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Health benefits of soy beans and soy products: a review

Christina S Venter

OPSOMMING

Sojabone is volop, ekonomiese dieetbronne van proteïen. Tans word gefokus op die moontlike rol van sojabone in die voorkoming en behandeling van sekere degeneratiewe Westerse siektes soos hart- en bloedvatsiektes, osteoporose en sekere tipes kanker. Heel sojabone bevat 40% proteïene, terwyl sojameel, sojaproteïenkonsentraat en geïsoleerde sojaproteïen respektiewelik 50%, 70% en 90% proteïen bevat. Verskeie nie-nutriëntbestanddele soos isoflavone, protease-inhibeerders, fitiensuur, saponiene en fitosterole kom in sojabone voor en is moontlik vir sekere van die voordelige gesondheidseienskappe van sojabone verantwoordelik. Die cholesterolverlagende effek van sojabone mag te danke wees aan die aminosuursamestelling daarvan, en/of verlaagde cholesterolabsorpsie of galsoutherabsorpsie, verhoogde laedigtheidlipoproteïen-(LDL-) reseptoraktiwiteite, verlaagde lewercholesterolsintese, anti-oksidantaktiwiteit of verhoogde plasmatiroksienvlakke. Die nie-nutriëntbestanddele van sojabone mag vir die cholesterolverlagende, antikarsinogeniese en beenversterkende effek verantwoordelik wees. Meer navorsing is nodig om die meganismes op te klaar waardeur sojabone en sojaprodukte die gesondheid van die mens beïnvloed.

— Prof CS Venter
Department of Nutrition and Family Ecology, PU for CHE, Potchefstroom

INTRODUCTION

Soy beans has been a food in China for thousands of years. It is an abundant, economic source of protein. No other nation has acquired the same taste for soy beans as the Chinese and Japanese, but the bean has become an important raw material for the international food industry. Attention has recently focused on the possible role of soy beans in the diet for the prevention and treatment of degenerative Western diseases (Anderson *et al*, 1995a; Knight & Eden, 1996; Kurzer & Xu, 1997; Potter, 1998). Several studies documented the hypocholesterolaemic effects of soy beans (Anderson *et al*, 1995b, Potter, 1998), the anticarcinogenic effects of soy beans (Barnes *et al*, 1996), and the ability of soy beans to lower the risk of osteoporosis (Adlercreutz & Mazur, 1997).
The purpose of this review is to describe the physiological and biochemical effects of soy bean components in the body, and their possible prevention of the above diseases. Recommendations are submitted for further research in this regard and on the amounts that may safely be included in the human diet.

COMPOSITION OF SOY BEANS

Soy beans are classified as oil seeds, not as dry beans. Table 1 contains the nutrient composition of 100 g of cooked dried haricot, kidney and soy beans (Langenhoven *et al*, 1991), and Table 2 presents the percentage contribution of the macronutrients in soy and dry beans to the total energy content. Whole dry soy beans contain about 40% protein (twice as much as most other pulses) and up to 20% fat. Whole soy beans are a good source of calcium, iron, zinc, phosphorus, magnesium, thiamin, riboflavin, niacin and folacin.

It was recently recognised that the human diet contains, in addition to essential macro and micronutrients, a complex array of naturally occurring bioactive nonnutrients called phytochemicals (plant-derived compounds) that confer significant long-term health benefits (Setchell, 1998). Among these phytochemicals is the broad class of nonsteroidal oestrogens called phytoestrogens that also behave as oestrogen mimics. The major classes of phytoestrogens that are of interest from a nutritional and health perspective, are the lignans and the isoflavones. Soy beans contain large amounts of the isoflavones diadzein, genistein an glycitein (1-3 mg/g) and their acetyl and malonyl conjugates (Song *et al*, 1998). Studies have shown that concentration and composition vary in different soy beans or soy protein products (Murphy,

TABLE 1: THE NUTRIENT COMPOSITION OF DRY AND SOY BEANS* COMPARED TO RECOMMENDED DIETARY ALLOWANCES**

Nutrient	100 g cooked beans			RDA **
	Haricot	Kidney	Soy	
Moisture (%)	69,6	70,5	62,6	
Energy (kJ)	413	423	706	
Protein (g)	6,6	7,1	16,6	63,0
Fat (g)	0,5	0,3	9,0	
Saturated fatty acids (g)	-	-	1,3	
Monounsaturated fatty acids (g)	-	-	2,0	
Polyunsaturated fatty acids (g)	-	-	5,1	
Carbohydrate (g)	16,6	17,1	4,8	
Dietary fibre (g)	7,4	5,1	1,6	
NSP*** total (g)	8,3	6,7	2,9	
Soluble NSP (g)	3,7	3,2	0,1****	
Insoluble NSP (g)	4,6	3,5	2,0****	
Calcium (mg)	65	19	102	800
Iron (mg)	2,5	1,7	5,1	10
Magnesium (mg)	45	33	86	350
Phosphorous (mg)	120	87	247	800
Potassium (mg)	320	400	515	
Sodium (mg)	15	16	1	
Zinc (mg)	1,0	1,0	1,2	15,0
Copper (mg)	0,14	0,16	0,41	
Vitamins: Thiamin (mg)	0,11	0,14	0,16	1,5
Ribloflavin (mg)	0,06	0,07	0,29	1,7
Niacin (mg)	0,7	0,7	0,4	19,0
A (RE)	-	-	1	1000,0
E (mg α -TE)	-	-	0,35	10,0
Folic acid (µg)	-	-	54	200,0

* South African Food Tables (Langenhoven *et al, 1991)*
*** RDA: Recommended dietary allowances (Food and Nutrition Board, 1989)
*** NSP: Nonstarch polysaccharides (Englyst *et al*, 1988)
**** AOAC: Association of Analytical Chemists, In Slavin, 1991

1982) and that this variation is due to species differences (Franke *et al*, 1995), geographic and environmental conditions (Eldridge & Kwolek, 1983), and the extent of the industrial processing of soy beans (Murphy, 1982; Coward *et al*, 1998). Table 3 illustrates the varied isoflavone concentration in a range of soy products.

PROCESSING OF SOY BEANS

The processing of soy beans as described by Snyder and Kwon (1987:74-78) may be summarised as follows:

Soy beans selected for processing are graded, cleaned, dried to about 10% moisture content, and

TABLE 2: CONTRIBUTION OF MACRONUTRIENTS TO TOTAL ENERGY CONTENT OF DRY AND SOY BEANS *

	Percentage contribution of total energy			
Nutrient	**Beans**			**Dietary goals**
	Haricot	**Kidney**	**Soy**	
Total fat	4,6	2,7	48,4	<30
Saturated	-	-	7,0	<10
Monounsaturated	-	-	10,7	10
Polyunsaturated	-	-	27,5	10
Carbohydrate	68,7	68,7	11,6	≥60
Protein	27,2	28,5	40,05	10-15

* Based on nutrient composition in Table 1

cracked to remove the hull. **Soy bean hulls** are processed to create fibre additives for breads, cereals, snacks and livestock feed. After dehulling, the beans are rolled into **full-fat flakes** that may be used in animal feed or processed into **full-fat flour** for various commercial food uses. Flaking ruptures the oil cells in the bean, improving the oil extraction process. The next step is to extract the **crude oil** which is later refined to produce cooking oil, margarine and shortening. **Defatted soy flakes** are used to produce animal feed and form the basis of a variety of products for human consumption, including soy flour, soy concentrates and soy isolates. These products are used extensively in manufactured foods to help retain moisture and to improve their shelf life, and they act as emulsifiers and as substitutes for meat in food products. **Soy flour** is produced by grinding the defatted flakes. The protein content of the flour is approximately 50%. Soy flour adds protein and improves the crust colour and shelf life of baked goods. **Soy isolates** are produced by a chemical process that withdraws most of the protein from the defatted flake, resulting in a product with about 90% protein content. Soy isolates contain no fibre or carbohydrates. Isolates are used in many dairy-like products, including cheese, milk, nondairy frozen desserts, coffee whiteners and meat products. **Soy concentrates** are prepared by removing the soluble sugars from defatted flakes. Soy concentrates contain about 70% protein and retain most of the bean's dietary fibre. The concentrates are used in protein drinks, as soup bases and in gravies. Soy flour and soy protein concentrates are used in meat products, primarily because of their fat and water absorption properties. These products are used in a **texturised form** as extenders in ground meat products, in convenience foods, in pizza toppings, meat and fish spreads, and in poultry products (Snyder & Kwon, 1987:74).

Texturised protein (textured vegetable protein (TVP)) is produced by the thermoplastic extrusion of defatted soy flour, soy concentrates or soy isolates, moistened and mixed with a variety of additives (Wolf *et al,* 1981). During the extrusion process, small chunks are produced which, when hydrated, have a chewy texture and a meaty taste (Wolf *et al*, 1981).

TABLE 3: ISOFLAVONE CONCENTRATION IN SOY PRODUCTS

Food	**Daidzein (µg/g)**	**Genistein (µg/g)**	**Glycitein (µg/g)**
Toasted soy flour*	1 343,4	1 509,5	242,5
Soy flour*	829,7	834,4	142,9
Isolated soy protein*	789,3	1 258,0	114,2
Textured vegetable protein*	919,7	1 092,1	98,4
Tofu**	133,1	169,0	20,9
Soy milk	1 772,0	3 804,0	327,0

**Coward et al, 1998s*
***Song et al, 1998*

CHOLESTEROL-LOWERING PROPERTIES OF SOY

Potential cholesterol-lowering effects

The judicious substitution of soy for animal protein reduces saturated fat and cholesterol intakes, indirectly resulting in a more favourable blood cholesterol level and potentially reducing the risk of coronary heart disease.

The cholesterol-lowering effects of soy protein, compared to animal protein, have been recognised in animals for more than 90 years (Ignatowsky, 1908 in Anderson *et al*, 1995). A number of human studies over the past 20 years have shown that the daily consumption of 30 g to 60 g of soy protein contributes to a decrease in total and LDL cholesterol of between 10% and 20% in individuals with elevated serum cholesterol (Carroll, 1991). High-density lipoprotein (HDL) cholesterol either remains unchanged or is increased under these circumstances (Anderson *et al*, 1995b; Baum *et al,* 1998). In addition, a significant 10% reduction in triglycerides has been reported in several studies, as noted in a meta-analysis by Anderson *et al* (1995b). According to these studies changes in lipid concentrations were independent of changes in body weight and the dietary intake of total fat, saturated fat and cholesterol.

As little as 30 g to 60 g of isolated soy protein in muffins, breads, cookies and other commonly eaten bakery items effectively lower raised cholesterol (Potter *et al*, 1993). Replacing milk with a soy beverage has been shown to decrease total serum cholesterol by 5% to 10% and low-density lipoprotein (LDL) cholesterol by 10% to 20% within four weeks (Steele, 1992). It is therefore suggested that very modest changes in the diet to include soy products have a measurable effect on the blood lipid levels.

Potential mechanism(s) of soy in lowering serum cholesterol concentrations or the risk of coronary heart disease

The mechanisms responsible for the effects of soy on serum lipoproteins are not well known. Carroll (1991) and Potter (1995) reviewed various hypotheses that are presented in this section. These include the amino acid composition of soy protein, an interruption of the intestinal absorption of bile acids and dietary cholesterol, direct effects on the hepatic metabolism of cholesterol, alteration of the hormone concentration involved in cholesterol metabolism, and the effects of components such as isoflavones, fibre and saponins in soy beans.

Studies on experimental animals have shown that the dietary substitution of amino acids patterned after soy protein produces significantly lower serum cholesterol concentrations than amino acids patterned after casein. The extent of cholesterol lowering, however, is not as great compared to the values in animals that were fed intact soy protein (Huff *et al* 1977; Tasker & Potter, 1993). According to Potter (1995), this indicates that there may be another constituent associated with soy protein that is either lost or liberated during hydrolysis of the protein, to be partly responsible for the cholesterol-lowering effect.

Sugano and Koba (1993) also reported that an indigestible fraction of soy protein lowers the serum and liver cholesterol concentrations. In this study soy protein was digested with microbial proteases, and the digestible and indigestible fractions were fed to rats. The results indicated that progressive replacement of casein with the indigestible fraction progressively lowered the serum and liver cholesterol. Faecal excretion of both neutral and acidic sterols increased in animals that were fed the indigestible fraction. However, when the undigested fraction was treated with a methanol extraction or was digested further, the cholesterol-lowering effect diminished. There appears to be some component in the indigestible fraction that is either lost or altered upon methanol extraction or further digestion.

Potter (1995) suggests that a component such as a saponin or isoflavone or a peptide-peptide sequence that alters the intestinal absorption of cholesterol and bile acids may be a candidate. According to Oakenfull (1981), only those plant fibres that contain saponins bind bile acids *in vitro*. Potter *et al* (1979) suggest that the hypocholesterolaemic action of whole soy protein or protein hydrolysates is attributable to the presence of saponins. In the studies with amino acids patterned after the intact proteins (Nagata *et al*, 1982; Tanaka *et al*, 1984), general decreases in serum cholesterol concentrations were noted - albeit less pronounced than when intact soy protein was fed - without influencing faecal bile excretion. Increased bile acid excretion on soy diets was observed primarily in rabbits and rats (Huff & Carroll, 1980; Nagata *et al*, 1982; Nagoaka *et al*, 1997). Reports on other species, including humans, are less consistent (Fumagalli *et al*, 1982; Grundy & Abrams, 1983). More recently, however, Wong *et al* (1996) as quoted by Potter (1998), found increases in the pool size of chenodeoxycholic acid in humans who were given soy protein to eat, but neither the cholesterol absorption nor the cholic acid pool size was affected.

In summary, it appears that when intact proteins are fed, cholesterol-lowering on feeding soy protein may be mediated by enhanced bile acid excretion in certain species. However, when amino acids are fed, cholesterol-lowering may be mediated by another mechanism(s).

Studies in animal models (Huff & Carroll, 1980; Nagata *et al*, 1982) have shown that soy protein consumption may directly influence the hepatic metabolism of cholesterol by increasing the activity of 3-hydroxy-3-methylglutaryl coenzyme A (HMG CoA) reductase, thereby inhibiting hepatic cholesterol synthesis. Lovati *et al* (1987) reported a sevenfold increase in LDL receptor activity in humans, resulting in increased clearance of cholesterol from the blood in pa-

tients with raised serum cholesterol concentrations who consumed a soy protein (Cholsoy) diet compared to a standard low-lipid diet with animal protein.

These results were confirmed by other researchers, as reported by Potter (1998). However, the hypothesis of an activation of LDL receptors in liver cells is still controversial and more extensive studies are needed to ascertain the cholesterol-lowering mechanism of soy beans.

It has been postulated that the consumption of soy protein alters many hormones involved in lipid metabolism (Forsythe, 1986; Scholz-Ahrens *et al*, 1990). Scholz-Ahrens *et al* (1990) reported increases in plasma total thyroxine, free thyroxine, and triiodothyronine in minipigs fed soy protein compared to those that were fed casein. Forsythe (1986) and Ham *et al* (1993) reported decreased cholesterol concentrations and increased plasma thyroxine in gerbils and humans respectively when soy protein was included in the diet. However, Potter (1998) investigated this phenomenon in several studies on animals and humans and did not find consistent results. In one study involving gerbils, soy protein concentrate and soy protein isolate significantly reduced the total and LDL cholesterol concentrations, but only soy protein isolate increased the thyroid hormone concentrations (Potter *et al*, 1996).

As all these hormones are known to be involved in cholesterol metabolism, it has been proposed that variation in hormone secretion is responsible for the cholesterol-lowering effect of soy protein. Especially with regard to the thyroid hormones, the metabolic effects of hyperthyroidism are very similar to those observed with soy protein feeding. That is, LDL receptor activity increases, HMG CoA reductase activity increases, bile acid excretion increases, and total and LDL cholesterol decrease (Potter, 1995). Some observers, as discussed by Carroll (1991), suggest that changes in the ratio of serum glucagon to insulin in patients on a soy protein diet may be important**.** High insulin:glukagon ratios are thought to be associated with increased risk of cardiovascular disease because of the stimulation of lipogenesis.

Isoflavones are known to have weak oestrogenic activity in biologic systems. Therefore it is increasingly popular to speculate that the mechanism by which soy beans decrease serum cholesterol is via "estrogenic" effects stimulated by the ingestion of isoflavones (Potter, 1995; Anthony *et al*, 1996). It is well known that mammalian oestrogens have a significant impact on serum lipids, promoting decreases in LDL and increases in HDL cholesterol. Evidence for an effect of isoflavones on serum cholesterol concentrations has been demonstrated in rats, hamsters, nonhuman primates and humans (Cassidy *et al*, 1995; Pelletier *et al*, 1995; Anthony *et al*, 1996; Balmir *et al*, 1996; Clarkson *et al*, 1998). The three primate studies reported by Anthony *et al* (1994, 1995a, 1995b) demonstrated that soy protein rich in isoflavones favourably affected serum lipids, and that soy protein from which the oestrogens had been extracted had a minimal effect. The authors concluded that soy isoflavones may account for 60% to 70% of the hypocholesterolemic effects of soy beans.

Cassidy *et al* (1995) reported that human consumption of 45 mg of isoflavonoids per day significantly reduced the total and LDL cholesterol concentrations in young females. Similar findings were reported by Potter *et al* (1993) and Bakhit *et al* (1994). In contrast, Nestel *et al* (1997) reported no significant effect on blood lipid concentrations of 45 mg of the isoflavone genistein, administered over a 5 to 10-week period. However, a significant improvement in systemic arterial elasticity was found in these women.

The effect of isoflavones on coronary vascular reactivity in an atherosclerotic primate model was studied by Honore *et al* (1997). They reported that the arteries of females fed a low-isoflavone diet constricted in response to acetylcholine, whereas the arteries of females who were fed a high-isoflavone diet dilated. In a study involving male primates (Anthony *et al*, 1997), the prevalence of atherosclerotic lesions was the lowest in monkeys fed soy protein plus isoflavones, intermediate in monkeys fed an alcohol-extracted soy protein low in isoflavones, and highest in monkeys fed a mixture of casein and lactalbumin. Another mechanism whereby soy beans may decrease the risk of cardiovascular disease is to lower the susceptibility of LDL cholesterol to oxidation (Lichtenstein, 1998). Isoflavonoids have been reported to inhibit the oxidative modification of LDL by macrophages (Kapiotis *et al*, 1997), enhance the resistance of LDL to oxidation (De Whalley *et al*, 1990; Kanazawa *et al,* 1995), and exhibit antioxidant activities in an aqueous phase (Ruiz-Larrea *et al*, 1997). Genistein inhibits bovine aortic endothelial cell-mediated and human endothelial cell-mediated LDL oxidation, and protects vascular cells from damage by oxidised LDL (Kapiotis *et al*, 1997). Nestel *et al* (1997) did not observe the antioxidative effect of genistein.

The soluble fibre content of soy beans is relatively low (see Table 1). Yet some data demonstrate that soy fibre is effective in lowering serum cholesterol in patients with raised cholesterol levels (Tsai *et al*, 1983; Shorey *et al*, 1985; Lo *et al*, 1986). However, in two studies that investigated whether different amounts of soy protein with and without soy fibre were effective in lowering serum lipids (Potter *et al*, 1993; Bakhit *et al*, 1994), no additive cholesterol-lowering effect of soy cotyledon fibre could be demonstrated. According to Potter *et al* (1993), this may indicate that the cholesterol-lowering effect of soy protein consumption may override the effects others observed with soy cotyledon fibre (Shorey *et al*, 1985; Lo *et al*, 1986). The beneficial effects of the insoluble fibre components of soy beans on bowel function (increased stool weight and decreased gastrointestinal transit time) have been demonstrated repeatedly, as discussed by Slavin (1991) in a review article. The fibre component of soy beans is therefore probably not responsible for the cholesterol-lowering effect of soy beans. It is also

likely that the cholesterol-lowering effect of soy is due to a combination of components acting together, and that the mechanism varies in different species. More work is required to determine the mechanisms of intact soy beans as well as its components in animals and humans. A better understanding of the mechanisms involved would help to optimise the use of dietary soy protein for the treatment of raised cholesterol concentrations.

ANTICARCINOGENIC EFFECTS OF SOY BEANS

Potential anticarcinogenic effects

Evidence from epidemiological studies suggests, although not entirely consistently, that soy bean-based diets protect against cancer of the breast (Nagasawa, 1980; Wu *et al*, 1998), prostate (Severson, 1989; Shimizu *et al*, 1991) and colon (Watanabe & Koessel, 1993). An epidemiological study carried out in Singapore found an inverse relation between the consumption of soy bean products and the risk of breast cancer in premenopausal women (Lee *et al*, 1991), but a subsequent study of Chinese women failed to find a similar association (Yuan *et al*, 1995). Further evidence that soy may protect against breast cancer development was provided by studies of rodent cancer models in which dietary soy supplements inhibited chemical and radiation-induced breast tumours (Troll *et al*, 1980; Barnes *et al*, 1990; Constantinou *et al*, 1998), prostatic dysplasia (Mäkelä *et al*, 1991) and colon cancer (Weed *et al*, 1985; Thiagarajan *et al*, 1998). Cell culture experiments have also shown that soy bean constituents completely prevent or suppress the induction of tumours in various organs (reviewed by Herman *et al*, 1995). Epidemiological studies as well as animal and cell culture experiments therefore provide evidence that suggests that the intake of soy beans lowers the risk of cancer.

Possible mechanisms in preventing cancer

A number of different compounds in soy beans may be responsible for various types of anticarcinogenic activity. These compounds include a protease inhibitor (the Bowman-Birk inhibitor), a trypsin inhibitor, isoflavones (genistein and diadzein), saponins, inositol hexaphosphate (phytic acid) and the sterol, -sitosterol (reviewed by Kennedy, 1995). Examples of different types of *in vitro* anticarcinogenic activity reported for a variety of soy bean constituents are summarised by Kennedy (1995). These constituents include the ability to prevent malignant transformation (protease inhibitor), the ability to suppress promotion (trypsin inhibitor), the inhibition of proliferate growth of human breast cancer cell lines in culture (genistein), and inhibition of the expression of an oncogenic virus (saponins).

Twenty to 25% of the total protease inhibitor content of soy bean protein is the Bowman-Birk inhibitor (BBI) (Kennedy, 1995). BBI has shown the greatest suppression of carcinogenesis in animal carcinogenesis assays. St Clair *et al* (1990) observed that BBI can completely prevent colon carcinogenesis (100% suppression). It suppresses carcinogenesis in the liver by 71%, in the oral epithelium by 86%, and in the lung by 48%. The ability of BBI to suppress carcinogenesis in the various systems that were studied far exceeds the ability of other soy bean-derived compounds (Kennedy, 1995). The anticarcinogenic activity of BBI has been observed in many different tissues, in many different cell types (including cells of epithelial and connective tissue origin), with many different types of carcinogenic agents, including ionising radiation used in the mammary carcinogenesis studies reported by Troll *et al* (1980) and chemical carcinogens used in the studies reported by Barnes *et al* (1990), reviewed by Kennedy (1993). The trypsin inhibitor inhibits the growth of a variety of malignant cell types *in vitro*, but this protease inhibitor does not have the ability to suppress oral carcinogenesis induced by 7,12-dimethylbenzanthracene (DMBA) in hamsters (Messadi *et al*, 1986).

The observation of Barnes *et al* (1990) that both raw and autoclaved soy beans inhibited chemically induced mammary cancer in rats, was important because the protease inhibitors in soy beans, which are thought to be potent chemopreventive agents, are destroyed by autoclaving (Messina & Messina, 1991). The data of Barnes *et al* suggested that the isoflavones in soy beans were responsible for tumour inhibition. *In vitro* genistein inhibits tyrosine protein kinases, DNA topo-isomerases and S6 kinases (Yamashita *et al*, 1990). The activity of these enzymes is enhanced in oncogene-transformed cells (Yamashita *et al*, 1990). Isoflavones may consequently have a role to play in preventing a wide range of cancers. Several studies have looked specifically at the oestrogenic/antioestrogenic effects of soy beans (Wilcox *et al*, 1990; Cassidy *et al*, 1995). These studies suggest that isoflavones possess both antioestrogenic and oestrogenic activity, and in premenopausal women soy consumption influences hormonal patterns in a way that is potentially protective against breast cancer (Messina & Messina, 1991). Lamartiniere *et al* (1998) recently reported that pharmacologic doses of genistein given to mature rats enhance mammary gland differentiation, resulting in a significantly less proliferative gland that is not as susceptible to mammary cancer. These authors speculate that breast cancer protection in Asian women on traditional soy-containing diets is, in part, derived from early exposure to genistein-containing soy.

Three other compounds in soy beans have also been shown to suppress carcinogenesis in animals, namely saponins, phytic acid and -sitosterol. Saponins are cytotoxic to sarcoma cells in culture (Huang *et al*, 1982, in Kennedy, 1995) and they inhibit the expression of an oncogenic virus (Tokuda, 1988). Phytic acid was observed in one experiment on mice to suppress colon carcinogenesis by 25% (Shamsuddin *et al*, 1989). In an experiment in which the soy bean sterol ß-sitosterol was assayed for its ability to sup-

press colon carcinogenesis, the sterol was able to reduce the total number of benign and malignant tumours by 39% (Raicht *et al*, 1980).

As discussed above, there are a number of different compounds in soy beans with various types of anticarcinogenic activity. For all of these compounds there are likely to be toxic effects that have to be studied along with their anticarcinogenic activities. Human cancer prevention trials of the isoflavones and of BBI have begun recently.

BONE-STRENGTHENING EFFECTS OF SOY BEANS

There are indications that soy beans reduce the incidence of postmenopausal osteoporosis. Genistein in low doses maintained bone mass in ovariectomised rat models (Anderson *et al*, 1995a; Arjmandi *et al*, 1996). Adlercreutz and Mazur (1997) reported some effects of soy or isoflavonoid intake in patients with menopausal symptoms such as hot flushes, vaginal dryness and bone resorption, and discussed the low incidence of menopausal problems in Japanese women compared to Canadian, American and Finnish women. The results of a study of the short-term effects of soy bean isoflavones on bone strength in postmenopausal women indicated that a high-soy diet increased bone mineral content and bone density in the lumbar spine (Erdman, 1998). Potter *et al* (1998) also reported a significant increase (2%) in both bone mineral content and bone density in the lumbar spine of postmenopausal women after six months on a diet that included 40 g of protein per day from isolated soy protein containing 2,25 mg isoflavones/g protein. Their findings are of interest for two reasons:

Firstly, of all the skeletel sites they measured, the spine is the area that is most sensitive to oestrogen because of its higher trabecular bone content. The spine is remodelled more rapidly than the hip which contains a higher proportion of cortical bone (Ettinger *et al*, 1992).
Secondly, although Potter *et al* (1998) had hypothesised that a isoflavone-containing soy protein diet would delay the decrease in bone density (compared to the control diet), they actually found that there was a slight increase in bone density and mineral content. However, this was a short study with respect to bone, and these findings should be confirmed by more extensive studies (e.g. 2-3 years).

Arjmandi (1998) reported improvement in femoral bone density in rats that were fed soy protein isolate for 35 days compared to rats fed a casein-based diet. However, he recommends additional long-term studies to determine the effects of soy beans on maintaining bone health. Adlercreuz and Mazur (1997) suggest that isoflavonoids may to some degree inhibit osteoporosis but may be insufficient for complete protection as single prevention strategy.

EFFECTS OF SOY ON THE MANAGEMENT OF DIABETES MELLITUS

Both Jenkins *et al* (1984) and Anderson *et al* (1984) did extensive research on the role of dietary fibre in the management of diabetes. Recent studies suggest that blood glucose may be influenced by various dietary fibres, although usually the most effective fibre sources for control of diabetes are soluble fibres such as guar gum and pectin (Slavin, 1991). However, they are neither highly palatable nor acceptable for long-term therapy of diabetes. It is considerably easier to incorporate soy fibre in a meal without greatly affecting the texture and palatability of the meal.

Tsai *et al* (1987) studied seven obese patients with noninsulin-dependent diabetes mellitus (NIDDM). The subjects were given a standard meal with and without 10 g of soy fibre. The soy fibre supplement significantly enhanced the return of serum glucose levels to fasting levels during the latter half of the test meal. Soy fibre had no effect on plasma insulin. Verster (1993) studied the long-term effect of either an energy-restricted high-carbohydrate, high-fibre, low-fat (HCHFLF) diet with a daily addition of 150 g (cooked weight) of dry beans compared to the influence of the same diet with the addition of 50 g (raw weight) of soy protein isolate on the metabolic control of sixteen NIDDM patients for a twelve-week period. Both diets improved glycaemic control as indicated by decreased glycated haemoglobin (HbA1) concentrations. Lo *et al* (1986) conducted glucose tolerance tests on patients with hyperlipidemia. Adding 25 g of soy fibre in a cookie to the diets of subjects significantly reduced their fasting glucose levels by 8,5%. Thus, although some studies found a positive effect on control of diabetes, more research is needed in this area.

RECOMMENTATIONS FOR OPTIMUM DIETARY INTAKE OF SOY PRODUCTS

Oriental populations consume 20 mg to 80 mg of the isoflavone genistein per day, almost entirely derived from soy, whereas the dietary intake of genistein in the United States is only 1 mg to 3 mg per day (Barnes *et al*, 1996). Soy beans contain 100 mg to 300 mg of the isoflavones genistein and daidzein (Herman *et al*, 1995). According to Craig (1997), it is possible to obtain substantial levels of dietary isoflavones through the daily consumption of 30 g to 60 g of soy protein. One half-cup of soy beans, one cup of soy beverage or 120 g of tofu provide 30 mg to 40 mg of genistein. Soy bean concentrates prepared by alcohol extraction display no oestrogenic activity due to genistein extraction in aqueous ethanol, and soy protein isolates contain only small amounts of isoflavones (Nash *et al*, 1967).

CONCLUSIONS

Researchers are just beginning to understand the physiological and biochemical effects of soy consump-

tion. Considerable progress has been made since the *First International Symposium on the Role of Soy in Preventing Chronic Disease* was held in 1995 (Messina *et al*, 1998). The potentially beneficial effects of soy consumption clearly indicate both the need and the justification for more clinical and experimental studies. Further studies are required to examine the effects of soy beans and soy bean products on cardiovascular risk factors, cancer, osteoporosis and the relief of menopausal symptoms. Although multiple factors are driving research on soy, the single most important factor is arguably that soy beans are a concentrated source of isoflavones. Whereas relatively little research on soy bean isoflavones had been conducted before 1993, well over 1 000 studies dealing with isoflavones were published between 1994 and 1996 (Messina *et al*, 1998). Definite data about the relationship between soyfoods and isoflavones and the risk of chronic disease may be many years away. However, the foundation has now been laid for research to determine not only the effects of soy and isoflavones on serum lipids, but also on the incidence of heart disease; not only on bone mineral density, but also on fracture risk, and not only on biomarkers of cancer risk, but also on cancer rates.

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