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Soybean (*Glycine max L*): A Synonym for Nutrition, Health and Longevity

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Abstract

Soybean, a nutrient nugget, is in use for more than 5000 years in China and South East Asia as a foodstuff. Despite being a legume crop, it is widely used as an oilseed. It has emerged as one of the important commercial crops in many countries. Soybean has immense potential as nutritive protein food. It can supply the much needed protein to human diets as it contains above 40% protein with essential amino acids, particularly rich in tryptophan and lysine. It has high content of polyunsaturated fatty acids, fiber, vitamins and minerals and low in saturated fat. Epidemiological studies show its importance in the prevention of several diseases. Consumption of soy foods may contribute to a lower incidence of coronary artery disease, type 2 diabetes mellitus, certain cancers such as breast and prostate and ensure a better bone health, relief of menopausal symptoms, as well as weight control. Many of the health benefits of soyabean are derived from its secondary plant metabolites such as flavones, phyto-sterols, lecithins, saponins etc. This review discusses the bioactive components of soybean and their role in prevention and management of diseases and provides information pertaining to some traditional foods products made from soybean.

Keywords: Estrogenic, Health benefits, Menopause, Osteoporosis, Omega-3 fatty acid, Soybean.

Introduction

Nutrition is one of the most important basic needs, a major determinant of health, labor productivity and mental development. In developing countries having a background of hunger and malnutrition majorly attributed to among population explosion, shortage of fertile land and high food prices; legumes with high protein and energy values accompanied by vitamin and minerals could become instrumental to take up the scourge (Vadiveli and Janardhanan, 2005). Among legumes, soybean has the potential to play an important role for improving nutrition. Soybean (*Glycine max* L.) belongs to family Leguminosae and subfamily Papilionidae. There are ten species of genus Glycine and several thousand varieties (Chauhan and Chauhan, 2007). It ranges in weight from about 100 to 300 mg each, with a diameter of 4-8 mm. The shape of the seeds varies from spherical to flattened discs and the colour from pale green and yellow to dark brown (Kumar et al., 2008). Soybean proteins are used in human foods in a variety of forms, including infant formulae, flours, protein isolates, concentrates, and textured fibers. Soy foods include cheese, drinks, miso, tempeh, tofu and vegetarian meat substitutes. New soy foods are continually being developed (Friedman and Liardon, 1985; Friedman, 1999). Consumption of soy foods is increasing because of reported potential beneficial effects on nutrition and health. These benefits include lowering of plasma cholesterol, prevention of cancer, management of diabetes and obesity and protection against bowel and kidney diseases.

Production

Though soybean originated in Eastern Asia U.S., Brazil, Argentina, China and India have become the world's largest soybean producers and represent more than 90% of global soybean production (http://www.agricommodityprices.com /soybean.php). India is the fifth largest producer of soybeans in the world (http://www.Spectrum commodities. com/education /commodity/ statistics/ soybeans. html). In India, soybean has been

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cultivated over a large area, mostly in the hilly areas. It is grown mainly in Madhya Pradesh, Uttar Pradesh, Haryana and Punjab. The world produces about 150 million tones of soybean of which less than 10% is used as human foods. Much of the soya meal is used for animal feed. This crop is also grown in Ethiopia, Nigeria, Uganda and Tanzania (Orhevba, 2011).

Nutrient Value of Soybean

Soybean contains all the three macronutrients required for good nutrition, protein (40%), carbohydrate (18%), fat (18%) and moisture (9%) as well as vitamins and minerals (5%) (National Soybean Research Laboratory, 2008). It is an excellent source of minerals especially calcium, iron, manganese, magnesium, copper, zinc and potassium. (FAO, 1971; Chaudhary and Pareek, 2010; Khetarpaul and Goyal, 2008). It is also a good source of vitamins like thiamine, riboflavin, niacin and folate (Orhevba, 2011). It contains protein, which is the highest among the pulses. Soybean oil is one of the few common vegetable oils that contain a significant amount of omega-3 and omega-6 fatty acids (Sacks et al., 2006). Because of its high protein and fat contents, it is being utilized for increasing the protein content of many processed foods including milk products (Shinde et al., 2001). It has vitamin E as antioxidant along with good levels of isoflavones (genistein and daidzein and glycitein), a combination which can reduce the risk of hazardous diseases like breast cancer, osteoporosis, coronary heart disease, kidney stones and relieves post reproductive women of post-menopausal symptoms (Kumar et al., 2002).

Soyprotein

Soybean acts as a concentrated source of vegetable proteins. Among legumes, soybean is considered an excellent source of quality protein and compares well with animal protein in essential amino acids pattern with the exception of sulphur containing amino acids (Gandhi, 2000). About 92-100% of soybean protein is digestible in humans. It contains about 40% protein, of which, 90% is comprised of two storage globulins, 11S glycinin and 7S β-conglycinin. Soybean also contains the biologically active protein components hemagglutinins, trypsin inhibitors, α-amylase and lipoxygenases (Liu, 1997; Dixit et al., 2011). Proteins are abundantly rich in lysine. Soybean protein provides all the nine essential amino acids in the amounts needed for human health. Fortification of cereals with soybean will not only improve protein quantity but also improve their quality such as amino acid balance (Singh et al., 2009).

Isoflavones

Isoflavones are a subclass of a larger and more ubiquitous group of phytochemicals called flavonoids. The soybean is most abundant source of isoflavones (up to 3 mg/g dry weight) in the nature (Dixit et al., 2011). Soybean contains three types of isoflavones, occurring in four chemical forms: the aglycones- genistein, daidzein and glycitin; the glucosides- genistein, daidzein, and glycitin; the acetyl glucosides- 6”-O-acetylgenistin, 6”-O-acetyldaidzin, 6”-O-acetylglycitin; and the malonyl glucosides- 6”-O-malonylgenistin, 6”-O-malonyldaidzin, and 6”-O-malonylglycitin (Kodou et al., 1991; Xu et al., 2002). In intact, minimally processed soyabean 6”-O-malonylgenistin is the major isoflavone followed by genistin, 6”-O-malonyldaidzin, and daidzin respectively. These four components contribute about 83% to 93% of the isoflavones. The remaining eight isoflavones represent about 7% to 17%. Isoflavones are structurally similar to mammalian estradiol and can bind to both α and β isoforms of estrogen receptor (ER), thus called phytoestrogens (Wuttke et al., 2003). Soy isoflavones, because of their selective binding with much higher affinity to ER β, are more accurately classified as selective estrogen binding modulators (SERMs) (Kuiper et al., 1996; Kuiper et al., 1998; Kuiper et al., 1997; Messina and Wu, 2009). Once ingested, intestinal microflora hydrolyze isoflavone glucosides to absorbable aglycones or transformed into metabolites such as equol or O-desmethylangolensin (O-DMA) from daidzein (Watanabe et al., 1998; Setchell et al., 2002; Atkinson et al., 2005; Decroos et al., 2005; Franke et al., 2004).

Health benefits of Soybean

Soybean has been found to protect against diseases such as breast cancer, prostate cancer, menopausal symptoms, cardiovascular disease, and osteoporosis (Bingham et al., 1998; Setchell, 1998; Potter et al., 1998; Setchell and Lydeking-Olsen, 2003; Spence et al., 2005). It is also required for growth, physiological functions and maintenance in animals because of the presence of omega-3 and omega-6 fatty acids. Omega-3 fatty acids are also the primary components of the phospholipid bilayer in the membrane cells, brain, retina, nerve tissues. In addition, their antithrombotic, anti-inflammatory, anti-immunoreactive properties mark their significance in preventing atheroscelerosis, arthritis, allergies and other chronic diseases (Kumar et al., 2006). Health benefits of soybean seed are as follows.

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Soybean and Cardiovascular Disease

CVD is characterized by impaired blood flow in the coronary arteries which can result in angina, myocardial infarction and sudden dealth. According to the meta-analysis of 23 studies, 11 randomized controlled trials and recent critical reviews, intake of soybean foods containing soybean protein upto 36g/day or above and isoflavones upto 52 mg/day is assumed to decrease serum total cholesterol (3.77%-9.3%), LDL cholesterol (3% - 12.9%) triacylglycerol (10.5 %) and increased HDL cholesterol (2.4%) (Anderson et al., 1995; Anderson et al., 1998; Weggemans and Trautwein, 2003; Zhan and Ho, 2005; Balk et al., 2005; Dewell et al., 2006; Welty et al., 2007). Other beneficial effects of soybean which have been documented, decreased C-reactive protein, blood pressure, triglycerides, reduction of homocysteine levels in plasma (Jenkins et al., 2002) and oxidized LDL, thought to be responsible for CVD (Steinberg et al., 2003) (Anderson et al., 1995; McVeigh et al., 2006; Zhan and Ho, 2005). It also has some beneficial effects such as inhibition of proinflammatory cytokines or cell adhesion protein, inhibition of reactive nitrogen species (Yen and Lai, 2003), reduction of platelet aggregation (Dixit et al., 2011), reduction of hepatic cholesterol synthesis (Anderson and Hanna, 1999), reduction of the activation of an enzyme (HMG CoA Reductase) that participates in cholesterol synthesis (Delzenne and Kok, 2001), improvement of vascular reactivity (Steinberg et al., 2003), stimulation of the production of nitric oxide (Achike and Kwan, 2003) and have potent clinical vasodilatory and anti-inflammatory effects (Szmitko et al., 2003) which protect heart. Sagara et al., (2004) conducted a study in Scotland and they concluded that dietary intakes of soybean protein (at least 20 g) and isoflavones (at least 80 mg) for 5 weeks would be effective in reducing CHD risk among high-risk, middle-aged men. Because of substantial evidence that soybean protein intake improves serum lipid profile (Anderson et al., 1995; Yang et al., 2005), the US Food and Drug Administration and the American Soybean Association issued a recommendation of daily consumption of ≥25 g soybean protein as a preventive measure to reduce the risk of heart disease (Food and Drug Administration, 1999; Yang et al., 2005; Teixeira et al., 2000).

Soybean and Hypertension

Hypertension is elevated blood pressure. WHO defined it as a condition in which systolic pressure exceeds 160 mm Hg and diastolic pressure exceeds 95 mm Hg. Soybean isoflavones have been shown to decrease *in vivo* oxidation of biomolecules (Wiseman et al., 2000), arterial stiffness (Teede et al., 2001; Grundy 2003; Nestle, 2003), improve systemic arterial compliance (Mishra et al., 2000; Nevala et al., 1998) and favorably affect salt and water balance (Martinez et al., 1998), all of which suggest a protective role with respect to the development of hypertension. High magnesium content of soybean can cause expansion of the peripheral blood vessels thereby helps to decrease blood pressure (BP) to prevent hypertension. Soybean intake also lowers BP through a diuretic effect similar to furosemide (Martinez et al., 1998;Yang et al., 2005). Longitudinal study and several randomized controlled clinical trials showed that usual intake of soybean foods was inversely associated with both systolic and diastolic BPs, particularly among elderly women (Yang et al., 2005; Appel, 2003) and the reductions were substantially more pronounced in subjects with mild to moderate hypertension than in normotensive subjects (Rivas et al., 2002; Welty et al., 2007). Another study conducted by Washburn et al, 1999 found that soybean protein supplementation significantly reduced diastolic blood pressure (-5 mmHg) in perimenopausal women. It can be concluded that a soybean-based diet attenuated the development of hypertension in spontaneously hypertensive rats (Nevala et al., 2000).

Soybean and Cancer

Cancer is defined by abnormal growth and division of cells that can spread thoughout the body. Soybean isoflavones have been elucidated as anticarcinogenic agents protecting against hormone-dependent and hormone- independent cancer both *in vitro* and *in vivo* models (Messina, 1991; Messina, 2002). It has been documented to have robust effects on cellular signal transduction pathways, such as inhibition of tyrosine protein kinase (Ogawara et al., 1986; Akiyama et al., 1987), MAP (Mitogen activated protein) kinase (Frey and Singletary, 2003) and DNA topoisomerase (Constantinou and Huberman, 1995) which appear to be responsible for *in vitro* inhibitory effects on cancer cells (Ford, 2002; Constantinou et al., 1990). It has also been found to prevent LDL oxidation and inhibit DNA damage; a major factor in pathogenesis of cancer thus playing a role in preventing cancer (Giles and Wei, 1997). It also has been shown to have other cancer inhibitory properties, including the inhibition of inflammation, angiogenesis, and cell proliferation and to stimulate the production of sex hormone–binding globulin (SHBG) (Messina et al., 2006). Genistein has also been reported to augment transforming growth

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factor- β, an essential growth factor that inhibits the cell cycle and therefore progression of cell growth and decrease the amount and size of cancer tumors (Kris-Etherton et al., 2002).

From recent meta-analysis and cohort studies it is concluded that there is an inverse association of soybean intake and breast cancer risk (Lamartiniere et al., 2000; Lee et al., 2009; Butler et al., 2010; Jooyandeh, 2011). Nagata, 2000 conducted a study to evaluate the relationship between soybean product intake and mortality from several types of cancer in Japan and the results showed that soybean was found to have protective role against stomach cancer. On the other hand, Hakkak et al., (2001) conducted a study regarding colon cancer and it was found that adult male Sprague-Dawley rats fed soybean protein isolate-containing diets had significantly lower incidence of azoxymethane (AOM)-induced colon cancers than control rats fed casein diets while Yan and Spitznagel, 2009 found the reduction in prostate cancer risk in men. On the whole, it can be concluded that isoflavones may reduce the risk of a number of cancers, including those of the breast, lung, colon, rectum, stomach and prostate (Jooyandeh, 2011).

Soybean and Osteoporosis

Osteoporosis is a bone disease that is characterized by a decrease in bone mass density which can lead to an increased risk of fracture. Epidemiological evidence has shown that consumption of soybean protein increases bone mineral density (BMD) (Potter et al., 1998; Germain et al., 2001), reduces risk of fractures (Messina, 2002; Zhang et al., 2005) and decreases urinary calcium excretion due to its lower sulfur amino acid content (Breslau et al., 1988; Spence et al., 2002; Barzel, 1995). It has also been documented that consumption of soybean isoflavones, particularly genistein, upto 5 mg/kg body weight, reduced bone mineral loss at femoral neck and lumbar spine (Kotecha and Lockwood, 2005), hip fracture (Ross et al., 1991), ovariectomy-induced bone loss (Picherit et al., 2001), increased spine bone mineral density (SBMD) (Ma et al., 2008), maintained both cortical and trabecular bones in ovariectomized rats and had significant favorable effect on bone mass density (BMD) at the lumbar spine and hip in women (Liu et al., 2009). Brink et al., 2008 carried out studies in healthy men who were assigned to consume 40 g of either soybean protein (SP) or milk-based protein (MP) daily for 3 months. Serum insulin-like growth factor-I (IGF-I), which is associated with higher rates of bone formation, was greater ($P < .01$) in men supplemented with SP than in those consuming MP. In ovariectomized rats, soybean isoflavones have been shown to reduce the urinary excretion of deoxypyridinoline (Dpd), a specific marker of bone resorption, and genistin has been found to stimulate alkaline phosphatase activity of an osteoblast-like cell line, suggesting a positive effect on bone formation (Picherit et al., 2001; Ma et al., 2008; Choi et al., 2001). It is reasonable to suggest that soybean or its isoflavones enhance bone formation based on at least two lines of evidence: (1) Soybean isoflavones stimulate osteoablastic activity through activation of estrogen receptors (Ma et al., 2008; Choi et al., 2001), and (2) soybean or its isoflavones promote insulin-like growth factor-I (IGFI) production. It is well recognized that IGF-I enhances osteoblastic activity in humans and IGF-I concentrations have been reported to correlate positively with bone mass in pre- (Romagnoli et al., 1993), peri- (Nasu et al., 1997), and post- (Boonen et al., 1996) menopausal women. Lockwood, 2008 conducted a study on elderly people and concluded that dose of 60-100mg isoflavones/day may be sufficient for prevention of osteoporosis, and this translates to 2-3 servings of soybean food.

Soybean and Diabetes Mellitus

Diabetes mellitus is a group of diseases characterized by high blood glucose concentrations resulting from defects in insulin secretion, insulin action or both. Soybean has been shown to decrease postprandial hyperglycemia, improve glucose tolerance, and decrease amounts of glycosylated hemoglobin (Bhathena and Velasquez, 2002). Blair et al., 2006 suggested that soybean foods may be an appropriate part of diets to regulate blood glucose and insulin levels because of its low glycemic index. Regular consumption of soybean protein is associated with the reduced symptoms of type2 Diabetes (Villegas et al., 2008). *In vitro* studies showed that isoflavones may inhibit glucose uptake into the intestinal brush border by restraining the activity of protein tyrosine kinase or decreasing the sodium-dependent glucose. Evidence also suggested that the abundance of glycine and arginine in soybean protein (Liu et al., 2010) could be involved in insulin and glucagon secretion from the pancreas (Ascencio et al., 2004; Lavigne et al., 2000). Some small scale randomized controlled trials (RCTs) (Azadbakhi et al., 2005) showed that natural soybean foods and soybean protein isolates (SPIs) or isoflavones might improve glucose homeostasis and kidney function among subjects with diabetes (Liu et al., 2010). An observational investigation in postmenopausal

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women found a favorable association between regular consumption of soybean protein and a lower body mass index and lower fasting insulin levels (Bhathena and Velasquez, 2002). Several observational studies (Goodman-Gruen and Kritz-Silverstein, 2001) showed that habitual soybean/phytoestrogen intake was inversely associated with the risk of diabetes.

Soybean and Allergy

Food allergy denotes an adverse immunologic response to a specific substance with characteristic symptoms whenever food is ingested. It can also be defined as "altered reaction of the tissue to foreign protein or antigen (Srilakshmi, 2005). Cow's milk protein allergy (CMPA) is a common food allergy in early childhood with a prevalence of 2.0-7.5%. CMPA typically develops in early infancy, presenting at the time of weaning and is characterized by symptoms involving the skin (angioedema, urticaria), gastrointestinal tract (diarrhoea and colic), respiratory tract (wheezing, dyspnoea and cough) and failure to thrive (Tewari et al., 2006). Almost half of these infants begin to tolerate cow milk by the age of 2 years. After weaning from breast milk, infants with cow milk allergy (CMA) are usually given either an extensively hydrolyzed formula or a soybean formula. Soybean formulas have a long history as alternative formulas for infants who are allergic to cow milk (Seppo et al., 2005). Soybean protein based formulas offer an affordable and accessible vegan breast milk alternative. It is lactose-free and appropriate for use in infants with galactosaemia and hereditary lactase deficiency (Tewari et al., 2006).

Soybean and Menopause

Menopause is defined as the cessation of menstrual cycle and is determined by following 12 months of amenorrhea during the midlife period (Mahady et al., 2002). It is a period normally occupy one-third of women's life (Barrett-Connor, 1993; Hanachi et al., 2007). Reduced BMD is one of the most prominent symptoms during menopause (Dempster and Lindsay, 1993). This usually occurs between 45 and 55 years of age (Andrews, 1995). Soybean isoflavones, an estrogen like compound, (Kurzer and Xu, 1997) can reduce BMD in menopausal women. (Messina, 2002; Zhang, et al., 2005; Coward et al., 1993; Messina, 1999). During menopause, between 55–75% of women experience vasomotor symptoms (hot flashes) or other symptoms such as depression, mood swings, sleep disorders, vaginal dryness, and joint pain (Brosage, 1995; Mahady et al., 2002). According to the several studies it can be documented that soybean isoflavones alleviate the symptoms of hot flashes by 25-75% reduction (Adlercreutz et al., 1992; Loprinzi et al., 2001). Evidence in healthy women suggests that phytoestrogens can alter serum hormones, lengthen the menstrual cycle and improve vaginal dryness (Patten et al., 2002).

Soybean and Obesity

Obesity is a disorder of energy balance and is associated with hyperinsulinemia, insulin resistance and abnormalities in lipid metabolism and it is one of the most important risk factors in the development of Type2 diabetes, cardiovascular disease, atherosclerosis and certain cancers. Adipocytes play a central role in lipid homeostasis (Jooyandeh, 2011). These cells store energy in the form of triglycerides during periods of nutritional abundance and release it as free fatty acids in times of nutritional deprivation. Excess fat consumption can stimulate enlargement of existing adipocytes and induce differentiation of dormant preadipocytes in the adipose tissue into mature adipocytes to accommodate the demand for extra storage (Harp, 2004). Hormones including estrogen, growth hormone, thyroid hormone, catecholamines, glucagons, insulin and insulin-like growth factor are regulators of the adipogenesis (Hausman et al., 2001). 17β-estradiol, the most ubiquitous estrogen, is a major regulator of adipocyte development and adipocyte number in females and males (Anderson et al., 2001). As a result of isoflavones structural similarities to endogenous estrogens, isoflavones elicit weak estrogenic effects by competing with 17β-estradiol for binding to the intranuclear ERs and exert estrogenic or antiestrogenic effects in various tissues (Orgaard and Jensen, 2008). In a study on postmenopausal women found a favorable association between usual consumption of soybean protein and a lower body mass index, higher HDL cholesterol concentration and lower fasting insulin levels (Bhathena and Velasquez, 2002). Isoflavones especially genistein may help to stay lean by causing us to produce fewer and smaller fat cells (Naaz et al., 2003).

Soybean and Immunity

The immune system encompasses an array of defense that helps to guard against the development of age-related diseases. Its functions can be adversely affected by oxidative damage and hormonal changes (Watanabe et al., 2002). The immune system may be compromised after menopause due to diminishing concentrations of

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estrogen, an immune-modulating hormone. Isoflavones, plant-derived compounds with estrogenic and antioxidant properties, may affect immunologic benefits to women during this stage of life. Consumption of isoflavone containing soybean foods modulates cytokine production and daidzein enhances the activity of natural killer cells in vitro (Zhang et al., 1999). Therefore the immune system may benefit from the various biological properties of isoflavones. Enhanced immune responses have been found in animals fed soybean foods (Guo et al., 2002; Guo et al., 2001).

Side Effects

Despite these favorable observations, several studies have failed to show that isoflavones or isoflavone rich soybean protein affects BMD (Alexandersen et al., 2001). Although overall the data are intriguing, the results from long-term trials are needed before firm conclusions about the skeletal effects of isoflavones can be made. Overall, animal studies indicate that isoflavone-rich soybean protein and isolated isoflavones inhibit induced mammary cancer but the epidemiologic data are much less consistent and supportive. (Messina and Loprinzi, 2001). Consumption of soybean products by women can increase the concentration of phytoestrogens in breast milk by 10-fold. The increase in phytoestrogen levels in breast milk is of concern because genistein can be transferred from the lactating mother to the neonate via the milk. Since it has been shown that infants can digest and absorb dietary phytoestrogens in active forms and since neonates are generally more susceptible than adults to perturbations of the sex steroid milieu, exposure to these naturally occurring estrogenic compounds may pose a developmental hazard to the developing offspring and affect target tissue functions later in life (Hughes et al., 2004).

Conclusion

This research article has shown that soybean is an important crop. It has a good amount of protein, fat, fibre as well as trace elements and minerals. Besides its nutritional value, soybean also possesses various medicinal properties due to the presence of isoflavones. It is known to prevent and cure human diseases like cardiovascular diseases, hypertension, cancer, osteoporosis and diabetes mellitus. Soy protein has been approved as functional food making it one of the most valuable vegetable proteins. Soybean can contribute to nutrient biodiversity in an instrumental way.

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