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Nutraceutical Potential of Soybean: Review

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ABSTRACT

Soybean has received the status as one of the most important edible plants known for its seeds as a source of protein, oil and nutraceuticals. The content of the isoflavones and folic acid has made it a versatile crop for health food applications. The utility of soybean crop for food applications is described. The soybean proteins are gaining importance as a vegetable source for protein based products, with abundance quantity of essential amino acids. Its content of quality fats and PUFA are also important from nutraceutical point of view. The fermented soybean meal is also a good source of nutritionally rich tofu. In addition the biological properties of isoflavones and folic acid add value to the formulations which has been described here. Patents filed for innovations in products and processes have gained popularity and holds promise for the future of soybean industry.

Key words: Soybean, glycine max, nutraceutical, health foods, isoflavones, folic acid, PUFA, essential amino acids

INTRODUCTION

Origin and history: Soybean (*Glycine max* Leguminosae) is an important grain legume that is not only a valuable oil crop but also used as feed for livestock and aquaculture. The origin and history of soybean plant is not known clearly, however, ancient Chinese literature points out that as early as in 2853BC, the Emperor Sheng-Nung of China named soybean as one of the five scared grain (Hymowitz, 1970). The crop was first cultivated during the shang dynasty in the eastern half of the north china, which is believed to be the center of origin for soybean. Soybean has been cultivated in China for more than 4,000 years. Soybean is a commercial crop and grown in over 35 countries as the major oil seed (Smith and Huyser, 1987). Globally 38% of total soybean crop is grown in US; followed by Brazil (25%) Argentina (19%), China (7%), India (3%), Canada (2%) and Paraguay (2%) (Singh *et al*., 2008). The native of soybean is China, the major producers in the world of soybean products are the United States, Brazil, Argentina and India have been extensively used as important source of dietary protein and oil throughout the world.

Plant characteristics: The genus *Glycine* is divided into two subgenera: *Glycine* and *Soja*. The former consists of *Glycine canescens* and *Glycine tomentella* Hayata perennial wild species. Three annual species from Asia *Glycine max, Glycine soja* and *Glycine gracilis. Glycine max* is cultivated worldwide (Hymowitz and Newell, 1981), whereas *Glycine soja* is cultivated in China, Japan,

Korea, Russia and Taiwan and *Glycine gracilis* is cultivated only in china (Hymowitz and Singh, 1987). Soybean is an annual plant, grows prostrate with pods, stems and leaves covered by fine brown or grey hairs. Leaves are trifoliate having 3-4 leaflets per leaf and fall before the seed mature (Lersten and Carlson, 1987). Soybean fruit is simple or curve shape of the waxing pod, 3-7 cm length, including 1 or 2 seeds. Unripe seeds are green in color and mature have from light yellow by green to brown color. Modern cultivar of soybean seeds have spherical shape and yellow and green color is the most desirable (Sikorski, 2007). Flowers are papilionaceous type and purple, pink and white in color. Anthers mature in the bud and shed their pollen directly onto the stigma of the same flower and soybean flower is high degree of self pollination (Lersten and Carlson, 1987).

Soybean as food ingredient: Soybean is used as raw material for oil milling and soy residue used as feedstuff for domestic animals. Soybean contains a high nutritional value due to the high concentration of oil (18-25%) and protein (38-50%) and is a popular food all over the world (Muller *et al*., 1998). Production and consumption of soy product increased in western countries. In Asian countries soybean is used as fermented and non fermented food stuff such as soy sauce, miso, natto, yogurts, kinako, protein crisp, desserts, baby food and soy milk which is further processed into tofu, aburage and yuba (Hammond and Jez, 2011). Soybean base product are used as a primary protein source for several disorders such as lactose intolerance and severe gastroenteritis in infants (Businco *et al*., 1992). Mature seeds of soybean contains, approximately 35% protein, 31% carbohydrate, 17% fats, 5% mineral and 12% moisture (Messina and Lane, 2007). Soybean protein contain acceptable amount of essential amino acid i.e. histidine, isoleucine, leucine, lysine, phenylalanine, tyrosine, threonine, tryptophan and valine which is recommended for daily intake as a balanced diet (Erdman and Fordyce, 1989). The detailed composition of the nutrients is given in Table 1. Soybean has been reported to impart several health benefits such as lowering of plasma cholesterol (Anthony *et al*., 1996), prevention of cancer (Kennedy, 1998), improvement in bone mineral density (Kreijkamp-Kaspers *et al*., 2004) and provide protection against bowel and kidney disease (Friedman and Brandon, 2001). These health benefits are caused by the presence of isoflavone, saponins , protein and peptide in soybean (Friedman and Brandon, 2001; Michelfelder, 2009; Xiao, 2008).

Proteins: Liu (1997) has reported that Soybean contains 35-40% protein on a dry-weight basis, it include globulins, 11S glycinin and 7S β-conglycinin (Table 1). These proteins contain all amino acids essential to human nutrition, which makes soy products almost equivalent to animal sources in protein quality but with less saturated fat and no cholesterol. Soybean also contains the biologically active protein components hemagglutinin, trypsin inhibitors, α-amylase and lipoxygenases (Liu, 1997). As per the FDA's 'Protein Digestibility Corrected Amino Acid' source method, soybean is not only high quality protein, but it is now thought to play preventive and therapeutic roles for several diseases (Grieshop *et al*., 2003).

Oil: Soybean contains roughly ~19% oil, of which the triglycerides are the major component. Soy oil is characterized by relatively large amounts of the polyunsaturated fatty acids (PUFA), i.e., ~51% linoleic acid and ~8% α-linolenic acid, stearic acid ~4, palmitic acid ~10, oleic acid ~23 of total fatty acids (Messina, 1997) (Table 2). Soybean oil contains, essential fatty acids-linoleic acid and α-linolenic acid belonging to the ω-6 and ω-3 family, which plays an important role in the regulation

Table 1: Concentration of amino acids in soybean (Dry weight basis)

Soybean protein and amino acids	Range
Protein (%)	35-40
Amino acid composition (g/16 g N)	
Aspartic acid	12.61
Alanine	4.49
Threonine	4.11
Glycine	4.46
Valine	3.37
Proline	5.53
Cystine	0.78
Glutamic acid	19.76
Serine	5.74
Methionine	1.34
Leucine	7.90
Tyrosine	3.90
Arginine	8.64
Phenylalanine	4.85
Histidine	2.60
Lysine	6.19

Source: USDA nutrient database

Table 2: Concentration of oils, vitamins and nutraceuticals in soybean (Dry weight basis)

Parameters	Values
Fatty acid composition (total oil content (%))	
Linolenic acid	7-10
Stearic acid	4
Linoleic acid	51
Palmitic acid	10
Oleic acid	23
Vitamins (μg g^{-1})	
Riboflavin	0.92-1.19
Thiamine	6.26-6.85
Vitamin E	
α-tocopherol	10.9-28.4
δ-tocopherol	24.6-72.5
τ-tocopherol	150-190
Carbohydrate (%)	35
Stachyose	4
Raffinose	1.1
Phospholipid (%)	1-3
Phosphatidyl choline	35
Phosphatidyl ethanolamine	25
Phosphatidyl inositol	15
Phosphatidic acid	5-10
Others	
Minerals	5
Ash	5.9
Isoflavone	0.1-0.4
Saponins	0.1-0.3
Phytosterols (mg g^{-1})	1-1.5

Source: USDA nutrient database

of a number of metabolic pathways and exerts important nutritional and physiological functions. Oil also contains 1-3% phospholipids, ~35% phosphatidyl choline, ~25% phosphatidyl ethanolamine, ~15% phosphatidyl inositol, ~5-10% phosphatidic acid.

Carbohydrates: Soybean contains ~35% carbohydrates, polysaccharides, oligosaccharides such as, stachyose (4%) and raffinose (1.1%) (Table 2). Stachyose is a tetraose with a galactose galactose-glucose-fructose structure, while raffinose is a triose with a structure of galactose-glucose-fructose

Table 3: Soybean products worldwide

Soybean products	Descriptions
Soy sauce	A condiment produced from fermented paste of boiled soybean, roasted brine, grain and *Aspergillus oryzae* or *Aspergillus sojae* molds. Soy sauce is conventional ingredient in East and Southeast Asian countries
Natto	It is traditional Japanese breakfast food made from fermented soybean with *Bacillus subtilis*. As a rich source of protein. It has acquired taste
Misco	It is traditional Japanese flavor food produced by soybean with salt and the fungus kojikin
Douche	It used for making black bean sauce. Product are similar to ogiri and iru (African fermented bean products)
Tempeh	It is traditional soy product. Made by fermentation process. it is unique product a rich protein
Gouchuisng	It is salty and strong fermented traditional food made of red chilli, glutinous rice, fermented soybean and salt a rich source of carbohydrate and protein
Tofu	It is also known as bean curd it is made of coagulant soy milk. It contain large amount of protein and high iron
Stinky tofu	A form of fermented tofu that has strong smell made of fermented milk
Soymilk	It is traditional staple of Asian countries. it contain protein, fat and carbohydrate
Tamari	It is type of soy sauce, darker in appearance and richer in flavor.
Soy biscuit	Biscuits contain minimum 12% protein, 5% fat and maximum 4% crude fiber, 6.5% ash and 10% moisture. Color of biscuit is creamy to yellow and nutty and crunchy taste and texture of biscuit
Soy bread	Soy bread contain minimum 30% protein, 1.5% fat, maximum 4% crude fiber, 40% carbohydrate, 6.5% ash and 40% moisture. Color of soy bread is creamy to yellow and nutty and soft taste and texture of bread

(Grieshop *et al*., 2003). Polysaccharides are composed mainly of insoluble dietary fiber. Soybean curd refuse (*Okara*) contains soluble polysaccharides with galacturonic acid. In addition to use as a dietary fiber supplement, soluble polysaccharides have been used to modify the physical properties of various foods (Espinosa-Martos and Ruperez, 2006).

Vitamins and minerals: Soybean is a better source of vitamins B compared to cereals, although it lacks B12 and vitamin C (Liu, 1997) (Table 2). Soybean oil also contains tocopherols which are tremendous natural antioxidants. Soybean also contains ~5% minerals. It is relatively rich in K, P, Ca, Mg and Fe. Soy ferritin can extra reasonable quantities of iron (Sugano, 2006).

SOYBEAN PRODUCT

Oriental soy foods, both fermented and nonfermented products are part of the daily diet in many areas of the world. Products such as soy sauce, tofu, tempeh and others are becoming more popular in the United States and Europe. Soy sauce is made either by hydrolysis or by fermentation. Some commercial sauces have both fermented and chemical sauces. Traditional soy sauces are made by mixing soybeans and grain with mold cultures such as *Aspergillus oryzae* and other related microorganisms and yeasts (Table 3). Soymilk originated in China. Soy milk is a complete protein; it can replace animal protein and other sources of dietary fiber, vitamins and minerals (Sacks *et al*., 2006). Soy products contain sucrose as the basic disaccharide, which breaks down into glucose and fructose. Since soy does not contain galactose a product of lactose breakdown, soy-based infant formulas can safely replace breast milk in children with galactosemia (Gandhi, 2008) (Table 2). Natto has a distinguishing smell, somewhat similar to a strong cheese. Stirring natto produces lots of sticky strings (Hosking, 1996). Natto is 55% water, 18% protein, 11% fats, 5% fiber and 5% sugars. It is traditional Japanese breakfast food made from fermented soybean with *Bacillus subtilis* as a rich source of protein (McCloud, 1992). Many companies are involved worldwide for soybean product (Table 4 and 5).

SOYBEAN AND HEALTH BENEFIT

Traditionally soybean based-foods of have been consumed for centuries in most of the Asian countries and recently, this food has had a great popularity in the west hemisphere (Messina, 2008). Transgenic soybean is included in agriculture technology to increase productivity primarily by reducing inputs and thus production cost (Persley *et al*., 1999). Soybean is gaining importance as a nutritionally important crop and also becoming popular for nutraceutical

Table 4: Companies involved in soybean products

Companies	Located	Products
Soya shakthi	Coimbatore Tamil Nadu, India	Soya chunk, soya flakes, soya granules and soy flour
Gokul Refoils solvent Ltd	Ahmedabad Gujarat, India	Soybean oil
Ruchi soya industries Ltd	Bangalore Karnataka, India	Neutrals, chunks, granules and soy oil
Pristine plants India Pvt Ltd	Faridabad, Haryana, India	Soymilk and tofu
Kikkoman corporation	Noda, Japan	Soy sauce
Oilen's indopesion foods	California	Tempe
Amoy canning crop	Chin Bee Avenue, Singapore	Soy sauce
Eng Har Hin Co	Singapore	Tofu
Kwong Bee Chun Sauce factory	Taiping perak, Malaysia	Soy sauce
Runnels foods	California	Tempe
Tin chan sauce factory	Selangor, Malaysia	Soy sauce

Source: Wikipedia

Table 5: Soybean production worldwide

	Productions (Million Mt)						
Country	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
United States of America	60.00	80.749	91.471	90.083	82.3	82.79	91.39
Brazil	58.90	57.800	68.000	65.000	72.0	82.00	86.70
Argentina	45.50	32.000	54.000	50.000	48.0	49.30	54.00
India	1.44	9.308	9.725	10.100	11.0	11.50	13.34
China	16.20	15.540	15.567	16.090	13.5	13.05	12.20
World	182.04	195.397	238.736	231.273	226.8	238.64	257.63

Source: USDA database

properties as it contains essential amino acid and secondary metabolites such as isoflavone, saponins, phytic acids, phytosterols, trypsin inhibitors and peptides (Isanga and Zhang, 2008). Soy, isoflavone daidzein and genistein, their precursors formononetin, biochanin A, their glycosides, glycosides malonates and acetyl glycosides were determined in red clover (*Trifolium pratense*) extracts using chromatographic and spectrometric methods (Sabudak and Guler, 2009) that are natural phytoestrogens able to inhibit LDL oxidation, thus decreasing the risk of atherosclerosis (Wiseman, 1999). Ito *et al*. (2006) isolated two new isoflavonoids from leaves of *Millettia taiwaniana* (Leguminosae), millewanin-F and furowanin-A, together with previously known five isoflavonoids. Wiseman *et al*. (2000) reported a decrease in susceptibility of LDL particles to oxidation with soy protein consumption. Isanga and Zhang (2008) reported that the phytochemicals contained in soybean as functional ingredients influences the reduction of cholesterol and prevention of cardiovascular diseases, diabetic symptoms, bone lose straight and cancer. Messina and Lane (2007) suggested that soybean-based food can help to reduce the level of cholesterol, soybean will help to this change since provide quality protein, in addition is low in saturated fat and is devoid of cholesterol. Tavva *et al*. (2007) reported that transgenic soybean with content of α-tocoferol by expressing the gene γ-tocoferol methyltransferase of *Perilla frutescens* which is used in prevention of oxidative damage of lipids during seed storage and germination. Eating soybeans, which are good sources of calcium and protein and easy way to help build strong bones and even reduce the risk of osteoporosis. Research shows that it is the isoflavones, genistein and daidzein in soybeans, that prevent bone loss or the breakdown of bones. Also, the protein in soybeans helps to conserve calcium in our bodies. The folic acid present in soybean has synergistic effects in prevention of bone loss. Isoflavones include a class of organic compounds, regularly naturally occurring, related to the isoflavonoids (Kaufman *et al*., 1997). Besides isoflavones, the other subclasses of flavonoids include flavonols, aurones, flavones, flavanols, chalcones, red and blue anthocyanin pigments. isoflavones is the phenyl ring B is connected at position 3 of 1, 4-benzopyrone ring. The soybean is most rich source of isoflavones (up to 3 mg g^{-1} dry weight)

in the nature (Kudou *et al*., 1991). Chen *et al*. (2003) and Setchell *et al*. (2005) reported that after the soybean is consumed, the glycosidic forms of the isoflavones undergo hydrolysis due to the action of the brush border and bacterial β-glucosidases to remove the sugar moiety, the aglycone form is then either absorbed or undergoes further metabolism by intestinal bacteria in the large bowel . Devi *et al*. (2009) studied the functional attributes of soybean seeds and products, with reference to isoflavone content and antioxidant activity. Isoflavone prevent the different kinds of diseases like bone health, cancer, cardiovascular, menopause, diabetes and obesity (Dixit *et al*., 2011; Kushwaha *et al*., 2014). Bondesson and Gustafsson (2010) studied the epidemiological and clinical studies of isoflavone they have concluded that most epidemiological investigations have found that soy intake is associated with a modest reduction in breast cancer risk. Byun *et al*. (2010) evaluated the effects of consuming yellow soybeans, black soybeans (*Glycine max*) or sword beans (*Canavalia gladiate*) on lipid and oxidative stress levels in an ovaryectomized rat model. They have suggested that consumption of various types of beans may inhibit oxidative stress in postmenopausal women by increasing antioxidant activity and improving lipid profiles. Notably, intake of black soybean resulted in the greatest improvement in risk factors associated with cardiovascular disease. Sotoca *et al*. (2010) studied the quantitative proteomics and transcriptomics addressing the estrogen receptor subtype-mediated effects in T47D breast cancer cells exposed to the phytoestrogen- genistein they have concluded that the effects of genistein on proteomics and transcriptomics end points in the T47D-ERβ cell model are comparable with those reported previously for estradiol with the ultimate estrogenic effect being dependent on the relative affinity for both receptors and on the receptor phenotype (ERα/ERβ ratio) in the cells or tissue of interest. Li *et al*. (2009) reported that genistein depletes telomerase activity through cross-talk between genetic and epigenetic mechanisms they have shown that genistein is working, at least in part, through epigenetic mechanisms of telomerase inhibition in breast benign and cancer cells and may facilitate approaches to breast cancer prevention and treatment using an epigenetic modulator combined with genistein. Soy extract is more potent than genistein in the inhibition of tumor growth (Kim *et al*., 2008). Nagarajan (2010) suggested that soy isoflavone might be restrain the endothelial cell activation effect which is associated to chronicle disease such as atherosclerosis by blocking the activation of inflammatory cells and the adhesion to the vascular endothelium. Furthermore the atherosclerotic protection of soy isoflavones is arbitrated through the regulation of monocyte activation.

Folate plays a vital role in the one-carbon metabolism for physiological nucleic acid synthesis and regulation of gene expression, cell division, neurotransmitter synthesis and amino acid metabolism (Djukic, 2007). Blencowe *et al*. (2010) studied folic acid to reduce neonatal mortality from neural tube disorders. Their study provides a quantitative estimate of the effect folic acid on the fall in risk of neonatal mortality by folic acid fortification and supplementation. Barua *et al*. (2014) has investigated the effect of folic acid supplementation in pregnancy and implications in health and disease. Folate can help to reduce risk of heart disease. Number of other health outcomes is highly controversial throughout the pregnancy by the effect of folate (Fekete *et al*., 2010). Soybean is a source of folic acid with about 2500 μg kg^{-1} on dry matter basis. There is scope for studying the folic acid levels in the processed grain and products there from, with bioaccessability of the vitamin. The processing conditions have adverse effects on folic acid levels. Folic acid has been implicated in many other health disorders like anemia, mal absorption of nutrients, brain development in infants, in treating Alzheimer's disease, age related hearing loss etc. Therefore the diets rich in Soybean a good source of this vitamin could be of value to nutrition.

Table 6: Some recent representative patents on soybean

Titles	Patent No.	Inventors	Published
Soybean cultivar 131TD735	US2014/0109255 A1	John A. Schillinger and co-workers	April 17 2014
Quantitative trait loci associated with soybean cyst nematode resistance and methods of their use	US 2014/0215657 A1	Nguyan and co-workers	July 31 2014
Novel application of soybean emulsion composition to soybean-derived raw material containing food or beverages	US 2014/0113013 A1	Samoto and co-workers	April 24 2014
Method to identify Asian soybean rust resistance quantitative trait loci in soybean and compositions thereof	US 2014/0137299 A1	Baley and co-workers	May 15 2014
Soybean variety A1026692	US 2013/0042356 A1	Jesse Gilsinger	Feb 14 2014
Processed soybean material and method for producing processed material	US 2013/0183429 A1	Samoto and co-workers	July 18,2013
Method for preparing soy isoflavone nanopartical by precipitation with compressed antisolvent using a supercritical fluid	US 2013/0190392 A1	Luo and co-workers	July 25 2013
Soybean transgenic event MON87751 and methods for detection and use thereof	WO2014/201235 A2	Beazley Kim and co-workers	Dec 18 2014
Method for preparing fermented soybean meal to increase feed efficiency and milk yield of dairy cows	WO2014/200241 A1	Lee Jong Hwa and Koo Bon Tag	Dec 18 2014
Use of pro-fungicides of UK-2a for control of soybean rust	CA2872022 A1	Owen John and co-workers	Nov 14 2013
Method of preparing soy isoflavone nanoparticles by precipitation with compressed antisolvent using a supercritical fluid	US20130190392 A1	Kathy Qian Luo	Jul 25 2013
Method of preparing a controlled release particle of soy isoflavone with biodegradable polymer using a supercritical fluid extraction of emulsion process	US20130189320 A1	Kathy Qian Luo	Jul 25 2013
Folic acid in solid dosage forms	US64465013 B1	Douglas P. DeBernardi	15 Oct 2002
Folic acid containing pharmaceutical compositions and related methods and delivery systems	US20060281723	Michael E. Kafrissen, Godfrey Oakley	14 Dec 2006
Complete nutritional powder and preparation method there of	US20150140178 A1	L.U. Mignfu	21 May 2015
Conjugates of noscapine and folic acid and their use in treating cancer	US20110286919 A1	Harish C. Joshi, Surya N. Vangapandu, Ritu Aneja	24 Nov 2011

PATENTS ON SOYBEAN

Due to tremendous commercial importance of the soybean products, there is increasing rush to patent inventions of Soybean to compete in the world market (Table 6). The patents on soybean crop deal with its improvement both for productivity and also quality traits. Also the patents deal with the process of making several improved products which are of value in food and also in health foods sector. Thus the patents on soybean are ever increasing. Here only some representative ones are given to emphasize the importance of soybean patents from mentioned perspectives.

CONCLUSION

Soybean is becoming an important crop for its nutritional value and also health food applications. Though traditionally a crop of Asian region has been now cultivated extensively worldwide and the food technological developments have added a number of newer applications. The research on the elucidation of bioactive properties has been in full swing which adds greater credibility to the claims made for health applications. In view of its utility for isoflavones as the

major bioactive molecules it is gaining importance in designer foods. The protein and the fermented products add value as nutritionally important recipes for people of all ages. As a source of edible oil this crop is already a big commercial success. The presence of folic acid is an additional attraction, since the deficiency of this nutrient is a serious concern globally. Though raw soybean contain about 2500 μg kg^{-1} on dry matter basis, cooked tempe will have additional benefit of B12 vitamin and isoflavone and the folic acid retained, with bioaccessability of over 80%. Thus soybean has a great potential as a source of important nutrients and nutraceuticals of implication to human health. Therefore the innovations that is taking place has in the development of processes and products of soybean will provide further boost to the aspect of utilization of soybean beyond the usage as oil seed crop.

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