010); e Soybean with high protein content without LOXs, with hull, thermally treated 150 °C for 30 minutes (Andrade et al., 2010)

Table 17.4. Isoflavone composition of conventional and genetically improved soybeans (µg/g).

Compounds	Embrapa 48 ^a	BRS-213 ^b	BRS-155 ^c	UFVTN 105AP ^d
Phytate	0.78	1.75	1.40	1.11
<i>IP</i> ⁶	0.62	1.01	0.82	0.67
<i>IP</i> ⁵	0.12	0.43	0.43	0.27
<i>IP</i> ⁴	0.04	0.23	0.12	0.12
<i>IP</i> ³	nf	0.08	0.03	0.05

nf: not found; a Conventional soybean with hull, with hull, thermally treated 150 °C for 30 minutes; b Soybean without LOXs, with hull, thermally treated 150 °C for 30 minutes; c Soybean with reduced trypsin inhibitor content, with hull, thermally treated 150 °C for 30 minutes; d Soybean with high protein content without LOXs, with hull, thermally treated 150 °C for 30 minutes (Andrade et al., 2010)

Table 17.5. Phytate content of conventional and genetically improved soybeans (mg/100g).

2.3 Protein quality

Protein content among studied soybean cultivars (commercial, triple zero, not without LOX and KTI, without LOX and KTI, with and without LOX KTI with LOX and KTI) varies from 31.32 to 44.07 g /100g (Ciabotti et al., 2006; Felix & Canniatti-Brazaca, 2008; Martino et al., 2007; Mendes et al., 2007; Monteiro et al., 2004; Oliveira et al., 2007; Silva et al., 2006; Toledo et al., 2007). The biological utilization of soy protein is lower than that animal protein due to limitations in some essential amino acids and the presence of phytochemicals with anti-nutritional effects such as protease inhibitors (KTI and BBI) (Monteiro et al., 2004; Wang et al., 2000). These compounds inhibit the proteolytic enzymes and, consequently, reduce protein digestion leading to a decrease in weight gain and growth of animals (Miura et al., 2005; Monteiro et al., 2004). However, these compounds are thermolabile and can be inactivated by heat treatment.

With genetic breeding, new cultivars of soybean have been developed without KTI, lectins and lipoxygenase to improve their protein quality and flavor, making them more suitable for human consumption. Heat treatment is also a determinant of protein quality since it can change the structure of compounds with effect anti-nutritional in conventional soybean cultivars and thus inhibit their negative nutritional effect by increasing protein digestibility. Some animal studies demonstrated that conventional soybean cultivars or genetically improved heat treated soybean showed values of Relative Protein Efficient Ration (R-PER) ranging from 30 to 77 and Relative Digestibility True (R-DV) from 82 to 90 (Carvalho, 2009; Monteiro et al., 2004). These variations in protein quality are related to genetic breeding of cultivars and processing, including heat output, binomial time: temperature, and peeling. *In vivo* studies showed that heat treatment of grains reduced the activity of trypsin inhibitor, urease and did not affect protein solubility (Andrade et al., 2010; Carvalho, 2009). In these studies, soybean with hulls presented higher nutritional quality, indicating that soy can be used in integral form as a source of quality protein, and in addition contributing to improving the intake of dietary fiber and minerals.

The soybean breeding programs have concentrated on developing more productive cultivars, and more recently, there is also a concern with quality characteristics such as content and composition of storage protein. These new cultivars need to be characterized from the nutritional point of view (Gonçalves et al., 2007), because the use of vegetable proteins influences the processing of the product, its amino acid profile and the presence of phytochemicals with potential anti-nutritional effect.

2.4 Mineral bioavailability

Besides the evaluation of protein quality, it is also of great importance the study of mineral content and its bioavailability in different soybean cultivars (Table 17.6). In the five cultivars presented in the following table, it stands out they contain relevant levels of calcium, iron and zinc, whose intake is marginal for some population groups in social vulnerability. It appears that the contents of some minerals, especially the so-called antioxidants, have not yet been quantified.

A comparative study of two genetically improved soybean cultivars (without LOX2 and LOX3) and a conventional cultivar, using an animal model and radioactive markers, revealed a lower iron and zinc bioavailability in the improved cultivar likely due to higher phytate content (Martino et al., 2007). However, in a study of a new cultivar, without lipoxygenase, a lower concentration of phytate and phytate:iron molar ratio and high protein content, using an animal model of depletion and repletion of hemoglobin,

demonstrated that the Relative Biological Values of hull and hull-less soybean flour were approximately 68% (Carvalho, 2009). These studies demonstrate the importance of combining the grain processing with the genetic breeding to promote the bioavailability of minerals. Stands out that soybean hull flours resulted in a good source of dietary fiber allowing elimination the initial hulling step in the industrial processing of soybean flour.

Minerals	BRS 133 ^a	BRS 258 ^b	OCEPAR-19 ^c	UFV-116 ^d	UFVTN 105AP ^e
Ca	290.4	335.4	208.0	171.0	177.9
Fe	22.3	26.3	40.0	40.0	nd
Zn	7.4	8.3	nd	nd	nd
K	nd	nd	1880.0	1740.1	1925.6
Na	nd	nd	2.4	2.5	3.2
P	524.4	1.2	nd	nd	nd
Mg	nd	nd	317.0	261.0	282.4
Cu	2.88	3.14	nd	nd	nd

nd: not determined; a Soybean with low protein content and with hull; b Soybean with high protein content and with hull (Paucar-Menacho et al., 2010); c Conventional soybean with hull thermally treated 80 °C for 20 minutes; d Soybean without LOX 2 and 3, hull-less, thermally treated 80 °C for 20 minutes (Esteves et al., 2010); e Soybean with high protein content without LOXs, with hull, thermally treated 150 °C for 30 minutes (Andrade et al., 2010)

Table 17.6. Mineral content of conventional and genetically improved soybeans (mg/100g in dry basis)

The heat treatment of soybean by removing the peel after soaking improved the availability of iron *in vitro* (Felix & Canniatti-Brazaca, 2008). A study using the femur ⁴⁵Ca uptake method, showed similar calcium bioavailability between genetically breed (without LOX 2 e LOX 3) and conventional cultivars thermally treated (80 °C for 20 minutes). In these study, the higher oxalate:calcium molar ratio and the higher content of oxalate and phytate in the improved cultivar did not affect calcium absorption (Martino et al., 2008). These observations are very important for individuals and populations that use soy diets since they demonstrate that the adequate heat treatment could be a good strategy for improving the minerals bioavailability of soybean. Also, the use of whole soybean, including the hull, is a good strategy to increase dietary fiber consumption in the human diet without impairing iron bioavailability.

3. Studies on functional properties of soybean

A food is defined as functional if, “in addition to providing nutrients, it contains bioactive compounds that act promoting health and/or reducing the risk of chronic diseases” (Diplock et al., 1999). In this context, soybean is considered a functional food with high potential. Experimental and epidemiological studies have provided evidence for a variety of health benefits derived from the consumption of soybean and soy food products.

3.1 Improvement in serum lipid profile

The consumption of soybean or its bioactive compounds has been reported to contribute significantly to reducing cholesterol and triglyceride levels in laboratory animals and humans (Esteves et al., 2011; Reynolds et al., 2006; Sirtori et al., 2007; Sirtori et al., 2009). The

beneficial effect on lipemia has been explained by the action of various constituents present in soybean which act via different mechanisms:

Amino acid protein profile. The high content of arginine and low methionine content (Wilson et al., 2007) can promote higher levels of nitric oxide (Gornik & Creager, 2004) and lower levels of homocysteine (Torres et al., 2006), favoring vessel relaxation and reduction of the risk of cardiovascular disease. There are suggestions that soy protein exerts hypolipidemic and antiatherogenic effects because the relationship between amino acids lysine/arginine alters the relationship insulin/glucagon which, when elevated, increases the risk of cardiovascular disease (Demonty et al., 2002; Torres et al., 2006).

Action of non-digestible peptides. The presence of peptides from soybean not digested in the gastrointestinal tract, has also explained their hypocholesterolemic effect. Peptides increase the fecal excretion of steroids, elevating both the hepatic synthesis of bile acids and receptors of LDL-c, as well as the uptake and oxidation of cholesterol in the liver (Belleville, 2002). Hypocholesterolemic effect has been found in peptide Leu-Pro-Tyr-Pro-Arg, a protein fragment derived from soybean glycinin, which reduced serum cholesterol in mice (-25.4% in total cholesterol and -30.6% in LDL-c) (Yoshikawa et al., 2000). This peptide has structural homology to enterostatin (Val-Pro-Asp-Pro-Arg). Although both have hypocholesterolemic activities, enterostatin did not increase excretion of bile acids in feces, suggesting that they may act by different mechanisms (Takenaka et al., 2004).

Bioactivity of isoflavones. Isoflavones, acting on the β -estrogen receptors present in the liver, lead to increased number of hepatic receptors of LDL-c, and favors the catabolism of cholesterol and β -oxidation of fatty acids (Dewell et al., 2002; Douglas et al., 2006; Torrezan et al., 2008). The antioxidant effect of isoflavones can act protecting the oxidation of copper-dependent LDL-c and favor a serum lipid profile associated with protection against atherosclerosis (Teixeira Damasceno et al., 2007).

Hypolipidemic action of storage proteins. β -conglycinin and glycinin showed hypolipidemic effect, through increased fecal excretion of fatty acid, induction of β -oxidation in the liver and decreased hepatic synthesis of fatty acids by down regulation of fatty acid synthesis and up regulation of liver VLDL receptors (Duranti et al., 2004; Fukui et al., 2004; Moriyama et al., 2004).

Hypolipidemic action of phytate. The phytate intake improves the serum lipid profile and reduces the hepatic lipid deposition in animal model of atherosclerosis (Lee et al., 2007). It is known that phytate exerts effect on hepatic glucose-regulating enzyme activities and reduce the risk of high fat diet-induced hyperglycemia (S.M. Kim et al., 2010).

The evidences commented above show that the beneficial effects of soybean on lipid profile improvement is mediated by various constituents present in the grain and thus the intake of whole soybean has potential to exert greater effect in comparison with supplementation of their components. This idea is supported by some evidence.

The hypocholesterolemic effect of soy consumption may be attributed not only to the presence of bioactive compounds (intrinsic effect) but also to replacing animal foods rich in saturated fat and cholesterol (extrinsic effect). A recent study estimated the intrinsic and extrinsic effects of soybean to reduce cholesterol and verified that the combined effects are important to reduce cholesterol in approximately 4% (Jenkins et al., 2010). In fact, the synergistic action of amino acids and isoflavones in improving lipid metabolism and activation of the LDL-c has been demonstrated (Bertipaglia de Santana et al., 2008).

A study performed with a group of postmenopausal women found no significant hypocholesterolemic effect of consuming soy milk for 4 weeks, despite good adherence of the participants (Beavers et al., 2010). The authors discussed that the baseline cholesterol status, supplement type, dosage, and duration, as well as dietary control, are all potential confounding factors that have been identified as determinants of the conflicting results.

3.2 Protection against oxidative stress

Isoflavones and its metabolites formed by bacterial action in the intestinal lumen, have structural determinants to exert strong antioxidant activity (Arora et al., 1998). Studies in humans have shown that the antioxidant effect of soy products. The intake for 2 weeks, of soy bars containing 7 and 12 milligrams of daidzein and genistein, respectively, increased the resistance of oxidation of isolated LDL (Tikkanen et al., 1998), although the ingestion of a product isolated soy containing protein and isoflavones did not show antioxidant effects of plasma and LDL-c (Steinberg et al., 2003). The antioxidant effects are mediated by direct elimination of free oxygen radicals by isoflavones (Teixeira Damasceno et al., 2007) and by increasing the concentrations of antioxidant enzymes, improving the body's antioxidant defense (Engelman et al., 2005; Rios et al., 2008). It is believed that a diet rich in isoflavones causes LDL-c to become resistant to peroxidation, that is responsible for the generation of a cascade of events that produces atherosclerotic plaques, making the consumption of soy a protective factor against atherosclerosis (Mateos-Aparicio et al., 2008; Sacks et al., 2006).

Several amino acids that composed bioactive peptides, such as Tyr, Met, His, Lys, and Trp, have antioxidant properties. Saito et al. (2003) evaluated 108 peptides containing either 2 His or Tyr residues and 114 peptides structurally related to Pro-His-His. They observed that the tripeptides containing Trp or Tyr residues at the C-terminus had strong radical scavenging activities, but very weak peroxy-nitrite scavenging activity. They also found that the antioxidative peptides may exert strong synergistic effects with some other antioxidants, such as phenolic compounds.

Phytates present in soybeans also have a positive effect on health, exerting a protective action against oxidative stress (Lee et al., 2007; Martinez Dominguez et al., 2002). Phytate binds to iron, suppressing the catalysis of this ion in oxidative reactions, which favors the preservation of the seed. Through this mechanism, there is inhibition of lipid peroxidation and consequent acceleration of the autoxidation of ferrous ions to ferric ions, with the formation of ferric chelates (Quirrenbach et al., 2009).

It is known that the protective effect of soybean against oxidative stress involves the action of several bioactive compounds and once again, it is reasonable to state that soy intake may offer greater antioxidant protection mediated by the synergistic effect of several components: isoflavones and their metabolites generated in the intestinal lumen, peptides and phytic acid. In addition, the action of other antioxidants such as vitamin E and minerals like copper, iron, zinc and manganese, although not present in high concentrations in soybean, help in the antioxidant protection of the body. All these factors suggest that eating whole soybean would be more effective than the intake of their isolated components.

3.3 Effect on glycemic control

Soybean has shown a potential to exert physiological effects through mechanisms that stimulate insulin production and decrease the glycemic index of diet, suggesting the possibility of their health claim to act in the prevention and control of diabetes and obesity and its metabolic complications.

The effect of isoflavones in reducing blood glucose may be explained by the stimulus by genistein to pancreatic β cells which increases insulin production and consequently also the glucose uptake by cells (Esteves et al., 2011). These effect has been demonstrated in studies with animals that received genistein (Jonas et al., 1995) and also in a *in vitro* study, which used adipocytes and insulinoma cells, showing that bioactive compounds formed from isoflavonoids and soy peptides during the fermentation process to produce meju, activated signaling cascades that stimulated insulin release (Kwon et al., 2011).

The dietary fiber contained in soybeans is effective in controlling blood glucose (Penha et al., 2007). It can reduce the rate of emptying of the digestive tract, increase the rate of peristalsis of the bowel and slow down the rate of glucose uptake and therefore its importance in the control of blood glucose (Takahashi et al., 2003). In a clinical study, the intake of soybean fiber resulted in decreased the blood glucose levels after ingestion of a glucose solution. Thus, soy fibers may adsorb glucose in the intestine and slow their release for absorption (Messina et al., 1992). A cake made with whole soybean flour showed low glucose and insulin indexes in study with a group of 20 individuals (Oku et al., 2009).

Phytate also shows potential in controlling diabetes, as demonstrated by its hypoglycemic effect in diabetic mice (S.M. Kim et al., 2010; Lee et al., 2007). Lee (2006) observed that consumption of diets containing phytate reduced the high blood glucose levels and glycated hemoglobin in diabetic mice.

In summary, various bioactive soy compounds may act on mechanisms that improve the metabolism of carbohydrates, working in reducing the risk of diabetes and metabolic complications of obesity. As an adjunct to control diabetes, it stands out the importance of dietary fiber to improve the glycemic index of diet as well as the antioxidant components to minimize the oxidative stress that is present in this disease. However, in diabetic individuals, studies are needed to prove whether pancreatic β cells of these individuals are responsive to stimulation of soy isoflavones to increase insulin release.

3.4 Antihypertensive effects and protection of the endothelium

Antihypertensive soybean peptides are the most extensively studied. Peptides as Tyr-Val-Val-Phe-Lys, Pro-Asn-Asn-Lys-Pro-Phe-Gln, Asn-Trp-Gly-Pro-Leu-Val, Ile-Pro-Pro-Gly-Val-Pro-Tyr-Trp-Thr, Thr-Pro-Arg-Val-Phe, Ile-Ala, Tyr-Leu-Ala-Gly-Asn-Gln, Phe-Phe-Leu, and Ile-Tyr-Leu-Leu show their activity by inhibiting angiotensin-converting enzyme-ACE, which is a nonspecific dipeptidyl carboxypeptidase associated with the regulation of blood pressure by modulating the rennin-angiotensin system (Chen et al., 2004).

Some peptides such Val-Pro-Pro and Ile-Pro-Pro, released during the fermentation of soybean meal, added of casein to produce of miso, showed hypertensive action by inhibiting ACE (Inoue et al., 2009).

Black soybean extract showed potent inhibitory activity of the platelet aggregation induced by a collagen *in vitro* model, using platelets isolated from humans (K. Kim et al., 2010).

Animal studies suggest that soybean may exert a protective effect against cardiovascular disease when the fetus is exposed to isoflavones via maternal diet (Bonacasa et al., 2011).

3.5 Chemopreventive effects

Epidemiologic studies have demonstrated the direct association between the protection of breast cancer and soy intake (Dong & Qin, 2011). This effect has been attributed to the bioactivity of isoflavones and their estrogenic effect. However, intervention studies do not always demonstrate benefits of supplementation of isolated soy isoflavones in reducing the

risk of breast cancer. In a study with 406 premenopausal women, who received 80 or 120 mg/day of isoflavones or placebo, during two years, did not showed modification in mammographic density, which is a marker of risk of breast cancer. However, there was a significant reduction of the marker over time (Maskarinec et al., 2009). There is evidence that early exposure to the bioactive compounds of soybean, via maternal diet, may alter the paracrine signaling in adipocytes of breast tissue and increase the differentiation of epithelial tissue, with implications in prevention of breast cancer associated with obesity (Su et al., 2009).

In prostate cancer, the chemopreventive effect of the soybean mediated by mechanisms of modulations of gene expression was evidenced in a study in which isoflavones derived from soybean cake exhibited antiproliferative effects on prostate cancer cells, decreasing the expression of cyclin B1 (Wang et al., 2009). A recent study investigated the effect of administration of soy isoflavones as an adjunct in hormone therapy and verified that for postmenopausal women there was lower risk of cancer recurrence, for a monitoring period of 5.1 years (Kang et al., 2010).

Although components of soybean have demonstrated potential to act as antiproliferative agents, their effect in reducing cancer risk is still controversial. It is possible that the metabolic imprint is the main mechanism to explain the inverse association between cancer and soy intake. In fact, it was found that for breast cancer, the association is present for the Asian population and not for the western population (Dong & Qin, 2011). For this reason, the habit of soy intake by the population through successive generations could be a useful strategy to obtain the chemopreventive benefits of the bioactive compounds in soybeans.

3.6 Effects on obesity and metabolic syndrome

Several anorectic peptides have been already identified to exert antiobesity activity through decreasing food intake, fat and lean body mass, and body weight (Challis et al., 2004). For example, Leu-Pro-Tyr-Pro-Arg, a peptide from soybean glycinin A5A4B3 subunit (Takenaka et al., 2004) and Pro-Gly-Pro have been found to have anorectic activities.

The consumption of soy protein may also lead to low hepatic deposits of triglycerides (Ascencio et al., 2004), reducing the risk of hepatic lipotoxicity and therefore of steatosis (Tovar et al., 2005). In animals, soybean protein modulated the expression of genes that regulated lipid metabolism and thyroid hormone, promoting weight loss (Simmen et al., 2010). These mechanisms of action may attenuate metabolic changes that occur in obesity, which are related to insulin resistance (Oh et al., 2011).

Soy protein isolate was found to lower plasma triglycerides, increase adiponectin (Nagasawa et al., 2003), accelerate lipid metabolism, and decrease body fat in obese rats and mice (Aoyama et al., 2000).

Thus, there is enough scientific evidence to motivate soybean research for exploring their potential for its use as a coadjuvant in the treatment of obesity and its complications.

3.7 Other diverse effects

Soybean peptides with immunomodulatory activities have also been identified from soybean protein hydrolysates. For example, immunostimulating peptide preventing the alopecia induced by cancer chemotherapy has been isolated from an enzymatic digest of soybean protein (Tsuruki et al., 2005; Tsuruki & Yoshikawa, 2004). Recently, it was shown that a lectin of 48-kDa purified soybean black Koreana inhibited the activity of reverse transcriptase of HIV-I with an IC₅₀ of 1.38 micromolar (Fei Fang et al., 2010).

Although there are suggestions of the benefits of soy on bone health, clinical studies do not always prove such effects (Alekel et al., 2010; Kenny et al., 2009). A prospective cohort study of the Chinese population showed that the intake of soybean and its products was associated with protection against hip fracture in women but no association in men (Koh et al., 2009). There are doubts if the intake of soybean can provide superior beneficial effect on bone health (Reinwald & Weaver, 2010).

Prebiotic effect with improvement in the balance of minerals especially calcium and magnesium was demonstrated in rats, which consumed the 120mg/day/animal of galactooligosaccharides contained in soybean serum obtained from by-product of the manufacturing of tofu (Tenorio et al., 2010).

Soy isoflavones derived from soybean cake exhibited effect in inhibiting apoptosis and inflammation induced by UVB in *in vitro* and *in vivo* mice models, suggesting bioactivity of soy components against aging (Chiu et al., 2009).

In animal models of neurotoxicity induced by beta-amyloid, neuroprotective effect of soy isoflavones were demonstrated, indicating the possible benefit of bioactive compounds as co adjuvant in disease (Ma et al., 2009).

The benefits of soy isoflavones as an alternative to estrogen therapy for the treatment of menopausal symptoms are still uncertain (Steinberg et al., 2010). A recent review on the subject states that the number of studies is limited to assess the effectiveness of soy foods in alleviating vasomotor and urogenital symptoms (Levis & Griebeler, 2010). Study on animals showed that the soybean extract rich in isoflavones increased the epithelium and vaginal collagen (Carbonel et al., 2011).

4. Conclusion

Soybean is a legume with great potential for use as human food, offering especially protein, lipids, fiber, minerals and bioactive compounds. Studies have shown their nutritional value and health properties, with potential of reducing the risk of non-communicable diseases. Many studies focus on the use of isolated soy constituents, especially isoflavones, bioactive peptides and protein. Therefore, it is necessary to intensify research that allows the use of whole soybeans for the supply of nutrients and bioactive compounds and to evaluate the synergistic effect of these. Studies with different processing techniques should continue, since they can optimize the nutritional and functional quality of conventional soybeans or genetically improved varieties.

Health policy in Western countries should be implemented to encourage increased consumption of whole soybean, such as a partial substitute for refined ingredients.

5. References

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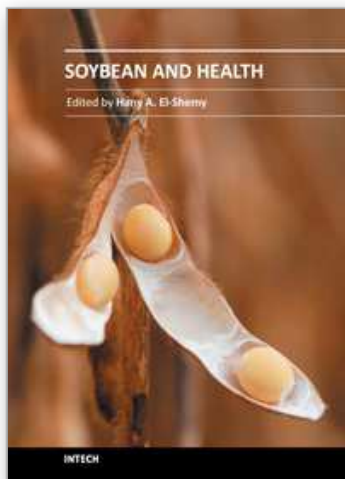
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Worldwide, soybean seed proteins represent a major source of amino acids for human and animal nutrition. Soybean seeds are an important and economical source of protein in the diet of many developed and developing countries. Soy is a complete protein, and soy-foods are rich in vitamins and minerals. Soybean protein provides all the essential amino acids in the amounts needed for human health. Recent research suggests that soy may also lower risk of prostate, colon and breast cancers as well as osteoporosis and other bone health problems, and alleviate hot flashes associated with menopause. This volume is expected to be useful for student, researchers and public who are interested in soybean.

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