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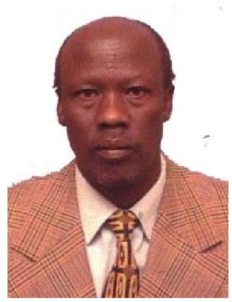
SOYBEAN NUTRITIONAL PROPERTIES: THE GOOD AND THE BAD ABOUT SOY FOODS CONSUMPTION-A REVIEW

Lokuruka MNI[1]*



Michael Lokuruka

*Corresponding author email: lokuruka@hotmail.com

[1]Senior Lecturer in Food Science, Egerton University, Department of Dairy and Food Science and Technology, P.O. Box 536-20115, Egerton, Kenya.

ABSTRACT

Consumption of soy foods is increasing worldwide mainly due to their acclaimed health benefits. However, nutritional demerits associated with soy foods consumption exist. Proteins and lipids, some vitamins and minerals, are major nutritionally-important components of soybeans; carbohydrates are major constituents quantitatively. Whole soy foods are also good sources of dietary fibre, B-vitamins, calcium, and omega-3 essential fatty acids. This review examines the merits and demerits of consuming soy foods. The amino acid composition of soybean protein complements that of cereals. Also, the high biological value of soy proteins increases their value as feedstuff. Processing generally increases digestibility of soybean protein; soy protein concentrate and isolate have higher digestibility than soy flours. Trypsin and chymotrypsin inhibitors in flours lower protein digestibility. However, despite demonstrated growth inhibition in animals, due to antinutrients, methionine supplementation in infants is useful only when dietary protein intake is marginal. Although processing considerably reduces antinutrient levels, care must be taken not to reduce protein nutritional value by excessive heating, which can result in loss of thermolabile amino acids. Significant lowering of plasma cholesterol has been reported in hypercholesterolemic subjects with hyperlipoproteinemia, when soy protein replaced animal protein in diets. Also, a dose-response relationship has been shown with isoflavones, particularly genistein, in lowering low-density lipoprotein cholesterol in human kinetic studies. However, questions are being raised about soy isoflavones, especially when consumed as concentrated supplements by segments of the population. Data suggest that genistein may prompt growth of breast tissue in male mice, while other data suggest the opposite effect. Studies also showed that infants consuming soy formula had higher blood levels of isoflavones than women receiving soy supplements who show menstrual cycle disturbances. Also, some animal and human study results have linked soy isoflavones to goitre. Nevertheless, data linking soy consumption to reduced risk of osteoporosis, prostate, breast and colon cancers exists, despite the data being inadequate to make definitive conclusions. Despite concerns on soy isoflavones, the FDA-sanctioned claim on soy protein, covers a component generally accepted as heart-healthy. Nevertheless, the need for more research is emerging as well as caution on soy foods inappropriate consumption. As Africa produces small but increasing amount of soybeans, it will continue relying on imports to meet demand. As demand for soy products increases worldwide, due to its health benefits, African consumers are advised to take note of emerging unhealthy side effects of consumption of large amounts of soy products.

Key words: Soybean, nutrients, health benefits, demerits

INTRODUCTION-GLOBAL TRENDS IN SOYBEAN PRODUCTION AND UTILIZATION

The soybean (*Glycine max* (L) Merrill family *Leguminosae*) undoubtedly originated in the Orient, probably in China [1]. In the Orient, the main products from soybeans are oil and meal, alongside a fascinating variety of non-fermented and fermented soy foods. Although soybeans have served as food in the Orient over the centuries, the amounts used currently are not as great as one might expect, as even China, the home country of the soybean (SB), imports to meet its demand. In China, annual consumption is reported to be 15-20 kg per person in all forms [2]. This figure has not changed much as China imported close to 80% of its requirements in 2005 from the US [3]. The US and Brazil are the 1st and 2nd biggest producers of soybeans in the World with an output of 73 million metric tons (33%) and 42 million metric tons (MT) (28%), respectively, in 2008 [4]. More than 80% of the US SB crop is genetically modified. Egypt the largest producer of soybeans in Africa produces about 180,000 tonnes annually [4]. Consumption in the US is about 110 kg per person annually, but most of this is due to the use of soybeans as animal feed. Due to intense research over the last 5 decades or so, the discovery of health benefits associated with soybeans and their products as human food, has led to increasing worldwide production and consumption. However, in comparison to the major grains produced in the World, SB production is not impressive. In 1981/1982, worldwide production was approximately 450 million MT of wheat, 770 million MT of coarse grain (mainly maize), and 410 million MT of rice, but only 87 million MT of soybeans. The global output in 1992-3 of the 3 major grains rose to 560, 530 and 470 million MT of wheat, rice and maize, respectively [5], and 106 million MT of soybeans [6). In 2007, the worldwide production of soybeans rose to 221 million MT [7]. The increased production of soybeans in recent years has led to the dominance of SB oil (about 20%) among the various vegetable oils available for food use worldwide, although Africa consumes more palm, maize and sunflower oils than SB oil [8]. Kenya consumes 250,000 tonnes of vegetable oils annually, 80% of which is imported. It produces about 3 million MT of maize grain annually, with some being used for edible oil extraction; it, however, produced only 2,100 tonnes of soybeans in 2007. Soy oil is more expensive than other edible oils in the Kenyan market (except olive oil), probably because it is imported, although palm oil, the major oil consumed in Kenya is also imported. SB provided almost 61% of all the oil used for liquid oils, shortenings, specialty fats and oils in 2000 in the US [9]. Africa produced approximately 1.3 million MT of soybeans in 2007 [7] (about 5% of global output) up from 0.6 million MT in 2002 (more than 100% increase in 5 years) [10]. This is despite the long history of SB growing in Africa dating as far back as 1889. Two major problems were found in trying to introduce whole soybeans on a home level in Africa; they took too much time and fuel to cook and the taste was not well accepted. Nevertheless, there are concerted efforts to increase SB growing in Africa (in Kenya, South Africa, Nigeria, Algeria, Botswana, Uganda, Tanzania, Zambia and Zimbabwe) [8]. This is bolstered by the worldwide demand, the touted health benefits from its consumption, and the help of the International Soybean Center (INTSOY) at Urbana-Champaign, Illinois, USA. The worldwide demand for soybeans and the need to substitute soy products imported by African countries from the US, may lead to further interest in growing soybeans on a larger scale than currently. However, this author believes the acreage under soybeans is unlikely to expand in Africa substantially in the near future, unless overwhelming commercial benefits of replacing the acreage under maize and other staple and traditional crops are more than evident. This is despite the value of the SB as a high protein and oil crop, economic advantages it has over many other oil seeds.

TRENDS IN SOY FOODS CONSUMPTION

Today, supermarkets in developed countries are displaying tofu dogs, tofu burgers, tofu sliced meat, tofu with mango, with berries, tofu cutlets, soy dream mocha fudge, tofu ice cream, etc. Because they are generally cheap, they are an attraction. Due to its bland taste, SB is cherished with these mixtures. However, nutritionally, it is also packed with nutrients. Because the USFDA has recommended soybeans as heart-healthy [11], tofu is now a poster functional food-food with health improving properties. In this sense to deter the No. 1 killer in the World, heart attack [12]. Functional foods are vying with organic foods as the new trend in food consumption. After age 60, the fear of heart attacks may make one rush to SB and other functional foods to live to 100 years, and why not as the Chinese have been eating soy foods for years, and are reputed to rarely get heart attacks and little or no breast cancer until they migrate to the West; they are, however, more prone to stomach, liver and oesophageal cancer than American women [13]. It is also generally documented that Asians have lower incidence of uterine, breast and prostate cancer than Americans [14], mainly due to the nature of diet and the consumption of

fruits and vegetables [13]. These revelations corroborate the findings of a large prospective cohort study involving 64,915 Chinese women whose mean age of recruitment was 51 years and who were followed for a mean period of 2.5 years, between 1997 and 2000. The mean dietary intake of soy was 7.36 g/day. The study showed that soy food consumption was significantly and inversely associated with the risk of coronary heart disease (CHD) in Chinese women [15]. This study provided a strong argument to support the recommendation of the American Heart Association (AHA) to increase soy food intake to promote heart-health. The Chinese do not generally eat tofu, but emphasize fermented soy foods, miso, soy sauce, etc. [1]. The Western World is trying to substitute soy protein isolate (SPI) and tofu for animal meats. Because of the health claims related to its potential to lower serum cholesterol and triglycerides, while increasing high-density lipoprotein level (HDL) [16], the sales of soy foods have soared in the 1990s and continue going up in the 2000s; so that soybeans are currently processed into a variety of foods. An increasing number of foods found in many supermarkets, even in developing countries, are likely to contain soy in part to lower the saturated fat content. These trends are catching up in Africa in the major cities including Nairobi, where specialty shops dealing with health foods, have shelves stacked with considerable amounts of organic foods and imported soy foods for the health conscious shopper. The expanding trade links between Africa and China are already evident in the food retail sector as soy products (e.g., soy sauce) are an increasing part of stocks on supermarket shelves, even in smaller cities like Nakuru in Kenya, in the observation of this author. A number of soy products including instant soy drinking powder and whole soybean powder are noticeable on shelves alongside other foods in Kenyan supermarkets, most of them being made from imported soybeans. These trends may be similar in most countries of the world where healthy living through the consumption of foods that are touted to confer health benefits, is an emerging lifestyle. In developing countries where food aid is an important part of national economies, many food items are likely to contain soy in the various food blends. In Africa, the use of soy foods and soybean components as ingredients in health foods is a fairly new phenomenon. However, due partly to globalization of diets, the consumption of soy foods is probably going to pick up as is being witnessed in other parts of the World where soy food products were not part of traditional diet.

SOYBEAN NUTRITIONAL PROPERTIES

Soybeans are good sources of protein, lipid, and other nutrients (Table 1). Soy protein products can be good substitutes for animal products because, unlike some other beans, soy offers a "complete" protein profile [1]. Soybeans contain all the essential amino acids (except methionine) [1] (Table 2), which must be supplied in the diet because they cannot be synthesized by the human body. Soy protein products can replace animal-based foods-which also have complete proteins but tend to contain more fat, especially saturated fat-without requiring major adjustments elsewhere in the diet. Proteins and lipids, some vitamins and minerals, are the major nutritionally important components of soybeans. Although carbohydrates are major constituents quantitatively, they play a minor nutritional role. This is mainly because soybeans are consumed more for their protein content and value, than for their carbohydrate contribution to the human diet. Also, structural carbohydrates are the major fraction of SB carbohydrates. Cereals, which tend to be higher in carbohydrate content than SB, are the major contributors of energy in human diets (Table 1). Nevertheless, SB protein contributes about 45% to the energy in a meal in which it is the major component (Table 3). Whole soy foods are also good sources of dietary fibre, B-vitamins, calcium, and omega-3 essential fatty acids, all important food components.
The proportion of energy from SB and various foods is given in Table 3.

The Protein Content of Soybean Products

SB protein is particularly valuable because it has an amino acid composition that complements that of cereals (Table 2). Soybeans are limiting in the sulphur-containing amino acids for most animal species, including humans, but contain sufficient lysine to overcome the lysine deficiency of cereals [5]. A soybean-rice combination is complementary for lysine and methionine and may help to explain the successful use of soy protein products such as soybean curd in the rice eating cultures of Asia. The amount of protein in soybeans, 38-44%, is larger than the protein content of other legumes, 20-30%, and much larger than that of cereals, 8-15% [1]. This large amount of protein in soybeans along with the high biological value (BV) increases their value as feedstuff and is one reason for the economic advantage that soybeans

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Email: oniango@iconnect.co.ke OR info@ajfand.net www.ajfand.net

have over other oil seeds. It is evident from Table 2 that soybeans occupy an intermediate position between animal proteins (with high biological value and a good profile of the essential amino acids), and the cereal proteins, based on biological and chemical evaluation systems. It was, however, found that proteins that are deficient in the sulphur amino acids are not well evaluated by the protein efficiency ratio method (PER) with rats [1]. The digestibility of SB protein is low when the only treatment is heating, but further processing-including soaking, sprouting, fermentation, grinding, and hot water extraction increases digestibility considerably [17]. The digestibility of SB protein also varies with the type of modern soybean product, with soybean concentrate (SPC) and SPI having higher digestibility than soy flours [18]. The presence of considerable levels of trypsin and chymotrypsin inhibitors in soy flours may be one reason for the lower digestibility of their protein. However, despite demonstrated growth inhibition in animal experiments, supplementation with sulphur amino acids may overcome the effect of the antinutrients. But in infants, methionine supplementation has been demonstrated to be useful only when total dietary protein intake is marginal; it therefore seems that there is little justification for supplementation when soy protein is part of a mixed diet, and when dietary protein intake is adequate. Heating, toasting and organic solvent use in processing considerably reduce levels of antinutrients; but care must be taken not to reduce nutritional value of protein by excessive heating which can result in loss of lysine, cysteine and cystine through thermal destruction and non-enzymatic browning [1]. It has been reported that statistically significant lowering of plasma cholesterol is achieved in humans by replacing dietary animal protein with soy protein, especially in hypercholesterolemic patients [19, 20]. It was evident that the reduction is considerable in hyperlipoproteinemic individuals with serum cholesterol >300 mg/dL [21]. A meta-analysis of 38 studies showed that soy protein may reduce low–density lipoprotein cholesterol (LDL-C) by as much as 12.9% [22]. Despite being largely acceptable, there was some controversy surrounding this meta-analysis as it was perceived by a section of the scientific community to have been designed to favor particular commercial interests. Phytohaemagglutinins, do not seem to have any pervasive role in growth inhibition in experimental animals and humans. However, their increased consumption may impair nutritional quality of legume diets because being glycoproteins, they are poorly digested, and also participate in chemical reactions during processing, thereby reducing protein digestibility [23]. They are, however, potentially useful as they have been shown to contribute to intestinal mucosal growth and regeneration, thereby preventing gut atrophy [24].

Soybean Lipids and Micronutrient Profiles

SB oil provides calories, the essential fatty acids and vitamins A and E, but contributes insignificant amounts of Vitamins D and K [25]. It has one of the highest iodine values of oilseeds (a value of 134), which is similar to that of sunflower oil; peanut butter, maize and palm oils have iodine values of 101, 127 and 51, respectively, indicating lower unsaturation compared to SB oil [26]. In SB oil, the fatty acids linoleic, oleic, palmitic and linolenic, make up 54, 24, 12 and 8%, respectively [5]. Due to the considerable unsaturation (unsaturated fatty acids are >85% of total fatty acids) of SB lipids, which tends to lower serum cholesterol,

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Josem Trust Place, Bunyala Road, Upper Hill, Nairobi
P.O. Box 29086-00625 Tel: +254-20-2351785 Fax: +254-20-4444030, Nairobi, KENYA
Email: oniango@iconnect.co.ke OR info@ajfand.net www.ajfand.net

soybean consumption may be helpful. Soy oil can serve as a good source of oleic and the essential fatty acid (EFA) linoleic acid, with even the partially hydrogenated soy oil containing 25% linoleic and 3% linolenic acid [5]. Where the dietary intake of the EFA is a problem among the poor in tropical developing countries, the supply of SB, simsim, peanuts, etc. is potentially beneficial. However, the polyunsaturation of soy oil is a disadvantage during hydrogenation and bleaching of soy oil; hydrogenation takes place at temperatures of 120-230 ^{o}C. The amounts of *trans* isomers formed during the thermal processing of liquid plant oils, such as soy oil that contain large amounts of dienoic and trienoic fatty acids is considerable, depending on hydrogenation conditions [27]. Soy oil contains 55-68% dienoic and trienoic acids, amounts that are large enough to influence formation of considerable levels of *trans* isomers of linoleic and linolenic acids [27]. During hydrogenation, the normally *cis* isomers are converted to the *trans* geometric isomers [9]. *Trans* fatty acid isomers have been implicated in the incidence and progression of cardiovascular disease [28].
Soy oil is a good source of vitamin E, but is a poor source of beta carotene, a precursor of vitamin A. Bleaching during oil processing reduces the small amount of beta carotene further [1].

Genetically modified (GM) soybean oil
Due to formation of considerable levels of *trans* fatty acids during hydrogenation and the instability during storage due to the high polyunsaturated fatty acid (PUFA) content of SB oil, significant effort has been carried out mainly in the US, in modifying the fatty acid composition of soybeans through plant breeding techniques, mainly mutation breeding, although genetic engineering has also been used**.** Four major modifications have been done-namely, decreasing the linolenic fatty acid, increasing oleic acid, decreasing palmitic acid and increasing the saturated fatty acids in the GM oil. However, these products have faced problems with commercialization due to poor field yields, low trait stability, and identity preservation problems, which escalate the cost of GM oil [9].

Soybean Carbohydrates
The carbohydrates of soybeans, containing little starch and hexose, are largely polysaccharides with some oligosaccharides. Carbohydrates make up approximately 35% of the SB. Approximately 50% of SB carbohydrates are nonstructural in nature and include: low molecular weight sugars, oligosaccharides and small amounts of starch. The other half comprises polysaccharides that include considerable amounts of pectic polysaccharides. The small amounts of free galactose, glucose, fructose and sucrose make up the low molecular weight sugars. Galacto-oligosaccharides (raffinose, stachyose and verbascose) comprise approximately 5% of the SB dry matter, while starch represents less than 1% [29]. The structural carbohydrates can be divided into cotyledon meal polysaccharides and hull polysaccharides. The primary cotyledon meal polysaccharides are arabinogalactan and an acidic polysaccharide that is similar to pectin, whereas the hull polysaccharides include pectin, hemicellulose and cellulose. Many factors affect the nutritional value of SB carbohydrates including cultivar, genotype, and processing. The SB polysaccharides are considered unavailable to humans mainly due to difficulties in digestion. Besides its

indigestibility, crude fibre may depress digestibility of other nutrients including minerals to a considerable extent [30]. An important benefit of dietary fibre to humans is increasing the water-holding capacity of stools. Increased stool bulk, softness, and increased transit time may reduce diverticular disease, haemorrhoids and possibly other diseases of the lower gastrointestinal tract [30]. Dehulled SB flour contains 6.2% neutral fibre, 5.7% acid detergent fibre, 4.6% crude cellulose, 0.5% crude hemicellulose and 1.3% lignin [1]. While soy concentrates contain slightly higher fibre, SPI have none. Another problem with soy products is the flatulence due to oligosaccharides, which may be reduced by fermentation, sprouting and leaching.

Soybean Minerals

Dry SB has an ash content of about 5%, which is quite considerable. The major forms of minerals in SB are sulphates, phosphates and carbonates. Potassium is found in the SB in the highest concentration, followed by phosphorus, magnesium, sulphur, calcium, chloride and sodium in that order [31]. Minor minerals include silicon, iron, zinc, manganese, copper, molybdenum, fluoride, chromium, selenium, cobalt, cadmium, lead, arsenic, mercury, and iodine. They range from 0.01-140 ppm. Like other components, minerals in SB are influenced by variety, growing location and season [31].

Generally, mineral bioavailability from consumption of animal foods is better than from plant foods [32]. Calcium, zinc and phytate in soy foods interact to form a highly insoluble complex, which reduces zinc absorption to a greater extent than phytate alone [32]. Also, haeme iron (the form in animal foods) is more readily available than the non-haeme iron as found in SB. However, a study showed that the amounts of soy protein used in feeding programmes did not adversely affect iron bioavailability [33].

Goitrogenic and Estrogenic Substances in Soybeans

The isoflavone glucosides genistein, and glycitein-O-β-glucoside are the major soybean goitrogenic compounds. Other isoflavones, namely, 6,7,4'-trihydroxyflavone, coumesterol, are also found in soybeans in insignificant amounts. Diethylstilbesterol is 10^5 times more active than genistein, while daidzein is three-fourths as active as genistein, and so the estrogenic activity of soy isoflavones is usually thought to be minimal [34]. The content of iodine in soybeans is insignificant, although it was shown that greater thyroid hypertrophy occurred when rats were fed raw full-fat soy flour than when they were fed lower iodine, toasted and defatted soy flour or SPI [35]. Studies have identified genistein and daidzein as inhibitors of thyroid peroxidase, which data suggest may prompt goitre and autoimmune disorders of the thyroid. However, critics of such studies suggest that iodine deficiency may be a factor that needs to be considered when evaluating study results. However, a study carried out in Japan on human volunteers showed that soy consumption resulted in diffuse goitre and hyperthyroidism in some subjects, even though the dietary intake of iodine was adequate [36]. Showing a dose-response relationship, isoflavones in soybeans, particularly genistein, lowered LDL-C in human kinetic studies [37, 38], suggesting that the hypocholesterolemic effect of soy foods is probably multi-factorial [38], since soy protein has a similar effect. SB meal prepared by alcohol extraction is almost devoid of the alcohol-soluble genistein, so that SPI have an insignificant isoflavone content. This may be of practical nutritional significance and worth noting in view of the health concerns surrounding soybean isoflavones.

Soybean Vitamins

The water-soluble vitamins of the SB mainly include thiamine, riboflavin, niacin, pantothenic acid and folic acid. Vitamin C is negligible in the mature beans, but is present in measurable quantity in immature and germinated beans [25]. The main oil-soluble vitamins include A (retinol) and E (tocopherol). The Vitamin D and K content is negligible. Vitamin A exists as the pro-vitamin β-carotene. Like Vitamin C, its content is negligible in the mature bean, but is measurable in immature and germinated seeds [25]. The tocopherol content of SB varies with variety.

Soybean Omega-3 Fatty Acids

This family of fatty acids derives its name from the location of the double bond on the third carbon atom from the methyl (CH_3) end of the fatty acid molecule (chain), known as the omega end. In soybeans, these fatty acids include alpha-linolenic acid (ALA) and linolenic acid (18:3, n-3). However, unlike other oil seeds used for food preparation, SB contains more omega-6 fatty acids than most other omega-3 oil seeds. This validates the classification of its oil as both an omega-3 and omega-6 commodity [39]. ALA can be converted enzymatically to eicosapentaenoic acid (EPA) (C22:5, n-3) and decosohexanoic acid (DHA) (C22:6, n-3), omega-3 fatty acids that predominate in fish oils, and which are precursors of the eicosanoids-prostaglandins, thromboxanes and leukotrienes, all of which are anti-inflammatory, anti-thrombotic, anti-arrhythmic and vasodilatory. These eicosanoids are reported to protect against cardiovascular diseases (CVD) [39, 40]; consumption of soy products is therefore potentially heart-healthy. The n-6 fatty acids such as linoleic acid, which is also found in SB in considerable amount, is a precursor of its longer chain fatty acid derivative, arachidonic acid. This latter is a precursor of a different group of eicosanoids that are anti-inflammatory and pro-thrombic. ALA and linoleic acid compete for the same enzyme in the production of EPA and DHA from seed oils, but not from fish oils where EPA and DHA are already pre-formed. Omega-3 fatty acids are used to treat hyperlipidemia, hypertension and rheumatoid arthritis; there are no known drug interactions with the omega-3 fatty acids.

THE FDA-APPROVED SOY HEALTH CLAIM

All foods, including soy, are complex collections of chemicals that can be beneficial for many people in many situations, but can be harmful to some people when used inappropriately. This is the problem currently facing soy foods. Vegetarians and health enthusiasts have known for many years that foods rich in soy protein offer a good alternative to meat, poultry, and other animal-based products. As consumers have pursued healthier lifestyles in recent years, consumption of soy foods has risen steadily, bolstered by scientific studies and reviews showing health benefits from their consumption [15, 41, 42]. In 1999, the US FDA gave food manufacturers permission to put labels on products high in soy protein indicating that these foods may help lower heart disease risk [11]. The agency reviewed research from 27 clinical studies that showed soy protein's value in lowering total cholesterol and low-density lipoprotein (LDL, or "bad" cholesterol). For consumers interested in increasing soy protein consumption to help reduce their risk of heart disease, health experts say they need not completely eliminate animal-based products such as meat, poultry, and dairy foods to reap soy's benefits. While soy protein's direct effects on serum cholesterol levels are well documented, replacing some animal protein with soy protein is a valuable way to lower saturated fat intake. The AHA recommends that soy products be used in a diet that includes fruits, vegetables, whole grains, low-fat dairy products, poultry, fish, and lean meats [43]. The AHA also emphasizes that a diet to effectively lower cholesterol should consist of no more than 30% of total daily calories from fat and no more than 10% of total calories from saturated fat. Foods made with the whole soybean, such as tofu, may qualify for the claim if they have no fat other than that naturally present in the whole SB. Available evidence on soy protein benefits is much clearer. That is why the FDA limited its health claim to foods containing intact soy protein. The claim does not extend to isolated substances from soy protein such as the isoflavones genistein and daidzein. To qualify for the health claim, a food should contain and provide 25% soy protein on a daily basis when consumed. Food marketers are allowed to use the following FDA-sanctioned claim, or a reasonable variation, on their products: "Diets low in saturated fat and cholesterol that include 25 grams of soy protein a day, may reduce the risk of heart disease. One serving of (name of food) provides - grams of soy protein." To qualify for the claim, foods must contain per serving:

- 6.25 grams of soy protein
- Low fat (less than 3 grams)
- Low saturated fat (less than 1 gram)
- Low cholesterol (less than 20 milligrams)
- Sodium value of less than 480 milligrams for individual foods, less than 720 milligrams if considered a main dish, and less than 960 milligrams if considered a meal.

Soy by itself is not a magic food, but rather it is an example of the type of food that taken together with other foods in a complete diet, can have a positive effect on human health. For consumers reluctant to try soy foods because they fear a bad taste, food manufacturers are continuously creating new lines of soy-based products that contain enough soy to meet the claim requirement, but are also developed specifically to taste good.

OTHER POTENTIAL HEALTH BENEFITS OF SOY FOODS CONSUMPTION

In an extensive review of over 150 studies with emphasis on those involving women, it was shown that soy intake is associated with a third-reduction in the risk of breast cancer in both pre- and postmenopausal women [42]. Also in a meta-analysis, it was concluded that soy intake may be associated with a small reduction in breast cancer risk [44]. Goodman et al. [45] also concluded in a study that a diet rich in isoflavones from soy products reduces the risk of post-menopausal breast cancer, particularly in multi-ethnic populations with comparatively high phytoestrogen excretion. However, in another study, it was shown that soy foods intake was significantly and inversely related with the risk of breast cancer in pre-menopausal but not in post-menopausal Chinese women [46]. The general protective role of SB consumption against breast cancer has been supported by an earlier review pointing to the beneficial effect of isoflavones [47], although phytosterols, phytates, various phenolic acids, and saponins may also contribute to the protective effect. Nevertheless, there are studies that do not clearly support the beneficial effect of the isoflavones on breast cancer risk. Also, it seems that the protective effect of soy products on breast cancer is contingent upon regular consumption of soybeans and soy foods from early in life. Other studies point to the opposite effect, such as cancer cell proliferative effect of isoflavones and SPI as shown in breast fluid secretion and in histologically normal breasts of pre- and post-menopausal women, respectively [48, 49]. The findings of these latter studies were corroborated in a Japanese Cohort Study (JACC), which found that consumption of soy foods had no protective effect against breast cancer [50]. Other studies indicate that even short-term soy consumption improves glycemic control and the lipid profile in post-menopausal women with the metabolic syndrome [41]. Data also show that soy consumption can modulate some serum lipids in a direction that is beneficial for CHD risk in adults with type 2 diabetes. In regard to osteoporosis, soy food consumption may reduce the risk of bone fracture in postmenopausal women, particularly those in the early years of menopause [51]. The isoflavone genistein in particular, has been shown to inhibit proliferation in vitro of human prostatic cancer cell lines [52]. In conclusion, the epidemiological data available are inconclusive to support the idea that soy intake is associated with a decreased risk of postmenopausal breast cancer. Nevertheless, the limited though inconsistent data suggest that soy intake is associated with a reduced risk of postmenopausal breast cancer [28]. Data linking soy consumption to potential reduced risk of other illnesses including osteoporosis, prostate and colon cancers also exists.

HEALTH PROBLEMS ASSOCIATED WITH ESTROGENIC COMPONENTS

Recent concerns with respect to soy foods have focused on the isoflavones, particularly genistein and diadzein, not the whole bean or intact soy protein. These chemicals, available over the counter in pills and powders, are often advertised as dietary supplements for use by women to help lessen menopausal symptoms such as hot flashes. The problem, researchers say, is that isoflavones are phytoestrogens, a weak form of estrogen that could have a drug-like effect in the body. This may be pronounced in postmenopausal women; some studies suggest that high isoflavone levels might increase the risk of cancer, particularly breast cancer [49]. Research data, however, are far from conclusive, and yet some studies and reviews show just the opposite-that under some conditions, soy may help prevent breast cancer [42, 47]. It is this scientific conundrum, where evidence simultaneously points to benefits and possible risks, that is causing some researchers to urge caution. However, unlike the controversy surrounding soy isoflavones, available evidence on soy protein benefits is much clearer as stated previously. That is why the FDA limited its health claim to foods containing intact soy protein. The claim does not extend to isolated substances from SB such as genistein and daidzein. While isoflavones may have beneficial effects at some ages or circumstances, this cannot be assumed to be true at all ages. Isoflavones are like other estrogens in that they are two-edged swords, conferring both benefits and risks. There is also a body of scientific opinion suggesting that soy may be fattening. Other studies have shown the converse, i.e., consumption of soy seems to reduce the tendency to adiposity. One such study showed that genistein decreases adipose tissue deposition in mice [53]. There are also studies that show that the plant estrogens in soy that lower cholesterol also change hormonal balance (a Swiss study estimated that 100 g soy provides the estrogenic equivalent of the birth control pill) and block the absorption of other nutrients and affect child development **[**54**] .** High levels of isoflavones in infants consuming soy formula have been found in one study to be 6-11x higher on a body weight basis than the dose that has hormonal effects in adults consuming soy foods [55]. In a New Zealand study, it was estimated that an infant fed exclusively on soy formula receives the estrogen equivalent (based on body weight) of at least 5 birth control pills [56]. In contrast, no phytoestrogens have been detected in dairy based infant formula or in human milk even when the mother consumes soy products. Breast cancer survivors are also sometimes advised to avoid soy. However, in an extensive review of more than 150 studies, it was evident that at consumption levels of < 100 mg/day of soy isoflavone, it seemed unlikely that isoflavone consumption elicits adverse breast cancer promoting effects in healthy or breast cancer survivors who are not undergoing active treatment [57]. Therefore recurrence at the level of consumption of <100 mg/day of isoflavone does not seem likely. Nevertheless, the authors admitted that more data were clearly needed to address the issue. In other studies, the evidence adduced seemed to suggest that avoiding weight gain after breast cancer diagnosis may help prevent resurgence [58, 59]. Duffy et al. [59] cautioned against the use of supplemental phytoestrogens beyond levels currently consumed as this would not be helpful in the prevention of resurgence of breast cancer.

SUMMARY AND RECOMMENDATIONS

Traditionally, soy foods consumption was limited to the Orient in the past, but their consumption is increasing worldwide. With the increased emphasis on healthy diets, production of soybeans and sales of soy products are projected to increase worldwide, probably due in part to the FDA-approved health claim. Research shows that regular soy protein consumption lowers cholesterol to varying degrees. Most studies report that soy protein can reduce plasma concentrations of total and LDL cholesterol and triglycerides, but does not adversely affect levels of HDL, which has been associated with a reduction in heart disease risk. Other studies hint that soy may have benefits beyond fostering a healthy heart. Data linking soy consumption to a reduced risk of illnesses as diverse as breast cancer, osteoporosis, prostate and colon cancers exists. However, the data is inconsistent, inadequate and inconclusive. The FDA-approved health claim only covers soy protein, a form that can be incorporated into the diet in a variety of ways to help reach the daily intake of 25 grams of soy protein considered beneficial. While existing scientific data support the value of increasing soy protein as described in the health claim, questions have been raised about soy isoflavones, especially when consumed as concentrated supplements by segments of the population. Data generated from using rats suggest that genistein alone may prompt undesirable effects such as growth of breast tissue in males. Studies have also shown that infants consuming soy formula had 5-11 times higher levels of isoflavones in their blood than women receiving soy supplements who show menstrual cycle disturbances. Concerns about the effects soy may have on the function of the thyroid gland have also been expressed. Animal and a few human study results link soy isoflavones to goiter. Studies have identified genistein and daidzein as inhibitors of thyroid peroxidase, which may prompt goiter and autoimmune disorders of the thyroid. Because the research community has varying degrees of concern about a possible "dark side" to soy consumption, the need for more research is evident as well as caution on its inappropriate consumption. The FDA-sanctioned health claim, however, focuses on uses of soy protein foods that are generally accepted among health professionals as useful for heart-healthy diets, and not other isolated components of soybeans.

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Table 1:Composition (dry solids-g/100 g) of various foods

Food	Protein	Lipids	Carbohydrates	Moisture
Soybean	45	25	15	7
Peanuts	25	50	20	9
Pea	23	2	70	12
Field bean	30	2	60	12
Wheat (grain)	14	2	78	10
Maize	10	5	80	10
Sorghum	11	4	81	11
Cassava	3	0.8	90	63
Yam	9	0.7	84	73
Potato (tuber)	9	0	73	78

Source: [60]

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Table 2:Nutritional quality of proteins based on biological value evaluation and on amino acid composition

Protein	PER	BV	NPU	Limiting amino acid	Chemical score
Whole egg	3.8	87-97	91-94	None	100
Cow's milk	2.5	85-90	86	Sulphur amino acids	60
Beef muscle	3.2	76	71-76	Sulphur amino acids	80
Salmon	-	72	71	Tryptophan	75
Soybean	0.7-1.8	58-69	48-61	Sulphur amino acids	69
Peanut	1.7	56	43-54	Sulphur amino acids	70
Rice	1.9	75	70	Lysine	57
Maize	1.2	60	49-55	Lysine	55
Wheat	1.0	52	52	Lysine	57

Source: [1]

Legend: **PER**-protein efficiency ratio [(weight gain of rats/weight of protein ingested) x 100].
BV-biological value [(nitrogen retained/nitrogen absorbed) x 100]
NPU-net protein utilization [(nitrogen retained/nitrogen ingested) x 100]
Chemical score-(mg of limiting amino acid in 1 g of test protein/mg of amino acid in 1 g of reference protein) x 100

Table 3:Protein content of various foods expressed as contribution (%) to energy from ach food

Value of food as a source of protein	Proportion of energy from protein (%)
Poor protein sources	
Cassava	3.3
Cooked bananas	4.0
Sweet potatoes (*Ipomoea batatas*)	4.4
Taros	6.8
Adequate protein sources	
Potatoes	7.6
Rice (home pounded)	8.0
Maize (wholemeal)	10.4
Millet (*Setaria italica*)	11.6
Millet (*Pennisetum glaucum*)	13.6
Sorghum (*Sorghum vulgare*)	11.6
Wheat flour (medium extraction)	13.2
Good protein sources	
Groundnuts (peanuts)	18.8
Cow's milk (3.5% fat)	21.6
Beans and peas	25.6
Beef (lean)	38.4
Cow's milk, skimmed	40.0
Soya bean	45.2
Fish, fatty	45.6
Fish, dried	61.6

Source: [30].

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