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Soybean and Its Products: Nutritional and Health Benefits

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Abstract

Soybean is a nutritional and economically important crop originated in Asia. Soybean is utilized globally for a healthy diet due to its high contents of iso-flavonoids and folic acid. Dietary Soy products are the subject of increasing scientific interest due to their potential beneficial impact on human health. The important soy components that exhibit biological activity are proteins or peptides, saponins, isoflavones, and protease inhibitors. Soybean and its components possess anti-oxidant, anti-diabetic, anti-proliferative, anti-obesity and anti-inflammatory properties. Their consumption has been correlated to various potential health benefits and in reduction of numerous chronic illnesses like cardiovascular disease, diabetes, immune disorders, certain types of cancer and obesity. Several investigations have proved that soy products ample in protein help in reduction of cholesterol. This mini-review article is focused on soybean, its products and their potential roles in prevention and treatment of various chronic diseases. Studies on novel bioactive compounds of soybean having health benefits can lead towards their application in functional foods and pharmaceutical development which can replace synthetic drugs having various ill effects.

Key word: Soybean; Health Benefits; Nutritional; Antioxidant; Soy Products.

Introduction

Soybean (*Glycine max*) crop is considered to be the main source of oil globally, and is important due to its nutritional value and commercial importance [1]. Cultivation of soybean was originated in Asia about 5000 years ago, first in China and then followed by Japan. It was brought to Europe in the 18th century and then to the United States in the 19th century [2,3,4]. Since it is an excellent source of vegetable oil and proteins, thus has become an economically important crop worldwide [5,6].

In forthcoming years, it is expected that purchasing power and world's population will increase economy of developing countries especially in Asian countries, which concentrates the maximum consumption potential. The studies have predicted that by 2050, population of the world will rise to nine billion demanding 333.674 million tons of food [7]. Apart from various industrial utilization of soybean, it has immense importance in animal feed [6]. There will be continuous increase in the demand for its grain in the future [5]. Soybean is commercially cultivated as the main oilseed crop in about 35 countries [8].

On the basis of dry weight of mature raw seeds, soybean is normally comprised of nearly 35 to 40% protein, 20% lipids, 9% dietary fibre, and around 8.5% of moisture [4]. This composition varies with the location, climate of the planting and variety of soybean. Soy foods are great sources of minerals, proteins, fibres, and vitamins and are also low in saturated fats. Soy products of wide varieties have been prepared such as roasted soybean, boiled soybean, soymilk, soy mayonnaise, miso, soy cheese, soy yogurt, tempeh, soy sauce, tamari, Textured Vegetable Protein (TVP), or Textured Soy Protein (TSP) and tofu [9].

The important soy components that exhibit biological activity are proteins and peptides, saponins, isoflavones, and protease inhibitors [10,11,12].

Soybean is used globally for a healthy diet due to its high content of isoflavonoids and folic acid. Soybean and its products are considered as important sources of plant protein as they are constituted of a high amount of essential amino acids and they have various benefits on human health [Figure 1]. The contents of polyunsaturated fatty acids and quality fats in soybean are also essential from the nutraceutical perspective [8,13].

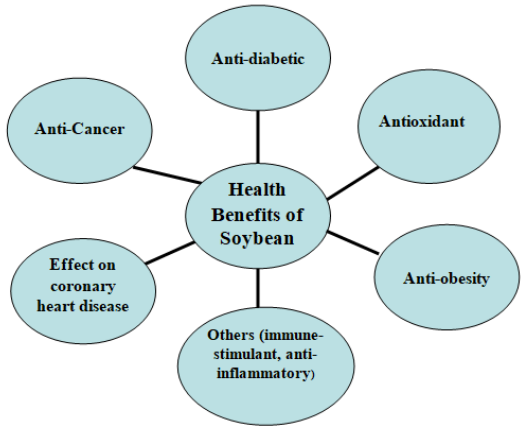

Figure 1 Various health benefits of soybean

Soy seeds contain adequate amounts of elements whose intake is marginal such as calcium, iron and zinc and have considerable higher amounts (5%) of minerals as compared to the cereal seeds (1%) [14,15].

Soy proteins are also a great source of different bioactive peptides and have exclusive health advantages, which are utilized for the prevention of chronic illnesses related to age, such as obesity, impaired immune function, cardiovascular disease, and cancer. Various soy components, their health benefits and molecular mechanism are mentioned in Table 1. Modern research proposes that, due to the valuable nutritional contents, soybean may be beneficial in decreasing the risk of osteoporosis and other bone degenerative diseases, colon, prostate, and breast cancers, and lessen hot flashes related with menopause [16]. In this mini- review, nutritional and health importance of soybean and its products has been discussed.

Table 1: Applications and molecular mechanism of various soy components

S.No.	Soy component	Applications	Molecular mechanism	References
1.	Isoflavones	Anti-cancerous, anti-fibrosis, anti-estrogen, osteoporosis, anti- artherosclerosis, type 2 diabetes, anti-oxidant, neuro-protection etc.	Form complexes with ER receptors because of structural similarities with estrogens, thus modulating estrogen receptor signalling pathways.	[45,71]
2.	Bioactive peptides	Antioxidative, anti-hypersensitive, anti-cancerous, anti-diabetic, immunostimulatory, anti-obesity.	Act as competitive inhibitors for enzymes responsible for diabetes and synthesis of cholesterol (di peptidyl peptidase-IV, HMG Co-A reductase etc).	[9,18,40]
3.	Saponins	Anti-inflammaotory, antimicrobial, anti-carcinogenic, cardio protective effects.	Form complexes with cholesterol and inhibit their absorption in intestine and also cause inhibition of tumour associated enzymes and hormone receptors.	[40,72];
4.	Protease inhibitors	Antiproliferative	Inhibit activities of trypsin, chymotrypsin, chymase, mitogen activated protein kinase. Also downregulate the protease activities, playing major role in cancer.	[73]

Anti- Diabetic Effects

Diabetes Mellitus (DM) is a metabolic disorder investigated as one of the major health issues globally. It has been rising invariably to around 336 million people in the world and is estimated to exist in around 552 million people by 2030 [17, 18].

There are various phytocompounds derived foods available for the treatment of DM. Among these, soybean and soy products have shown significant results towards the prevention of DM [9]. Dietary soy has proved to be essential and led significant impact on the patients with chronic kidney disease. In most cases, diabetes mellitus is related with the renal disorder at its advanced stages. In case of type 1 diabetes, use of soy proteins as replacement of animal proteins reduces Glomerular Filter Rate (GFR) and the proteinuria [19].

It has been reported that soy products enriched in isoflavonoids illustrated the anti-diabetic effect. It has also been shown that soybean extract is helpful in the inhibition of the glucose uptake into brush border membrane vesicles [9,20].

Anti-diabetic activity of stigmasterol from soybean oil has been studied by targeting the Glucose Transporter 4 (GLUT4). The anti-diabetic activity and the potential mechanism of stigmasterol (SMR) was investigated *in-vitro* and *in-vivo*. Stigmasterol is a phytosterol derived from the edible soybean oil which showed significant impact on the treatment of type 2 diabetes mellitus [21]. Chungkookjang, a Korean fermented soy product consisting of isoflavonoid aglycones and smaller peptides has also been studied for its improved insulinotropic activity in islets of type 2 diabetic rats [22].

Screening of fermented soy and flaxseed milk (FSFM) was done for their antidiabetic role in alloxan-induced diabetic rats utilizing the oral route. Fermented milk with probiotics enhanced the effectiveness of isoflavones in the cure of diabetic mellitus. The study on flaxseed and soy milk showed that it is potent in reduction of type 1 diabetes with no side effects [23].

Anti-Oxidant Effects

Oxidative stress takes place due to the imbalance between antioxidant mechanism and free radicals [24]. It continues as a major mechanism in a range of diseases including cancer, diabetes, etc. The soybean and its products are very effective in decreasing the oxidative stress and scavenging the free radicals [25]. Many studies have been performed on antioxidant activity of soybean and its products. Dou-chi, a traditional soybean food which was fermented using *Aspergillus* sp. showed potential to scavenge free radicals. In the study, isolation of various phenols and flavonoids was done and among them, 3'-hydroxydaidzein was found with high 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging effects [9,26,].

Soy milk is an essential soy product which has been found to inhibit oxidative stress in Type 2 Diabetes Mellitus (T2DM) in human trials. The analysis showed that fermented soy milk is beneficial in regulation of the total antioxidant, oxidized glutathione, 8-iso-prostaglandin F2α, glutathione peroxidase, malondialdehyde, and reduced glutathione (GSH) levels and in improvement of oxidative stress in T2DM [27].

Antioxidant peptides isolated from fermented soybean protein meal hydrolysate utilizing Sephadex G-15 gel filtration chromatography, revealed strong antioxidant activity [28].

Development of fermented soy foods with high nutritional constituents and effective biological properties has also been tested. Lee et al reported the alterations in nutritional components (fatty acids, isoflavones, and amino acids) and antioxidant potential of the fermented soybean against ABTS [2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)], DPPH, and hydroxyl radicals [29]. Furthermore, they also examined the variations of total phenolic contents, β-glucosidase effects, and α glucosidase inhibitory activities.

Anti-Cancer Effects

Cancer is an anomalous cell growth which either inhabits at a specific site or keeps extending within the body. Various dietary materials ample in nutrients have anti-cancer qualities and are effective in the prevention of a variety of cancer. It has been reported that fermented soy milk beverages were effective in suppressing the *in-vitro* proliferation of the human colon cancer cell lines Caco-2 and HT-29 [30]. Investigations have been performed on the inhibition of generation of reactive oxygen species and the growth of estrogen-receptor positive MCF-7 human breast cancer in mice, utilizing fermented soy milk [31]. The consumption of soybean and its products may have a considerable impact on the regulation of MMP (matrix metallopeptidase) levels and prevention of cancer [32].

Various investigations have been done on fermented soybean with antitumor and anticancer properties; however, there are only a few reports on peptides having potential against cancer. Anticancer properties of peptides in fermented soybean can be due the peptides formed on hydrolysis of soybean protein or the surfactants (containing cyclic peptide) or lipopeptides generated by the starter culture [33,34]. Soy peptides have also been recognized in various experimental systems to have anti-cancer properties [35,36,37]. Kim et al. reported that purified hydrophobic peptide X-MLPSYSPY from defatted soy protein arrested the cell cycle progression at G2/M phase, of murine lymphoma cells (P388D1) [38]. It has been revealed in various studies that most of the soy peptides exhibiting anti-cancerous properties belong to the minor 2S fraction of soybean proteins [11, 35, 39, 40].

Soy isoflavones have gained much attention over the years due to their potential role in prevention of cancer [41]. Soy isoflavones have been described as dietary components with potential role in reducing the occurrence of various cancers like prostate and breast cancers. Genistein, the prevailing isoflavone present in soybean, has been shown to be effective in the inhibition of carcinogenesis in animal models. There are various investigations that demonstrated the inhibitory effect of genistein on human cancer cells through the modulation of genes associated with the regulation of cell cycle and apoptosis. Furthermore, it has been reported that genistein is effective in inhibition of the activation of NF-κB and Akt signalling pathways, which are recognized to manage a homeostatic balance between cell survival and apoptosis [42]. The translocation of NF-κB dimers to the nucleus and their binding to DNA has been reported to be inhibited by the genistein, interrupting the transcription of NF-κB downstream genes [3, 43].

The antiproliferative influence of soy isoflavones has been generally associated to the interaction of estrogen receptor. The control of apoptosis, cell growth and survival, antioxidant properties or inhibition of angiogenesis and metastasis, have been investigated utilizing different isoflavone dosage and various breast cancer cells [44, 45].

Effects on Coronary Heart Disease

There are reports suggesting the significant impact of soy protein products on health. On the basis of total diet and nutritional perspective, various studies have explained the difference in mortality rates from different types of cancer and Cardiovascular Disease (CVD) in various countries. A number of investigations described that animal protein such as casein, is more cholesterolemic and atherogenic as compared to plant derived protein. Carroll showed that soy proteins have significant potential in lowering the cholesterol level of normal and hypercholesterolemic persons [46]. Anderson et al. conducted a meta-analysis and reported that by consumption of soy protein, blood lipid levels (total cholesterol, triglycerides and LDL-cholesterol) decreased significantly in humans [47,48].

It has been reported that the use of soy isoflavones decreases the risk markers of cardiovascular disease in men [49] and during the early menopause, they help in improvement of cardiovascular disease risk markers in women [50].

Blood pressure imbalance occurs as a crucial event in several cardiovascular diseases and it can be taken as a caution for cardiovascular symptoms. Tsai et al. reported the antihypertensive activity of peptides derived from the *Lactobacillus* fermented soy milk [51]. The results showed that with the increased peptide levels, there is reduction in the systolic blood pressure and thus it can be the explanation for the maintenance of blood pressure under control [9].

Anti- Obesity Effects

Obesity is the major health issue globally and has attained a pandemic proportion. New targets have been set to recognize the molecules that regulate adipose tissue distribution, arrangement, and decomposition which will help in prevention and treatment of obesity. Advances in food sciences and nutrition studies have highlighted the probability of balancing some specific physiological functions and molecular signalling in the human beings through food-sourced components, which focus at regulating and decreasing obesity progression at molecular level [52,53].

Soy foods are good sources of isoflavones, which probably combine with intracellular estrogen receptors and help in reduction of lipids accumulation and adipose tissue distribution. Various studies have shown the anti-obesity influence of soy foods and its components. Soy isoflavones and their derivatives have structural resemblance with 17β- estradiol (E2) and they revealed to exhibit estrogenic effect with binding affinity to estrogen receptors. Estrogen receptors are expressed in different types of cells and organs including adipose tissues, which perform important function in metabolism regulation and lipid or fat distribution [54].

The anti-adipogenic effect of genistein in primary human adipocytes regulated by its ER-dependent pathway has been investigated [55]. Genistein also exhibited lipolytic properties in fully differentiated 3T3-L1 adipocyte by increasing basal and epinephrine-induced lipolysis and elevating cellular cAMP level in fat cells [56,57].

Hwang and co-workers reported that genistein helps in inhibition of adipogenesis in 3T3-L1 cell by activating AMPK signalling pathway [58]. Genistein also inhibits different enzymes activities associated with estrogenic activities and adipogenic regulation, such as DNA to poisomerases I and II, tyrosine kinase, MAPK families, cdc2 kinase activity, and protein histidine kinase activity [59,60].

It is revealed that genistein down regulated the expression of adipogenic proteins (Fatty acid synthase and C/EBPα) by inhibiting phosphorylation signalling of two kinases (p38 and JAK2) at tyrosine residues [61]. Both genistein (100 μM) and daidzein (100 μM) treatment also showed the growth arrest phase in human preadipocyte cells, AML-I [62].

Various investigations have indicated significant influence of soy isoflavones on human body weight and lipid metabolism profile. Studies showed that intake of daidzein reduced gain in body weight and fat content in liver by down regulating stearoyl-CoA desaturase-1, which is a crucial enzyme in obesity, and up regulating uncoupling protein-1 in adipose tissue [63]. Ali et al. reported that soy isoflavone mixture (0.1% of meal, containing daidzein, glycitein and genistein) caused reduction in fat deposition in both lean and obese rats in a two-week treatment [64]. It also lowered total, low-density lipoprotein (LDL), and high-density lipoprotein (HDL) cholesterol in lean rats, while in obese rats, isoflavones reduced only total and LDL cholesterol.

There are two essential characteristics of adipose tissue driving to obesity, hypertrophy (increased adipocyte size) and hyperplasia (increased adipocyte number). Soy isoflavones are shown to be effective in the reduction of both the processes. Genistein has been reported to reduce adipose tissue *in-vivo* primarily by attributing to decrease in adipose size while daidzein could decrease overall fat mass *in-vivo* by reducing adipocyte numbers in mice [65]. Various studies demonstrated soy protein as well as peptides to be the active ingredient to reduce LDL cholesterol and triacylglycerol in human body [66].

Other Health Effects

In addition to the major health benefits mentioned above, soy and soy products also exhibit various other health benefits such as prevention of osteoporosis, maintenance of bone health and the normal endothelial function. Nattokinase (natto derived) activates fibrin degradation and acts as a therapeutic substitute in protection from comorbid asthma [67]. It also has essential role in maintenance of good condition of thyroid and impact on the developmental effects and fertility. Soybean products have also been revealed to be effective in immuno-stimulation. Cheonggukjang is a soybean paste in Korea, fermented by *Bacillus subtilis*. The polysaccharides gained from this soybean paste induced mRNA expression of various metabolic factors and help to stimulate the immune system by regulating the related parameters [68].

Hyperlipidemia and inflammation are always related with several pathological conditions. The existence of hyperlipidemic condition and low-grade inflammation collectively in atherosclerosis provides evidence for the disorder. The high n-3 FAs contents in soy products and bioactive components consisted of isoflavonoids and plant steroids may be effective on various low-grade inflammation-related diseases [69, 70]. Investigations have been performed on the impact of genistein in prevention of lipopolysaccharide (LPS)-induced cognitive dysfunction [71].

Conclusion

In the trend of nutrition and health, and active interest of people, soybean and soy proteins have attracted immense attention as these are highly nutritious, functional, and economical food ingredients. The soybean composition can be altered by conventional breeding programs or genetic engineering to meet consumer or industrial requirement. Soybean and its products can play an essential role in providing the nutritious foods according to the consumers' demand. Soybean contains large amount of proteins, vitamins, lecithin, isoflavonoids, micro- and macro-elements. The high amounts of biologically active components in soybean enable them to use in various pharmaceutical industries for production of drugs and dietary supplements. Soybean is also a major source of many peptides that have a broad range of biological activities such as anti-diabetic, hypolipidemic, anti-hypertensive, antioxidant, anti-obesity, anti-cancer, anti-inflammatory, neuro-modulatory and immune-stimulatory properties investigated in various models. Although much information has been gathered about the health benefits of soybean, and fermented soy products

but a complete investigation of the different molecular level studies and further clinical trials are required to conclude that soy products are advantageous for the human race as a dietary nutrient. More analyses are required for the identification of the quantity of active soybean peptides liberated by various methods (for instance, *in-vivo* or *in-vitro* digestions), and the influence of age and gender on the action or generation of bioactive soybean peptides. In addition, the study on synergistic multi-component impacts of soybean on biological functions is advised for further analysis.

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Conflict of interest

Authors declare that no conflict of interest exists.

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