10

Protease Inhibitors, Lectins, Antifungal Protein and Saponins in Soybean

NgTB[1], Cheung Randy CF[1], Ye X J[1], Wong Jack H[1] and Ye X Y[2]
[1]*School of Biomedical Sciences, Faculty of Medicine. The Chinese University of Hong Kong, Shatin, New Territories Hong Kong*
[2]*College of Biological Science and Technology,FuZhou Univercity, FuZhou. 350002 China*

1. Introduction

Many investigations have been conducted on soybean during the past decade since it is a unique dietary source of isoflavones which display a diversity of biological activities and reduce the risk of some chronic diseases. Soybean is distinctive in that it has a high content of isoflavones which allegedly diminish the risk of cancer, cardiovascular disease, and osteoporosis, and also alleviate menopausal symptoms. Isoflavones are weakly estrogenic. The isoflavone genistein also affects signal transduction. Soyfoods and isoflavones have arrested the attention of many researchers on account of their potential role in preventing and treating cancer and osteoporosis. The low breast cancer mortality rates in Asia and the putative antiestrogenic infer that soyfood intake reduces breast cancer risk. Soy or isoflavones may decrease the risk of prostate cancer. The low estrogenic activity of soybean isoflavones and their structural resemblance to the synthetic isoflavone ipriflavone, which elevates bone mineral density in postmenopausal women, suggest that soy or isoflavones may decrease the risk of osteoporosis.

Besides isoflavones, soybean also produces protease inhibitors, lectins, and antifungal proteins, which have important biological activities. This review encompasses a discussion of isoflavones, protease inhibitors, lectins and antifungal proteins.

2. Protease inhibitors

Protease inhibitors in soybeans can reduce protein digestion, and induce pancreatomegaly and enhance chemically induced pancreatic tumors in some animals (Grant, 1989). The quantity of protease inhibitors ingested would not have any adverse consequences in humans (Liener, 1994). The trypsin / chymotrypsin inhibitor (Bowman-Birk inhibitor) found in soybeans has been studied as an anticancer agent (Kennedy, 1995).

A large number of protease inhibitors belonging to various types have been purified from different kinds of legumes. In the study of Fang et al. (2010b), by using liquid chromatography techniques, a Kunitz type trypsin inhibitor (KBTI) was isolated from Korean large black soybeans. It exhibited a molecular mass of 20107.645 Da and inhibited the proteases trypsin and alpha-chymotrypsin with an activity of 8520 BAEE units/mg and

24 BTEE units/mg, respectively. Its trypsin inhibitory activity demonstrated pronounced thermal stability (0-100 ^{o}C) and stability over a wide range of pH values (pH 3-11). KBTI reduced the activity of HIV-1 reverse transcriptase activity with an IC_{50} value of 0.71 µM. It evoked the release of pro-inflammatory cytokines including TNF-alpha, IL-1beta, IL-2 and interferon-gamma at the mRNA level. KBTI exerted low antiproliferative activity toward CNE-2 and HNE-2 nasopharyngeal cancer cells, MCF-7 breast cancer cells, and Hep G2 hepatoma cells. It was devoid of mitogenic, ribonuclease and antifungal activities.

A 19-kDa trypsin inhibitor with an N-terminal amino acid sequence highly homologous to Kunitz-type trypsin inhibitors was purified from seeds of Chinese black soybean *Glycine max* cv. "Small Glossy Black" using a procedure that involved anion exchange chromatography on Q-Sepharose, cation exchange chromatography on SP-Sepharose and anion exchanger chromatography on DEAE-cellulose. It was bound on all three ion exchangers. It inhibited trypsin with an IC_{50} of 19 µM and chymotrypsin with an IC_{50} of 14.3 µM. Its trypsin inhibitory activity was relatively pH stable and thermostable. It was preserved in the pH range pH 3-pH 13 and in the temperature range 0 ^{o}C-60 ^{o}C. The trypsin inhibitory activity was reduced in the presence of dithiothreitol (from 5 to 25 mM) in a dose-dependent manner indicating the paramount importance of disulphide bonds to the activity. It inhibited HIV-1 reverse transcriptase with an IC_{50} of 0.16 µM, and exerted antiproliferative activity toward MCF-7 breast cancer cells with an IC_{50} of 4.3 µM and HepG2 hepatoma cells with an IC_{50} higher than 25 µM. The trypsin inhibitor was devoid of antifungal activity and mitogenic activity towards mouse splenocytes (Ye and Ng, 2009a).

A trypsin inhibitor from the seeds of Hokkaido large black soybeans possessed an N-terminal amino acid sequence that closely resembled those of 8-kDa Bowman-Birk trypsin inhibitors. The trypsin inhibitor was unbound on SP-Sepharose but bound on the anion exchangers DEAE-cellulose and Mono Q. It exerted antiproliferative activity toward breast cancer (MCF-7) cells and hepatoma (HepG2) cells with an IC_{50} of 35 and 140 µM, respectively. The trypsin inhibitory activity of the inhibitor was retained following thermal treatment up to 100 ^{o}C for 30 min and after exposure to the pH range 2-13 for the same duration. The trypsin inhibitor inhibited HIV-1 reverse transcriptase with an IC_{50} of 38 µM. Moreover, there was no antifungal activity toward *Fusarium oxysporum* and *Mycosphaerella arachidicola* (Ho and Ng, 2008).

Chinese 'Large Black Soybeans' produce a 60-kDa lectin and a 20 kDa trypsin inhibitor. Both proteins were absorbed on Q-Sepharose, but could be separated from one another on Mono Q. Further purification was achieved by gel filtration on Superdex 75. Both trypsin inhibitor and lectin were stable from pH 3 to 13 and from 0 ^{o}C to 65 ^{o}C. The trypsin inhibitor was stable at pH as low as 2, and it inhibited trypsin and chrymotrypsin with an IC_{50} of 5.7 µM and 5 µM, respectively. Its trypsin inhibitory activity was reduced in the presence of dithiothreitol indicating the importance of the disulphide bond to the activity. Both trypsin inhibitor and lectin inhibited HIV-1 reverse transcriptase (IC_{50} = 44 and 26 µM) and proliferation of HepG2 hepatoma cells (IC_{50} =9 6 and 17 µM) and MCF7 breast cancer cells (IC_{50} = 42 and 13.5 µM) (Ye and Ng, 2009b).

Studies utilizing different types of protease inhibitors as anticarcinogenic agents in vivo and in vitro systems have recently been reviewed. These studies suggest that the protease inhibitors which prevent carcinogenesis affect processes in the early stages of carcinogenesis, although they can be effective at long time periods after carcinogen exposure in both in vitro and in vivo systems. While there is strong evidence that these protease inhibitors can affect both the initiation and promotion stages of carcinogenesis, they have no

effect on already transformed cells. The results have suggested that the first event in carcinogenesis is a high frequency epigenetic event and that a later event, presumably genetic, leads to the malignant state. Protease inhibitors appear capable of reversing the initiating event, presumably by stopping an ongoing cellular process begun by carcinogen exposure. The major lines of investigation on the mechanism of the protease inhibitor suppression of carcinogenesis relate to the ability of anticarcinogenic protease inhibitors to affect the expression of certain oncogenes, and the levels of certain types of proteolytic activities. The anticarcinogenic protease inhibitors have no observable effects on normal cells, but can reverse carcinogen-induced cellular changes for several different end-points studied. The most direct method of determining the mechanism of action of the anticarcinogenic protease inhibitors is to identify and characterize the proteases with which they interact. In the cells of the in vivo and in vitro systems in which protease inhibitors can prevent carcinogenesis, only a few proteases have been observed to interact with the anticarcinogenic protease inhibitors. Proteases have been identified by both substrate hydrolysis and affinity chromatography (Kennedy, 1995).

3. Lectins

Lectins, a class of proteins that reversibly and non-enzymatically bind specific sugars, have been purified from different kinds of legumes. In the study of Fang et al. (2010a), a lectin (KBL) with a molecular mass of 48 kDa was isolated from Korean large black soybeans. The specific hemagglutinating activity of the lectin was 4096 titer/mg. The metal chelator EDTA brought about a decline of hemagglutinating activity. The activity could be reinstated by addition of Fe^{3+} ions and divalent cations such as Ca^{2+}, Mn^{2+}, Fe^{2+}, Cu^{2+}, Zn^{2+}, and Pb^{2+}. The lectin was specific to sugars including D-(+)-galactose, D-(+)-raffinose, L-(+)-arabinose, alpha-D-(+)-melibiose, and alpha-lactose, the hemagglutinating activity of the lectin could be inhibited by these sugars. The lectin manifested remarkable thermal stability and stability over a wide range of pH values. The lectin demonstrated HIV-1 reverse transcriptase inhibitory activity with an IC_{50} of 1.38 μM. However, it lacked antifungal, cytokine inducing, mitogenic and ribonuclease activities. In addition, it did not inhibit proliferation of nasopharyngeal cell lines at concentrations up to 20 μM.

A lectin was purified from the seeds of the cultivar of soybean (*Glycine max*), called the small glossy black soybean. The purification protocol involved anion exchange chromatography on Q Sepharose, cation exchange chromatography on SP Sepharose and fast protein liquid chromatography anion exchange chromatography on Mono Q followed by gel filtration on Superdex 75. The dimeric 50 kDa melibiose-binding lectin with an N-terminal sequence identical to that of soybean lectin was bound on all three ion exchangers. Of all the sugars tested, melibiose most potently inhibited the hemagglutinating activity of the lectin. The lectin was stable between pH 3-12 and 0-70 ^{o}C. The lectin elicited maximal mitogenic response from murine splenocytes at about the same molar concentration as Con A. Although the magnitude of the maximal response was smaller, the soybean lectin suppressed the activity of HIV-1 reverse transcriptase and exerted antiproliferative activity toward breast cancer MCF7 cells and hepatoma HepG2 cells with an IC_{50} of 2.82 μM, 2.6 μM and 4.1 μM, respectively. The lectin lacked antifungal activity. Another lectin isolated from a different cultivar of soybean called little black soybean was grossly similar to small glossy black soybean lectin but the former had a larger subunit molecular mass (31 kDa), a more potent mitogenic activity and lower thermostability. The data suggest that different soybean cultivars produce similar but not identical lectins (Lin et al., 2008).

4. Antifungal proteins

A 25 kDa monomeric antifungal protein with an N-terminal amino acid sequence exhibiting homology to a segment of chitin synthase, was purified from the seeds of the black soybean *Glycine soja*. The protein was designated as glysojanin. It potently inhibited mycelial growth of the fungi *Fusarium oxysporum* and *Mycosphaerella arachidicola*. It inhibited HIV-1 reverse transcriptase with an IC_{50} of 47 μM, [methyl-^{3}H]thymidine incorporation by mouse splenocytes with an IC_{50} of 175 μM, and ^{3}H-leucine incorporation into proteins in the cell-free rabbit reticulocyte lysate with an IC_{50} of 20 μM. The isolation protocol involved anion-exchange chromatography on DEAE-cellulose, affinity chromatography on Affi-gel blue gel, cation-exchange chromatography by fast protein liquid chromatography on Mono S, and gel filtration by fast protein liquid chromatography on Superdex 75 (Ngai and Ng, 2008).

5. Saponins

Saponins are glycosides composed of a lipid-soluble aglycone consisting of either a sterol or, more often, a triterpenoid structure linked to water-soluble sugar residues that vary in their type and quantity. Legumes are the major sources of dietary saponins. The same bean can have different types of saponins. Saponins are very poorly absorbed. Most saponins form insoluble complexes with 3-β-hydroxysteroids and interact with and form large, mixed micelles with bile acids and cholesterol. Although saponins were shown to lower cholesterol in some animal species, the hypocholesterolemic effects of saponins in humans are more speculative (Milgate and Roberts, 1995). Saponins may have anticancer properties, as suggested by a recent rodent study that found that a saponin-containing diet (3% by wt) inhibited by about two-thirds the development of azoxymethane-induced preneoplastic lesions in the colon (Koratkar and Rao, 1997). However, given that human intake of saponins is generally 200–300 mg/d whereas total food intake is <500 g (dry weight), it is not clear to what extent these results in rodents are relevant to humans (Ridout et al., 1988).

The effect of saponins isolated from soya bean flour on the incidence of aberrant crypt foci (ACF) induced by azoxymethane (AOM) in the colonic wall of CF1 mice was investigated. Four weekly injections of AOM, a known colon carcinogen, were administered to mice. One week after the last injection, mice were placed on an AIN-76 diet supplemented with 3% soya bean saponins or continued on the basal AIN-76 diet. Another group of mice was placed on the saponin diet without AOM initiation to observe the effect of saponins on the growth characteristics of mice. Dietary intake of soya saponins significantly reduced the incidence of ACF at the end of 14 weeks (postinitiation). Noninitiated mice maintained on a similar soya bean saponin-supplemented diet did not show any adverse effects on the growth and overall health of the animals. These findings suggest that soya bean saponins can play an important role in inhibiting the incidence of ACF in the colon of mice (Koratkar and Rao, 1997).

Daidzein, an isoflavone in soybeans, suppresses the growth of HL-60 cells implanted in mouse subrenal capsules (Jing et al., 1993). Genistein inhibits the proliferation of a diversity of both hormone-dependent and hormone-independent cancer cells *in vitro* with an IC_{50} between 5 and 40 mM (2–10 mg/mL), including breast (Peterson and Barnes, 1991; 1996; Pagliacci et al., 1994; Peterson et al., 1996; So et al., 1996; Clark et al., 1996; Zava and Duwe, 1997), prostate (Peterson and Barnes, 1993; Naik et al., 1994; Kyle et al., 1997), colon (Kuo et

al., 1997; Kuo, 1996), and skin (Rauth et al., 1997) cancer cells (Adlercreutz and Mazur, 1997; Akiyama and Ogawara, 1991; Constantinou and Huberman 1995). Genistein suppresses the metastatic activity of breast (Scholar and Toewa, 1994) and prostate (Santibáñez et al., 1997) cancer cells *in vitro* independent of the effects on cell growth. The anticancer effects of genistein *in vitro* (Wei et al., 1993) are attributed to its inhibitory effects on enzymes that play a role in signal transduction, including ribosomal S6 kinase (Linassier et al., 1990), MAP kinase (Thorburn and Thorburn, 1994), and tyrosine protein kinases (Akiyama et al., 1987). Genistein also inhibits the activity of DNA topoisomerase II (Constantinou et al., 1990) and raises the *in vitro* concentrations of transforming growth factor β (TGF β) (Peterson et al., 1998) which may suppress growth of cancer cells (Benson and Colletta, 1995; Benson et al., 1996; Markowitz and Roberts, 1997). Genistein has an important role as a potent inhibitor of angiogenesis *in vitro* (Messina, 1999).

Genistein exerts an inhibitory action on the growth of both estrogen-dependent and estrogen-independent breast cancer cells *in vitro*, but it is not certain if cellular concentrations of genistein *in vivo* can reach *in vitro* concentration capable of suppressing growth of breast cancer cells. Genistein inhibits proliferation of induced serum and epidermal growth factor–stimulated normal human mammary epithelial cells with IC_{50} values substantially lower than those for transformed human breast epithelial cells (Peterson and Barnes, 1994) suggesting that soy intake may inhibit the initiation of cancer cells, rather than impeding the proliferation of existing cancer cells. Because synergistic effects between genistein and daidzein have been observed *in vitro*, it would be of interest to examine their concerted action *in vivo* (Evans et al., 1995; Franke et al., 1995). The possibility remains that other components of soybeans, individually or in conjunction with isoflavones, account for the hypothesized anticancer effects of soyfoods. Wrensch et al (1991), McMichael-Phillips et al (1998), and Cassidy et al (1994; 1995) demonstrated that soy or isoflavones are potentially capable of producing physiological actions related to breast cancer risk. Cassidy et al (1994) noticed that the intake of soy, in particular isoflavone-rich soy (Cassidy et al., 1995), prolongs the follicular phase and circulation levels of gonadotropins. Brown and Lamartiniere (1995), Lamartiniere et al (1995), and Murrill et al (1996) were of the opinion that early consumption of soyfoods by young girls may prevent breast cancer development later in life. Neonatal or prepubertal exposure to genistein inhibits the development of dimethylbenz(a) anthracene-induced mammary tumors in rodents and prolongs the latency period (Brown and Lamartiniere, 1995; Lamartiniere et al., 1995; Murrill et al 1996).

Genistein exerts and antiproliferative action on both androgen-dependent and androgen-independent prostate cancer cells *in vitro* (Peterson and Barnes, 1993; Naik et al., 1994). It also diminishes the potential of prostate cancer cells to metastasise independent of cell growth inhibition. Concomitantly tyrosine phosphorylation of an unidentified molecular species declines (Santibáñez et al., 1997). Though the role played by estrogen in prostate cancer has not been clarified, estrogens are effective in the therapy of metastatic prostate cancer (Pienta and Esper, 1993). Hence the potential estrogenic effects of isoflavones may be protective. Genistein inhibits 5-α-reductase in genital skin fibroblasts and benign hyperplastic prostate tissue (Evans et al., 1995). This enzyme converts testosterone into a more potent form dihydrotestosterone, which stimulates the growth of prostatic tissue. Ross et al (1992) showed that biomarkers of 5-α-reductase activity are higher in white and black men compared with Japanese men. The *in vitro* results of Evans et al (1995) agree with data from Lu et al (1996), showing that following 1 month of soymilk consumption (36 oz/d), the

serum concentration of 3α, 17β-androstanediol glucuronide, a dihydrotestosterone metabolite, was significantly lowered. In mice fed a diet containing soy for 9 months, the incidence of prostatic dysplasia, considered to be a preneoplastic prostate lesion, was significantly diminished. At 12 months, however, difference between the 2 groups was much attenuated. These results are in line with the epidemiologic data noted above and also with the results of a study of MNU-induced prostate tumors in Lobund-Wistar rats (Pollard and Luckert, 1997).

Rats receiving a diet containing soy had a shorter latency period than those fed a diet containing soy high in isoflavones with a small quantity of isoflavones (Pollard and Luckert, 1997). A diet containing soy flour (33% by weight) for 4 months inhibited tumor growth in rats with Dunning R3327 PAP tumors implanted (Zhang et al., 1997). Schleicher et al (1998) Genistein (50 mg/kg body weight) given to rats subcutaneously in the dorsal scapular area every 12 h stranting at the time of tumor cell transplantation inhibited development of prostate tumor implanted with prostate cancer cells and totally inhibited development of lung metastases. Dalu et al (1998) reported that genistein (1 mg genistein/g diet) caused a decline in weight of the dorsolateral and ventral prostates and down-regulated the expression of tyrosine-phosphorylated proteins in rats. genistein dose-dependently inhibited ^{3}H-thymidine incorporation in cultured benign prostatic hypentrophy tissue and prostate cancer tissue (Geller et al., 1998) Although genistein suppressed growth of prostatic cancer cells in vitro, when the metastatic MAT-Lylu prostate cancer cells were injected into the right flank of rats, oral treatment with genistein did not suppress the prostate tumors development (Naik et al., 1994). The doses utilized more closely resembled human dietary intake than those employed in the investigations of Schleicher et al (1998) and Dalu et al (1998). Higher doses of genistein injected intraperitoneally had little effect on tumor growth (Naik et al., 1994). There are limited human data available for use in addressing the soy–prostate cancer hypothesis, although Severson et al (1989) noted that tofu consumption might produce a lower risk of prostate cancer. Isoflavones are detected in the prostatic fluid, at the highest concentrations in men from soyfood-consuming countries (Morton et al., 1997). Isoflavones are concentrated several-fold in the prostatic fluid compared to plasma concentrations,.

Genistein inhibits DNA synthesis in human prostate cells *in vitro* and reduces effect of testosterone in prostate cancer development in rats (Jenkins et al., 2003; Adlercreutz et al., 2000). However, a daily soybean intake sufficient to bring about a decline LDL-cholesterol, does not effect serum concentration of prostate specific antigen (Adlercreutz, 2002). Antifungal proteins (Ma et al., 2009) lectins/hemagglutinins (Lin et al., 2008) and protease inhibitors (Fang et al., 2010) demonstrate antiproliferative activity toward tumor cells *in vitro.* Some of these show pH stability and thermostability and thus their aforementioned activities may be retained *in vivo*.

Fotsis et al (1993) observed that genistein at high concentrations interfered with the action of bovine microvascular cells to invade collagen gels and form capillary-like structures when treated with basic fibroblast growth factor. Antiangiogenic agents by preventing tumor-stimulated angiogenesis, inhibit tumor growth beyond a size of 1–2 mm and thus from becoming clinically insignificant (Folkman and Klagsbrun, (1987). A low genistein concentration is required to inhibit angiogenesis *in vitro* (Adlercreutz and Mazur, 1997).

The antimetastatic activity of soybean saponin has been examined by assessing matrix production of the metalloproteinases MMP-2 and MMP-9 in HT-1080 cells (Kang et al., 2008). MMP-2 and MMP-9 mRNA expression levels were determined by RT-PCR analysis and the levels of secreted MMP-2, MMP-9 and tissue inhibitor of metalloproteinase-2 (TIMP-

2) were assessed by gelatin zymography and/or ELISA. The invasion of a Matrigel-coated membrane by human fibrosarcoma HT-1080 and HT-29 colon cancer cells was determined by counting the migrated cells. Exposure of HT-1080 cells to soybean saponin diminished the mRNA expression of and attenuated the secretion of MMP-2 and MMP-9. However, the secretion of TIMP-2 was enhanced in a dose-dependent manner. The invasion of HT-1080 cells through a Matrigel-coated membrane was suppressed. The antimetastatic activity of soybean saponin was further confirmed in an *in vivo* mouse experiment in which CT-26 colon cancer cells were injected via the caudal vein after administering soybean saponin in the diet. The incidence of metastatic tumor colonization of lungs in mice underwent a mild decline 14 days after injection of CT-26 cells via the caudal vein. Thus, soybean saponin reduces tumor cell metastasis by inhibiting production of MMP-2 and MM-9 production and enhancing TIMP-2 secretion.

The structural resemblance between estrogen, isoflavones and the synthetic isoflavone, 7-isopropoxyisoflavone (ipriflavone), which increases bone mass in postmenopausal women (Valente et al., 1994; Brandi, 1992), inhibits osteoclast activity in vitro (Tsude et al., 1986) raises speculation about the benfits of isoflavones bone health. The ipriflavone has to be metabolized in order to be maximally effective. Daidzein, a soybean isoflavone is one of the metabolites.

That genistein in particular affects bone density in rats (Blair et al., 1996; Fanti et al., 1998). Blair et al (1996) observed that the dry femoral mass of ovariectomized rats fed 30 mmol genistein in particular /day for 4 weeks was 12% higher ($P < 0.05$) than that of the controls. In a study by Fanti et al (1998), after 21 days of subcutaneous injection of 5 and 25 mg genistein/g body wt, tibial bone mineral loss in ovariectomized rats was significantly reduced. Potter et al (1998) reported that following 6 months of treatment, lumbar spine bone mineral density was significantly increased in postmenopausal women who had a daily intake of 40 g soy protein containing 2.25 mg isoflavones/g protein, while bone density remained unchanged in women who ingested the same amount of soy protein but containing only 60 % isoflavones (1.39 mg isoflavones/g protein). Some insight has been gained into the possible mechanism(s) regulating the effect of isoflavones on bone health in rats. Isoflavones may both stimulate and inhibit bone formation. Fanti et al (1998) reported that genistein augmented the number of osteoblasts and the serum osteocalcin level, but had no effect on number of osteoclasts.On the other hand, Blair et al (1996) noted that genistein inhibited avian osteoclast protein synthesis *in vitro* probably due to its inhibitory effects on tyrosine phosphorylation. Estrogen and tamoxifen, which inhibit bone resorption, induce apoptosis in osteoclasts, an effect which is antagonized *in vitro* by antibodies to TGF-β (Hughes et al., 1996). Since genistein enhanced TGF-β *in vitro*, the effect of the isoflavone bone resorption may involve TGF-β.

The decrease in hepatic cholesterol synthesis is caused by a decrease in serum insulin concentration because insulin activates an enzyme involved in cholesterol synthesis and, on the other hand, it might be attributed to a change in the hepatic bile acid profile (Mälkki, 2001). The isoflavones in diet containing soybean may retard atherosclerotic progression by virtue of their inhibitory activity toward LDL oxidation, which evokes a series of events forming atherosclerotic plaques. Isoflavones may elicit a cholesterol-lowering action due to interaction with estrogenic receptors, and structural similarity between isoflavones in a diet containing and their metabolites and estrogens. (Anderson et al., 1999). Various clinical studies have disclosed the importance of consumption of soybean protein with its isoflavones to achieve a hypocholesterolemic effect (Lichtenstein, 1998; Farriol et al., 2006).

The Asian diet is rich in soybean foods compared with the western diet (Craig, 1997). Inclusion of isolated soybean protein with isoflavones in the diet of postmenopausal women causes a decline in the incidence of hot flashes (Albertazzi et al., 1998; Setchell and Cassidy, 1999).

In postmenopausal women, isoflavones exert a weak estrogenic action and hence could be exploited as a dietary alternative or supplement to hormone replacement therapy (Setchell and Cassidy, 1999; Duffy et al., 2003). Improved cognitive ability was observed in postmenopausal women after intake of soybean extract containing isoflavones. Two types of estrogenic receptors (ER-α and ER-β) are found in the brain. Isoflavones bind preferentially to ER-β receptors, which play a role in cognitive function and are found in abundance in brain regions involved in cognition (Duffy et al., 2003).

From the foregoing account it can be seen that isoflavones represent important bioactive components of soybean. In addition, protease inhibitors, lectins and antifungal proteins in soybean display a multiplicity of health promoting activities such as antitumor, mitogenic and antimicrobial activities (Table 1). Hence the intake of soybean is beneficial to health.

6. Conclusion

The above review of literature has revealed that protease inhibitors in some cultivars of soybean have marked thermostability and pH stability and may account for the reduced incidence of cancer in populations favouring a diet rich in soybeans. Soybean saponins also may account for part of the antitumor activity in soybeans. Soybean saponins also display other health promoting effects such as anti-osteoporotic activity. Lectins and antifungal proteins also exhibit antitumor and other activities. Thus a regular dietary intake of soybeans is beneficial to health and should be encouraged.

Bioactive component s of soybean	Biological activities
Protease inhibitors (Bowman – Birk and Kunitz types)	Antitumor, HIV-1 reverse transcriptase inhibitory
Lectin	Antitumor, HIV-1 reverse transcriptase inhibitory
Antifungal protein	Antifungal, HIV-1 reverse transcriptase inhibitory, anti-mitogenic
Saponins	Hypocholesterolemic , anti-atherosclerotic , increase bone mineral density

Table 1. Bioactive components of soybean and their biological activities

7. References

Adlercreutz H, Mazur W, Bartels P, et al. (2000) Phytoestrogens and prostate disease. J Nutr 130: 658-659.

Adlercreutz H, Mazur W. (1997) Phyto-estrogens and western diseases. Ann Med 29: 95–120.

Adlercreutz H. (2002) Phyto-estrogens and cancer. Lancet Oncol 3: 364-373.

Akiyama T, Ishida J, Nakagawa S, et al. (1987) Genistein, a specific inhibitor of tyrosine-specific protein kinases. J Biol Chem 262: 5592–5.

Akiyama T, Ogawara H. (1991) Use and specificity of genistein as inhibitor of protein-tyrosine kinases. Methods Enzymol 201: 362–70.

Albertazzi P, Pansini F, Bonaccori G, Zanotti L, Forini E, De Aloysio D. (1998) The Effect of dietary soybean supplementation on hot flushes. Obstetrics & Gynecology 91: 6-11.

Anderson JJB, Thomsen K, Christiansen, C. (1987) High protein meals, insular hormones and urinary calcium excretion in human subjects. In: Christiansen C, Johansen JS, Riis BJ, eds. Osteoporosis. Viborg, Denmark: Nørhaven A/S, 240–5.

Anderson JW, Hanna TJ. (2002) Impact of non-digestible carbohydrates on serum lipoproteins and risk for cardiovascular disease. J Nutr 129: 1457-1466.

Anderson JW, Johnstone BM, Cook-Newell ME. (1995) Meta-analysis of the effects of soybean protein intake on serum lipids. N Engl J Med 333: 276-282.

Anderson JW, Major AW. (2002) Pulses and lipaemia, short- and long-term effect: potential in the prevention of cardiovascular disease. Br J Nutr 88: 263-271.

Anderson JW, Smith BM, Washnock CS. (1999) Cardiovascular and renal benefits of dry bean and soybean intake. Am J Clin Nutr 70: 464-474.

Anderson JW, Story L, Sieling B, Chen W-JL. (1984) Hypocholesterolemic effects of high-fibre diets rich in water-soluble plant fibres. J Can Diet Assoc 47: 140–8.

Armstrong WB, Kennedy AR, Wan XS, Atiba J, McLaren E, Meyskens FL. (2000) Single-dose administration of Bowman-Birk inhibitor concentrate in patients with oral leukoplakia. Cancer Epidemiol. Biomarkers 9: 43-47.

Barnes S, Grubbs C, Setchell KDR, Carlson J. (1990) Soybeans inhibit mammary tumors in models of breast cancer. In: Pariza MW, Aeschbacher H-U, Felton JS, Sato S, eds. Mutagens and carcinogens in the diet. New York: Wiley Liss, 1990: 239–53.

Benson JR, Baum M, Colletta AA. (1996) Role of TGFβ in the anti-estrogen response/resistance of human breast cancer. J Mammary Gland Biol Neoplasia 1: 381–9.

Benson JR, Colletta AA. (1995) Transforming growth factor β. Prospects for cancer prevention and treatment. Clin Immunother 4: 249–58.

Blair HC, Jordon SE, Peterson TG, Barnes S. (1996) Variable effects of tyrosine kinase inhibitors on avian osteoclastic activity and reduction of bone loss in ovariectomized rats. J Cell Biochem 61: 629–37.

Brandi ML. (1992) Flavonoids: biochemical effects and therapeutic applications. Bone Miner 19 (suppl): S3–64.

Brouns F. (2002) Soybean isoflavones: a new and promising ingredient for the health foods sector. Food Res Int 35: 187-193.

Brown NM, Lamartiniere CA. (1995) Xenoestrogens alter mammary gland differentiation and cell proliferation in the rat. Environ Health Perspect 103: 708–13.

Cancer facts and figures. (1994) Atlanta: American Cancer Society.

Cassidy A, Albertazzi P, Lise Nielsen I, Hall W, Williamson G, Tetens I, Atkins S, Cross H, Manios Y, Wolk A, Steiner C, Branca F. (2006) Critical review of health effects of soyabean phyto-estrogens in post-menopausal women. Proc Nutr Soc. 65(1): 76-92.

Cassidy A, Bingham S, Setchell KD. (1994) Biological effects of a diet of soy protein rich in isoflavones on the menstrual cycle of premenopausal women. Am J Clin Nutr 60: 333–40.

Cassidy A, Bingham S, Setchell KD. (1995) Biological effects of isoflavones in young women: importance of the chemical composition of soybean products. Br J Nutr 74: 587–601.

Clark JW, Santos-Moore A, Stevenson LE, Frackelton AR. (1996) Effects of tyrosine kinase inhibitors on the proliferation of human breast cancer lines and proteins important in the RAS signaling pathway. Int J Cancer 65: 186–91.

Constantinou A, Huberman E. (1995) Genistein as an inducer of tumor cell differentiation: possible mechanisms of action. Proc Soc Exp Biol Med 208: 109–15.

Constantinou A, Kiguchi K, Huberman E. (1990) Induction of differentiation and DNA strand breakage in human HL-60 and K-562 leukemia cells by genistein. Cancer Res 50: 2618–24.

Constantinou AL, Mehta RG, Vaughan A. (1996) Inhibition of N-methyl-N-nitrosourea–induced mammary tumors in rats by the soybean isoflavones. Anticancer Res 16: 3293–8.

Coward L, Barnes NC, Setchell KDR, Barnes S. (1993) Genistein, daidzein, and their β-glycoside conjugates: antitumor isoflavones in soybean foods from American and Asian diets. J Agric Food Chem 41: 1961–7.

Craig WJ. (1997) Phytochemicals: Guardians of our health. J Am Diet Assoc 97: 199-204.

Dalu A, Haskell J, Lamartiniere CA. (1998) Dietary genistein inhibits protein tyrosine phosphorylation in the dorsolateral prostate of the rat. Am J Clin Nutr 68(suppl): 1524S(abstr).

Duffy R, Wiseman H, File SE. (2003) Improved cognitive function in postmenopausal women after 12 weeks of consumption of a soya extract containing isoflavones. Pharmacol Biochem Behav 75: 721-729.

Evans BAJ, Griffiths K, Morton MS. (1995) Inhibition of 5”-reductase in genital skin fibroblasts and prostate tissue by dietary lignans and isoflavonoids. J Endocrinol 147: 295–302.

Fang EF, Wong JH, Lin P, Ng TB. (2010) Biochemical and functional properties of a lectin purified from korean large black soybeans--a cultivar of glycine max. Protein Pept Lett. 17(6): 690-8.

Fang EF, Wong JH, Ng TB. (2010) Thermostable Kunitz trypsin inhibitor with cytokine inducing, antitumor and HIV-1 reverse transcriptase inhibitory activities from Korean large black soybeans. J Biosci Bioeng. 109(3):211-7.

Fang EF, Wong JH, Ng TB. (2010) Thermostable Kunitz trypsin inhibitor with cytokine inducing, antitumor and HIV-1 reverse transcriptase inhibitory activities from Korean large black soybeans. J Biosci Bioeng. 109(3): 211-7

Fanti O, Faugere MC, Gang Z, Schmidt J, Cohen D, Malluche HH. (1998) Systemic administration of genistein partially prevents bone loss in ovariectomized rats in a nonestrogen-like mechanism. Am J Clin Nutr 68(suppl): 1517S (abstr).

Foster-Powell K, Miller JB. (1995) International tables of glycemic index. Am J Clin Nutr (suppl); 62: 871S–90S.

Fotsis T, Pepper M, Adlercreutz H, et al. (1993) Genistein, a dietary-derived inhibitor of in vitro angiogenesis. Proc Natl Acad Sci USA 90: 2690–4.

Geller J, Sionit L, Partido C, et al. (1998) Genistein inhibits the growth of human-patient BPH and prostate cancer in histoculture. Prostate 34: 75–9.

Grant G. (1989) Anti-nutritional factors of soybean: a review. Prog Food Nutr Sci 13: 317–48.

Ho VS, Ng TB. (2008) A Bowman-Birk trypsin inhibitor with antiproliferative activity from Hokkaido large black soybeans. J Pept Sci. 14(3): 278-82.

Hughes DE, Dai A, Tiffee JC, Li HH, Mundy GR, Boyce BF. (1996) Estrogen promotes apoptosis of murine osteoclasts mediated by TGF-β. Nat Med 2: 1132–6.

Jenkins DJ, Kendall CW, Marchie A, Jenkins AL, Augustin LS, Ludwig DS, Barnard ND, Anderson JW. (2003) Type 2 diabetes and vegetarian diet. Am J Clin Nutr 78: 610-616.

Jenkins DJA, Kendall CWC, D'Costa MA, et al. (2003) Soybean consumption and phytoestrogens: effect on serum prostate specific antigen when blood lipids and oxidized low-density lipoprotein are reduced in hyperlipidemic men. J Urol 169: 507-511.

Jing Y, Nakaya K, Han R. (1993) Differentiation of promyelocytic leukemia cells HL-60 induced by daidzein in vitro and in vivo. Anticancer Res 13: 1049–54.

Kang JH, Han IH, Sung MK, Yoo H, Kim YG, Kim JS, Kawada T, Yu R. (2008) Soybean saponin inhibits tumor cell metastasis by modulating expressions of MMP-2, MMP-9 and TIMP- 2. Cancer Lett. 261(1): 84-92.

Kennedy AR (1995) The evidence for soybean products as cancer preventive agents. J. Nutr. 125: 733S-743S.

Kennedy AR (1998a) Chemopreventive agents: protease inhbibitors. Pharmacol. Ther. 78: 167-209.

Kennedy AR (1998b) The Bowman-Birk inhibitor from soybeans as an anticarcinogenic agent. Am. J. Clin. Nutr. 68: 1406S-1412S.

Koratkar R, Rao AV. (1997) Effect of soya bean saponins on azoxymethane induced preneoplastic lesions in the colon of mice. Nutr Cancer 27: 206–9.

Koratkar R, Rao AV. (1997) Effect of soya bean saponins on azoxymethane induced preneoplastic lesions in the colon of mice. Nutr Cancer 27: 206–9.

Kuo SM, Morehouse HF Jr, Lin CP. (1997) Effect of antiproliferative flavonoids on ascorbic acid accumulation in human colon adenocarcinoma cells. Cancer Lett 116: 131–7.

Kuo SM. (1996) Antiproliferative potency of structurally distinct dietary flavonoids on human colon cancer cells. Cancer Lett 110: 41–8.

Kuo TM, Van Middlesworth JF, Wolf WJ. (1988) Content of raffinose oligosaccharides and sucrose in various plant seeds. J Agric Food Chem 36: 32–6.

Kyle E, Neckers L, Takimoto C, Curt G, Bergan R. (1997) Genistein induced apoptosis of prostate cancer cells is preceded by a specific decrease in focal adhesion kinase activity. Mol Pharmacol 51: 193–200.

Lamartiniere CA, Moore JB, Brown NM, Thompson R, Hardin MJ, Barnes S. (1995) Genistein suppresses mammary cancer in rats. Carcinogenesis 16: 2833–40.

Lee HP, Gourley L, Duffy SW, Esteve J, Day NE. (1991) Dietary effects on breast cancer risk in Singapore. Lancet 337: 1197–200.

Lichtenstein AH. (1998) Soybean protein, isoflavones and cardiovascular disease risk. J Nutr 128: 1589-1592.

Liener IE. (1994) Implications of antinutritional components in soybean foods. Crit Rev Food Sci Nutr 34: 31–67.

Lin P, Ye X, Ng T. (2008) Purification of melibiose-binding lectins from two cultivars of Chinese black soybeans. Acta Biochim Biophys Sin (Shanghai). 40(12): 1029-38.

Linassier C, Pierre M, Le Peco JB, Pierre J. (1990) Mechanism of action in NIH-3T3 cells of genistein, an inhibitor of EGF receptor tyrosine kinase activity. Biochem Pharmacol 39: 187–93.

Lu LJ, Anderson KE, Nagamani M. (1996) Effects of one month soya consumption on circulating steroids in men. Proc Am Assoc Cancer Res 37: 270 (abstr).

Ma DZ, Wang HX, Ng TB. (2009) A peptide with potent antifungal and antiproliferative activities from Nepalese large red beans. Peptides. 30(12): 2089-94.

Mackey R, Eden J. (1998) Phytoestrogens and the menopause. Climateric 1: 302–8.

Mäkela SI, Pylkkänen LH, Santti RSS, Adlercreutz H. (1995) Dietary soybean may be antiestrogenic in male mice. J Nutr 125: 437–45.

Mälkki Y. (2001) Physical properties of dietary fiber as keys to physiological functions. Cereal Foods World 46: 196-199.

Markowitz SD, Roberts AB. (1997) Tumor suppressor activity of the TGFβ pathway in human cancers. Cytokine Growth Factor Rev 7: 93–102.

McMichael-Phillips DF, Harding C, Morton M, et al. (1998) Effects of soyprotein supplementation on epithelial proliferation in histologically normal human breasts. Am J Clin Nutr 68(suppl):1431S–6S.

Milgate J, Roberts DCK. (1995) The nutritional and biological significance of saponins. Nutr Res 15: 1223–49.

Morton MS, Matos-Ferreira A, Abranches-Monteiro , et al. (1997) Measurement and metabolism of isoflavonoids and lignans in human male. Cancer Lett 114: 145–51.

Murrill WB, Brown NM, Zhang JX, et al. (1996) Prepubertal genistein exposure suppresses mammary cancer and enhances gland differentiation in rats. Carcinogenesis 17: 1451–7.

Naik HR, Lehr JE, Pienta KJ. (1994) An *in vitro* and *in vivo* study of antitumor effects of genistein on hormone refractory prostate cancer. Anticancer Res 14: 2617–20.

Nair SSD, Leitch JW, Falconer J, Garg ML. (1997) Prevention of cardiac arrhythmia by dietary (n23) polyunsaturated fatty acids and their mechanism of action. J Nutr 127: 383–93.

Ngai PH, Ng TB. (2008) Purification of glysojanin, an antifungal protein, from the black soybean Glycine soja. Biochem Cell Biol. 81(6): 387-94.

Oberleas D, Harland BE. (1981) Phytate content of foods: effect on dietary zinc bioavailability. J Am Diet Assoc 79: 433–6.

Pagliacci MC, Smacchia M, Migliorati G, Grignana F, Riccardi C, Nicoletti I. (1994) Growth-inhibitory effects of the natural phytoestrogen genistein in MCF-7 human breast cancer cells. Eur J Cancer 30A: 1675–82.

Peterson G, Barnes S. (1991) Genistein inhibition of the growth of human breast cancer cells: independence from estrogen receptors and the multi-drug resistance gene. Biochem Biophys Res Commun 179: 661–7.

Peterson G, Barnes S. (1993) Genistein and biochanin A inhibit the growth of human prostate cancer cells but not epidermal growth factor receptor autophosphorylation. Prostate 22: 335–45.

Peterson G, Barnes S. (1994) Genistein potently inhibits the growth of human primary breast epithelial cells: correlation with lack of genistein metabolism. Mol Biol Cell 5: 384a (abstr).

Peterson G, Barnes S. (1996) Genistein inhibits both estrogen and growth factor-stimulated proliferation of human breast cancer cells. Cell Growth Differ 7: 1345–51.

Peterson G, Coward L, Kirk M, Falany C, Barnes S. (1996) The role of metabolism in mammary epithelial growth inhibition by the isoflavones genistein and biochanin A. Carcinogenesis 17: 1861–9.

Peterson TG, Kim H, Barnes S. (1998) Genistein may inhibit the growth of human mammary epithelial (HME) cells by augmenting transforming growth factor beta (TGFβ) signaling. Am J Clin Nutr 68(suppl) : 1527S (abstr).

Pienta KJ, Esper PS. (1993) Risk factors for prostate cancer. Ann Intern Med 118: 793–803.

Pollard M, Luckert PH. (1997) Influence of isoflavones in soy protein isolates on development of induced prostate-related cancers in L-W rats. Nutr Cancer 28: 41–5.

Potter SM (1995) Overview of proposed mechanism for the hypocholesterolemic effect of soybean. J Nutr 125: 606-611.

Potter SM, Baum JA, Teng H, Stillman RJ, Shay NF, Erdman JW Jr. (1998) Soy protein and isoflavones: their effects on blood lipids and bone density in postmenopausal women. Am J Clin Nutr 68(suppl): 1375S–9S.

Rauth S, Kichina J, Green A. (1997) Inhibition of growth and induction of differentiation of metastatic melanoma cells in vitro by genistein: chemosensitivity is regulated by cellular p53. Br J Cancer 75: 1559–66.

Ridout CL, Wharf G, Price KR, Johnson LT, Fenwick GR. (1988) UK mean daily intakes of saponins—intestine-permeabilizing factors in legumes. Food Sci Nutr 42F: 111–6.

Ross PD, Fujiwara S, Huang C, et al. (1995) Vertebral fracture prevalence in women in Hiroshima compared to Caucasians or Japanese in the US. Int J Epidemiol 24: 1171–7.

Ross PD, Norimatsu H, Davis JW, et al. (1991) A comparison of hip fracture incidence among native Japanese, Japanese Americans, and American Caucasians. Am J Epidemiol 133: 801–9.

Ross RK, Bernstein LA, Lobo RA, et al. (1992) 5-Alpha-reductase activity and risk of prostate cancer among Japanese and US white and black males. Lancet 339: 887–9.

Rubio MA. (2002) Implicaciones de la fibra en distintas patologías. Nutr Hosp XVII(2): 17-29.

Santibáñez JF, Navarro A, Martinez J. (1997) Genistein inhibits proliferation and in vitro invasive potential of human prostatic cancer cell lines. Anticancer Res 17: 1199–1204.

Schleicher R, Zheng M, Zhang M, Lamartiniere CA. (1998) Genistein inhibition of prostate cancer cell growth and metastasis in vivo. Am J Clin Nutr 68(suppl): 1526S(abstr).

Scholar EM, Toewa ML. (1994) Inhibition of invasion of murine mammary carcinoma cells by the tyrosine kinase inhibitor genistein. Cancer Lett 87: 159–62.

Setchell KDR, Cassidy A. (1999) Dietary isoflavones: Biological effects and relevance to human health. J Nutr 129: 758-767.

Severson KJ, Nomura AMY, Grove JS, Stemmermann GN. (1989) A prospective study of demographics, diet, and prostate cancer among men of Japanese ancestry in Hawaii. Cancer Res 49: 1857–60.

So FV, Guthrie N, Chambers AF, Moussa M, Carroll KK. (1996) Inhibition of human breast cell proliferation by flavonoids and citrus juice. Nutr Cancer 26: 167–81.

Thorburn J, Thorburn T. (1994) The tyrosine kinase inhibitor, genistein, prevents a-adrenergic-induced cardiac muscle cell hypertrophy by inhibiting activation of the Ras-MAP kinase signaling pathway. Biochem Biophys Res Commun 202: 1586–91.

Thorne MJ, Thompson LU, Jenkins DJ. (1983) Factors affecting starch digestibility and the glycemic response with special reference to legumes. Am J Clin Nutr 38: 481–8.

Tsuda M, Kitazaki T, Ito T, Fujita T. (1986) The effect of ipriflavone (TC-80) on bone resorption in tissue culture. J Bone Miner Res 1: 207–11.

Valente M, Bufalino L, Castiglione GN, et al. (1994) Effects of 1-year treatment with ipriflavone on bone in postmenopausal women with low bone mass. Calcif Tissue Int 54: 377–80.

Wei H, Wei L, Frenkel K, Bowen R, Barnes S. (1993) Inhibition of tumor promoter-induced hydrogen peroxide formation in vitro and in vivo by genistein. Nutr Cancer 20: 1–12.

Wong JH, Ng TB. (2005) Lunatusin, a trypsin-stable antimicrobial peptide from lima beans (Phaseolus lunatus L.). Peptides. 26(11): 2086-92.

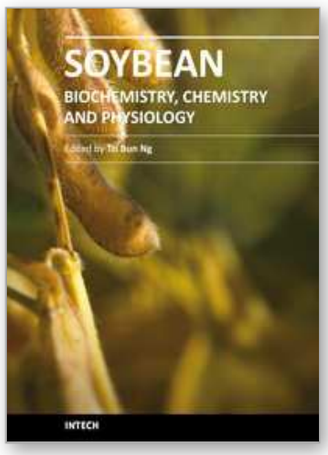
Wrensch MR, Petrakis NL, King EB, et al. (1991) Breast cancer incidence in women with abnormal cytology in nipple aspirates of breast fluid. Am J Epidemiol 135: 130–41.

Xe XJ, Ng TB (2009) Isolation and characterization of a trypsin inhibitor and a lectin from *Glycine max* cv. Large Black Soybean. Food Sci Biotechnol 18: 1173-1179

Ye X, Ng TB. (2009) A trypsin-chymotrypsin inhibitor with antiproliferative activity from small glossy black soybeans. Planta Med. 75(5): 550-6.

Zava DT, Duwe G. (1997) Estrogenic and antiproliferative properties of genistein and other flavonoids in human breast cancer cells in vitro. Nutr Cancer 27: 31–40.

Zhang JX, Hallmans G, Landström M, et al. (1997) Soy and rye diets inhibit the development of Dunning R3327 prostatic adenocarcinoma in rats. Cancer Lett 114: 313–4.



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