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The Power of Soybeans and Daidzein

Soybean Information & Recipe

A soybean is a pulse native to eastern Asia, and a member of the legume family. Soybeans are mainly grown in Asia, South America, and North America. After they are grown, there are certain regulations and requirements for the shipping of this legume. They are generally shipped as bulk cargo and require a cool, dry, well-ventilated environment with temperatures in the range 5 - 25 °C. Soybeans are available for purchase online at Amazon.com where one may buy 2 pounds of Organic Soybeans Whole for $12.00 plus $6.73 shipping.

Many recipes utilize this specific pulse, and we are particularly interested in Barbequed Soybeans. Ingredients for this recipe include: 4 cups of cooked soybeans, ¾ cup of catsup, ¼ cup mustard, ¼ cup molasses, 2 tablespoons of brown sugar, 1 teaspoon of chili powder, ½ teaspoon garlic powder, and a dash of Worcestershire sauce. It is important to properly prepare the soybeans and the steps include: rinsing the beans, presoaking (place in bowl and cover with water to an excess of 2 inches), let sit overnight (beans will approximately triple in size), bring pot to boil, reduce heat and simmer for 3 hours. Once that is complete, the directions for the recipe of Barbequed Soybeans are: combine beans with the sauce ingredients and bake in a covered loaf pan at 300 °F for 2 to 3 hours.


Nutritional and Health Benefits of Soybeans

Soybeans have many nutritional benefits, specifically when they are mature cooked and boiled without salt (portion size is 1 cup or 172 g for the following measurements.) The macronutrients for this 298 calorie portion of pulse include: 17 grams of carbohydrates (6% daily value), 29 grams of protein, and 15 grams of fat (24% daily value). It also contains 5% daily value of Vitamin C and 41% daily value of Vitamin K. Soybeans are a rich source of important minerals as well, such as: calcium (18% daily value), iron (49% daily value), magnesium (37% daily value), potassium (25% daily value), and no sodium. Soybeans contain isoflavone phytochemicals with a composition of roughly 50% genistein, 40% daidzein, and 10% glycine.

In addition to the nutritional benefits of soybeans, there are many health benefits that come from this pulse as well. For cooked and boiled soybeans, the 3 main health benefits are anti-diabetic effects, anti-cancer effects, and reduction of osteoporosis. Soybeans are low in carbohydrates, meaning they are low on the glycemic index, which is a measurement of the rise in blood sugar after a meal.) If food is low on the glycemic index, it is favorable for people with diabetes. The isoflavones (incl. daidzein), lectin, and lunasin in this legume may be responsible for the aforementioned anti-cancer properties. Osteoporosis is a condition of reduced bone density and therefore increased risk of fractures, which may be reduced in post-menopausal women due to the effects of soy protein, specifically in the isoflavones.


Identity, Type, and Structure of Daidzein

Daidzein (Scheme 1) is an isoflavanol because of its C6-C3-C6 ring structure and estrogenic activity. It provides many health benefits and generally comes from soybeans. Daidzein offers antioxidant, estrogenic, anti-estrogenic, anti-carcinogenic, anti-atherogenic, and anti-osteoporotic effects. The H-NMR spectra of daidzein (Figure 1) shows presence of aromatic hydrogens around 7-8 ppm as expected. The greatest amount of deshielding experienced is by the hydrogen adjacent to the ether on the B-ring due to the electronegativity and aromaticity found at this site. Peaks closer to 7 ppm show the hydrogens closest to the alcohol groups on the C-ring and the sixth carbon position of the A-ring because these protons do not feel the strength of the oxygen like the proton at the second position of ring A. The $^{13}$C-NMR spectrum of daidzein is shown in Figure 2.

(9) CAS Registry Number 486-66-8.
Scheme 1. Daidzein
Figure 1. $^1\text{H}$-NMR spectrum of daidzein.
Figure 2. $^{13}$C-NMR of daidzein.
Biosynthesis, Chemical Synthesis, and Function of Daidzein

The synthesis of daidzein (Scheme 2) starts with 2,4-dihydroxyacetophenone and \( N,N \)-dimethylformamide dimethylacetal (DMF-DMA) to form 3-dimethlamino-1-(2-hydroxy-4-methoxy)-phenlypropenone.\(^{10}\) The added enamine closed to form a second ring using iodination in methanol to make 7-methoxy-2-iodo-4H-chromen-4-one.\(^{10}\) At this point Biegasiewicz et al. used two different methods to produce daidzein. The pathway 5a utilizes a Suzuki coupling with a PEG 10000 to allow for the formation of isoformononetin while the pathway 5b produces dimethylaidzein.\(^{10}\) Both pathways require a 4-hour reflux in with trimethylsilyl idodide in a chloroform solvent, and give an overall yield around 60%.\(^{10}\) Nuclear magnetic resonance spectroscopy confirmed the product as daidzein.

While daidzein is notorious for its anti-carcinogenic and estrogenic qualities, there have been several recent studies of its antidiabetic effects. Scheme 3 presents the basis of the antidiabetic pathway of daidzein. Cheong et al. researched this pathway in obese-diabetic mice.\(^{11}\) The idea is that daidzein (I) activates AMPK (II)—the reaction mechanism remains unknown and it is worth noting that II is a simplification of AMPK.\(^{12}\) The effect of AMPK on glucose is known at least to the extent that AMPK possesses a \( \beta \)-subunit, or branch of molecule, capable of binding to glucose.\(^{12}\) Activated AMPK regulates cell homeostasis to keep insulin levels at the optimized range.\(^{12}\) In ii. activated AMPK causes the movement of the protein Glut4 into the plasma membrane (IV) directly responsible for glucose uptake.\(^{12}\) To see if there truly was an interaction between daidzein and GLUT4 HaloTag and Caveolin-3 imaging chemicals were placed inside a cell containing daidzein.\(^{12}\) Another cell without the daidzein was introduced to the daidzein-filled cell and the two merged into a new cell.\(^{12}\)


Scheme 2. Synthesis of Daidzein
Scheme 3. Antidiabetic Pathway

I \rightarrow \text{Glut4}
Figure 3. Glucose uptake with increased daidzein concentration.
Figure 4. GLUT4 and daidzein reaction.