Overview of the Nutritional and Health Attributes of Soyfoods, Soy Protein and Soybean Isoflavones. By, Mark Messina, PhD, MS

Foods made from soybeans have played an important role in the cuisines of many East Asian populations for centuries, beginning first in China and then spreading to Japan and surrounding countries. Much more recently, soyfoods have become popular in non-Asian nations being prized for their high protein content and ability to function as replacements for meat and dairy products. In addition to the traditional Asian soyfoods, such as tofu (soybean curd), miso (soybean paste) and edamame (green soybeans), there are modern soyfoods such as soy burgers, which are made from soy protein ingredients including soy protein isolate, soy protein concentrate and soy flour. These ingredients are comprised of approximately 90%, 65% and 50%, protein, respectively.[1]

Soy protein ingredients are used as a base for making meat and dairy analogues and are added to a vast array of foods in small amounts for functional purposes, for example, to extend shelf life, and increase moisture retention.[1] When used in this way, they make a negligible contribution to nutrient intake. Most soy consumed throughout the world is unfermented because the ethnic Chinese consume little in the way of fermented soyfoods (excluding soy sauce, which is a condiment, not a food).[2]

Based on nutrient content alone, evidence indicates soyfoods can positively contribute to an overall healthful diet. However, over the past 30 years, the scientific community has rigorously investigated the health benefits of soyfoods independent of nutrient content. Much of this interest is because the soybean is a uniquely rich source of isoflavones, a group of naturally occurring plant compounds. Isoflavones have been proposed to reduce risk of several chronic diseases.

Soybean Nutrition

Macronutrient content

The macronutrient content of soybeans differs markedly from other legumes, a group of foods that includes beans, peas, and lentils.[3,4] Most legumes are predominantly carbohydrate whereas less than 30% of the calories in soybeans are derived from this macronutrient. Further, about half of the carbohydrate in soybeans is comprised of oligosaccharides, small sugars that are poorly digested by our intestinal enzymes, so they travel to the colon where they can stimulate the growth of health-promoting bacteria.[5] For this reason, soybean oligosaccharides are classified as prebiotics.[6]

Soybeans are also much higher in fat than other legumes as about 40% of the calories in soybeans come from this macronutrient whereas most legumes are almost fat free. The fat in soybeans is comprised predominantly of polyunsaturated fat (~60%). Worthy of note is that the soybean is one of the few good sources of both essential fatty acids, linoleic acid, an omega-6 fatty acid, and alpha-linolenic acid, an omega-3 fatty acid.[7] As a testament to the healthfulness of the fat in soybeans, in 2017, the US Food and Drug Administration approved a qualified health claim for soybean oil based on its ability to lower blood cholesterol levels when replacing saturated fat.[8]

Finally, soybeans are higher in protein than other legumes. More importantly, the quality of soy protein is equal to the quality of animal protein and higher than the quality of other plant proteins.[9] The method accepted by most regulatory bodies around the world for evaluating protein quality is the protein digestibility corrected amino acid score (PDCAAS). The PDCAAS is determined by two factors, digestibility, and the pattern of indispensable amino acids. The PDCAAS for soy protein isolate and soy protein concentrate is approximately 1.0, the highest possible score.[9]

Micronutrient content

As is the case for many beans, soybeans are good source of many vitamins and minerals, especially potassium and folate.[3] Since some individuals may replace cow's milk with soymilk, evidence showing that calcium absorption from calcium fortified soymilk is similar to the absorption of calcium from cow's milk is notable.[10,11] This is also the case for tofu.[12] Although iron is generally poorly absorbed from plant foods, this may not be true in the case of soybeans because much of the iron in soy is in a form that is resistant to inhibitors of iron absorption.[13,14] One such inhibitor is phytate, which is found in whole grains and legumes.[15] However, research shows that in response to the chronic consumption of a high-phytate diet, such as a plant-based diet, the inhibitory effect of phytate on iron absorption is greatly reduced.[16]

Soybean isoflavones

Isoflavones are widely distributed within the plant kingdom, but among commonly consumed foods, soybeans and traditional Asian soyfoods are uniquely rich sources. This point is illustrated by the average isoflavone intake among older Japanese, which is about 40 mg/day,[2,17] whereas in Europe and the United States, intake is <3 mg/day.[18-22] In traditional Asian soyfoods, each gram of soy protein is associated with approximately 3.5 mg isoflavones,[2] whereas because of losses during processing, the isoflavone content of concentrated sources of soy protein, such as soy protein isolate and soy protein concentrate, is greatly reduced.[23] The three isoflavones in soybeans are genistein, daidzein and glycitein, which comprise roughly 50%, 40% and 10% of total isoflavone content, respectively.[23] Approximately 1,000 scientific papers are published on isoflavones each year.

Isoflavones have a chemical structure similar to the hormone estrogen, which allows them to bind to estrogen receptors and exert estrogen-like effects under certain experimental conditions. For this reason, isoflavones are commonly classified as phytoestrogens (plant estrogens). However, isoflavones differ from the hormone estrogen at the molecular level and clinically. In fact, isoflavones are more accurately classified as selective estrogen receptor modulators (SERMS) than as phytoestrogens.[24] SERMS have tissue-selective effects; that is, in some tissues they function as estrogen agonists, in other tissues as estrogen antagonists (anti-estrogens), and in many tissues affected by the hormone estrogen, they may have no effects at all.

To understand how two molecules with similar chemical structures can have different, and even opposite, physiological effects, it is instructive to consider the case of cholesterol (found in animal products) and phytosterols (found in plants). These two compounds have almost identical chemical structures, and yet, dietary cholesterol modestly increases blood cholesterol[25] whereas phytosterols markedly decrease it.[26] The ability of isoflavones to function as SERMS is attributed to their preference for binding to and activating estrogen receptor-beta in comparison with estrogen receptor-alpha.[24] When activated, these two receptors have different and sometimes opposite physiological effects. In contrast to isoflavones, the hormone estrogen binds with equal affinity to each estrogen receptor.

Coronary Heart Disease

Soyfoods may reduce risk of coronary heart disease by three separate mechanisms. One, soy protein directly lowers total cholesterol and LDL-cholesterol levels. The cholesterol-lowering effect of soy protein was first demonstrated clinically in 1967.[27] In 1999, after conducting its own evaluation of the literature, the US Food and Drug Administration (FDA) awarded a health claim for soyfoods and coronary heart disease based on the cholesterol lowering effect of soy protein.[28] The FDA established 25 g/day as the threshold intake for cholesterol reduction. Soy protein may also lower triglyceride levels,[29] another coronary heart disease risk factor.[30]

Two, when soyfoods displace foods high in saturated fat, because of the favorable change in the fatty acid content of the diet, blood cholesterol is reduced. Researchers from the University of Toronto estimated that by adding soyfoods to the diet, the combination of the direct effect of soy protein and the change in the fatty acid content of the diet, could decrease blood cholesterol levels approximately 8%, which over time, might reduce risk of coronary heart disease by an equivalent amount.[31]

Finally, although the evidence is somewhat inconsistent, many studies show that isoflavones can improve the health of the arteries. For example, research shows that isoflavones improve endothelial function as measured by flow mediated dilation.[32,33] The endothelium is the thin layer of cells that line blood vessels. When the function of these cells is impaired, heart disease risk is increased.

Breast Cancer

Much of initial research interest in soyfoods was because of evidence suggesting these foods reduce risk of several types of cancer. In 1990, the participants of a workshop organized by the US National Cancer identified several chemopreventive agents (anti-cancer compounds) in soybeans.[34] However, most subsequent research focused specifically on breast cancer and isoflavones. Interest in breast cancer was fueled in part by the historically lower breast cancer incidence rates in soyfood-consuming countries.[35]

Asian population studies show that women who regularly consume soy are less likely to have breast cancer than those who consume little soy.[36] However, substantial evidence indicates that for soy to reduce breast cancer risk, consumption needs to occur early in life, that is, during childhood and/or adolescence. This “early intake” hypothesis was first proposed in 1995.[37,38] All four of the epidemiologic studies, 2 from the United States[39,40] and 2 from China,[41,42] that have evaluated this hypothesis are supportive of efficacy. Three of these studies focused on consumption only during the teenage years. However, one of these, which examined consumption during 3 different periods of life, found consuming soy between the ages of 5 to 11, was even more protective than during the teenage years.[40]

In addition to these population studies, animal studies also support the early intake hypothesis[43,44] and several research groups have identified mechanisms by which early consumption of soy, because it contains isoflavones, reduces breast cancer risk later in life.[45-48] This hypothesis is consistent with evidence showing that early life events affect risk of developing several types of cancer.[45,49] Although more data are needed before definitive conclusions can be made, because studies show as little as 1 serving per day may be enough to reduce breast cancer risk by 25 to 50%, recommendations for girls to consume soy are justified.

Prostate cancer

The role of soy in preventing and treating prostate cancer has been widely investigated. Because prostate cancer is typically slow growing, even modestly delaying its onset and/or slowing its progression, will result in men dying with their cancer rather than of their cancer. As in the case for breast cancer, prostate cancer incidence rates are low in soyfood-consuming countries relative to the West, although with Westernization of the diet, rates have begun to increase.[50,51] In 2018, a statistical analysis of 30 population studies found that both soyfoods and soy protein intake was associated with a decrease in prostate cancer risk.[52] Another analysis found that among Japanese men, plasma isoflavone levels were associated with a decreased prostate cancer risk, although the finding did not quite reach statistical significance.[53]

Early on, studies indicated that both soy and isoflavones could decrease prostate specific antigen (PSA) levels in men with prostate cancer.[54] PSA is a marker of prostate tumor growth.[55] However, more recent work has not confirmed the results of these initial studies.[56-58] Somewhat parenthetically, one study found isoflavones may reduce some of the side effects associated with radiation therapy for prostate cancer treatment.[59] Overall, while there is suggestive evidence that soyfoods can reduce risk of developing prostate cancer, the data are too inconsistent to reach firm conclusions.

Osteoporosis

As women transit through menopause, because of the drop in estrogen levels, substantial amounts of bone loss occur. Because isoflavones exert estrogen-like effects under certain circumstances, researchers have been studying whether soyfoods reduce risk of osteoporosis. In 1998, the first clinical study to show isoflavone-rich soy protein reduced bone loss in postmenopausal women, was published.[60] Since that publication, statistical analyses of shorter-term clinical trials have found that isoflavone supplements and isoflavone-rich soy protein improve markers of bone health and/or bone mineral density in postmenopausal women,[61] although not all studies show benefits.[62,63] However, of the four large, multi-year clinical trials to examine the effects of isoflavones on postmenopausal bone mineral density,[64-68] only one found a beneficial effect.[67] Therefore, at this point, it is not possible to conclude that isoflavones promote bone health although the evidence is sufficiently suggestive to justify continued research. Furthermore, many soyfoods, such as calcium-set tofu and calcium fortified soymilk, are good source of bioavailable calcium. The high protein content of soyfoods may also benefit bone health.

Skin Health

The most visible part of aging may be the changes that occur in the skin. This type of aging is called intrinsic aging. The other type of aging is extrinsic aging, which refers to skin damage from solar exposure (photoaging). Skin aging is influenced by genetic, environmental, and hormonal factors. An example of the latter is the hormone estrogen, which favorably affects the health of the skin in several different ways including reducing wrinkles.[69-72] Recognition that estrogen benefits the skin prompted research into the effects of soy.

Several clinical trials in which participants consumed either soy protein containing isoflavones, or isoflavone supplements, have shown a reduction in wrinkles in comparison to the placebo group.[73-76] For example, a Japanese study found that drinking about one cup of soymilk daily improved the health of the skin based on questionnaires filled out by the participants as well as by skin biopsies.[73] A European study found a 10% reduction in wrinkle depth over a 14-week period in response to the intake of an amount of isoflavones found in just 1 to 2 servings of traditional Asian soyfoods daily.[75] Since the skin predominantly contains the type of estrogen receptor (estrogen receptor-beta) for which isoflavones have most affinity, it is certainly biologically plausible that soyfoods and isoflavones can improve skin health. Overall, the evidence is quite encouraging. As of this writing, a large, well-designed study examining the ability of isoflavones to reduce wrinkles is underway.

Cognitive function

As people age, more attention is often paid to engaging in activities that can help to maintain cognitive function. Some evidence suggests soyfoods may be helpful in this regard. The first clinical study to evaluate the effect of isoflavones on cognition was published in 2001.[77] This 10-week trial found that in healthy men and women, soyfood intake led to significant improvements in both short-term and long-term memory and in mental flexibility. Two additional trials by this research group support the efficacy of isoflavones for various aspects of cognition.[78,79] In 2015, a statistical analysis of 10 high-quality clinical studies involving over 1,000 postmenopausal women concluded isoflavone intake via supplements and soy protein, favorably affect cognitive function and visual memory.[80] Two years later, another analysis reached a similar conclusion.[81] And finally, in 2020, an analysis of 16 clinical studies involving 1,386 participants with a mean age of 60, concluded that soy isoflavones improve cognitive function.[82]

Hot Flashes

Hot flashes (also referred to as hot flushes) are the most common menopause-related symptom experienced by women.[83] They can persist for several years after menopause and for some women can interfere with daily activities or sleep to such a degree that treatment is sought. The drop in estrogen levels that occurs in menopause is one trigger for the onset of hot flashes. Thirty years ago, it was proposed that isoflavones possess sufficient estrogen-like activity to mitigate this drop in estrogen and alleviate menopausal hot flashes.[84] The first clinical trial to evaluate this hypothesis was published in 1995.[85] In 2012, a statistical analysis of 13 clinical trials showed that isoflavone supplements reduce the frequency of hot flashes by approximately 50 percent.[86] Isoflavones were equally effective at reducing the severity of hot flashes. Subsequently published trials support the efficacy of soybean isoflavones.[87,88] Studies suggest that about 50 mg isoflavones per day, the amount provided by approximately two servings of traditional soyfoods, is sufficient for hot flash alleviation.

Muscle mass and strength

Maintaining muscle mass and strength throughout life is important for overall health, but especially later in life. Loss of muscle mass and strength begins after the age of 30, and after the age of 50, estimates are that lean tissue and strength decrease by 1-2% and as much as 5% per year, respectively.[89] Recommendations for those engaged in resistance exercise training are to consume at least 1.6 g protein per kg body weight, twice the protein recommended dietary allowance.[90] Because of its high leucine content, whey, which accounts for 20% of the protein in cow's milk, has traditionally been viewed as the optimal protein for building muscle in response to resistance exercise.[91] Leucine is the key branched chain amino acid that triggers muscle protein synthesis.[92] Nevertheless, evidence shows that plant proteins are capable of maximally promoting gains in muscle mass and strength. Most importantly, a recent statistical analysis found that soy protein promotes gains in muscle mass and strength among these engaged in resistance exercise training to same extent as animal protein, including whey protein.[93]

Intake recommendations

As noted, the FDA established 25 grams per day of soy protein as the threshold intake for cholesterol reduction. However, for many of the other proposed benefits of soyfoods, studies suggest about two servings per day is sufficient to derive benefit. One serving of a traditional Asian soyfood provides about 6 to 10 grams protein and about 25 mg isoflavones. Moderation and variety are key factors to a healthful diet. Therefore, an upper limit to soyfood intake should be about 4 servings per day. Consuming more than this amount has not be shown to be harmful; however, no matter how beneficial, it best not to put too much emphasis on any single food.

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