Effects of processing on soy isoflavones

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Soybeans are a valuable resource for humans, providing protein and other nutrients. Evidence in the scientific literature shows that dietary soy protein can lower serum cholesterol levels, which in turn reduces the risk of heart disease, and also that consumption of soy foods can prevent various cancers. The World Cancer Research Fund and the American Institute for Cancer Research reported in 1997 that the Chinese population—compared to the North American population—has only one-tenth the risk of developing breast cancer and one-fiftieth the risk for prostate cancer. Although many factors contribute to these differences, researchers have credited isoflavones in soybeans for all these benefits.

Isoflavones are phenolic compounds. Soybean isoflavones exist as either glucosides or aglucons (free forms). Aglucons include daidzein, glyce tin, and genistein. The corresponding glucosides are daidzin, glycitin, and genistin, respectively. Two derivatives for each glucoside exist in soybeans: 6'-O-acetyl-daidzin, -glycitin, -genistin; and 6'-O-malonyl-daidzin, -glycitin, -genistin. The concentration and profile of isoflavones in soy foods and soy ingredients vary dramatically as a function of the genetics of soybean cultivars and growing environment and processing.

This article discusses the effects of processing on soybean isoflavones with respect to concentrations and isoform profiles.

**Isoflavone changes during ingredient processing**

Soy flour, soy protein concentrate, and soy protein isolate are three major soy protein products. They have different protein contents and have different applications. Soy flour, the least refined form among the three, has a protein content of about 55%. Different degrees of heat treatment during desolventizing/toasting produce soy flour with different functional properties. Soy protein concentrates contain more than 65% protein. They often are produced by washing defatted soy flakes with acidic water, hot water, or aqueous ethanol. Soy protein isolates are the most highly refined soy protein products, with a protein content of more than 90%. Soy protein isolate is made by alkali extraction of protein to remove insoluble fiber with subsequent acid precipitation to remove soluble sugars.

No significant changes are expected during the production of soy flour. The concentration of isoflavones in defatted soy flour should be higher than that of unprocessed soybeans because of the concentrating effect of defatting: Essentially no isoflavone is lost during solvent extraction. Toasted soy flour maintains the same total isoflavone concentrations, but heat transforms malonyl isoflavones to acetyl isoflavones.

Soy protein concentrates have significantly lower isoflavone concentrations than soy flours because the washing process that is designed to remove flatulent sugars also extracts isoflavones. Aqueous alcohol washing can almost completely eliminate isoflavones from soy protein concentrates, because 80% ethanol is the most effective solvent for extracting isoflavones.

Changes among isoflavones during soy isolate processing have been studied in the author’s laboratory. About 26% of the total isoflavones in soy flour remained in the soy protein isolate, whereas 74% was lost during processing. About 19, 14, and 22% of that went to solid waste, whey, and wash water, respectively (Figure 1).
Furthermore, the isoflavone profile of soy protein isolate was very different from its starting material, soy flour. The percentage of genistein in soy protein isolate was about 18.2%, whereas only 1.6% of the total isoflavone in soy flour was genistein. The percentages of daidzein and acetyl genistin in soy protein isolate also were much higher than those in soy flour. However, the percentages of genistin, daidzin, and glycitin in soy protein isolate were significantly lower than those in soy flour. The increases in genistein and daidzein apparently are due to the hydrolysis of the glucosidic forms of isoflavones during processing. The increase of acetyl genistin is probably due to heat conversion of malonyl genistin into acetyl genistin. The percentages of malonyl genistin and malonyl glycitin were slightly higher in soy flour than in soy protein isolate. However, the percentage of malonyl daidzein decreased significantly in soy protein isolate compared with that of soy flour. This was an indication that malonyl daidzein was more unstable than malonyl genistin and malonyl glycitin under the processing conditions.

The effects on isoflavone retention of the number of washings and washing pH were studied. As the washing times increased, the percentages removed of aglucones, genistein, and daidzein rose gradually. These changes reflected the hydrolysis of genistein and daidzein during washing. However, washing times have no significant effect on either isoflavone content or retention in soy protein isolates. Washing with pH 4–6 water did not have significant effects on total isoflavone recovery.

**Isoflavone changes during processing of traditional soy foods**

There have been no published studies on the effects of processing on isoflavones in traditional soy food products. However, indirect conclusions can be derived from studies of isoflavone concentrations. Different cultivars have different concentrations of isoflavones. Levels of aglucones and acetyl forms of isoflavones are very low in raw soybeans. Most of the isoflavones are in either malonyl or glucosidic forms.

In roasted soybeans, the total isoflavone concentration is expected to remain the same as in freshly harvested materials. (The thermal stability of isoflavones will be discussed in the next section.) However, the majority of the malonyl forms of isoflavones are converted to acetyl forms. There is also a slight increase of aglucones.

In tofu, the total isoflavone concentration is expected to be lower than in the starting material owing to loss during aqueous processing steps. It is also expected that the mass balance will follow a trend similar to that of soy protein isolates. The process also increases the ratio of aglucones glucoside hydrolysis during processing. In fermented products, such as tempeh and miso, the aglucones are the major forms.
of isoflavones, arising from enzymatic activities of the microorganisms used in the processes. In miso, malonyl forms of isoflavones are very low due to the heat treatment used.

The type of processing affects isoflavone concentrations and profiles in traditional soy foods. Much work is still needed to identify specific effects of each process.

**Thermal stability of isoflavones**

The results of a study on the effects of heat treatment on three pure isoflavones, genistin, daidzein, and genistein, are presented in Figure 2. It is apparent that isoflavones degrade faster at a higher temperature, and vary in the extent of degradation based on isoflavones. Genistin is the most thermally susceptible among the three isoflavones (Figure 2C). Heat treatment can break the glucosidic bond, releasing genistin. This observation is confirmed by the appearance of genistin in a heated genistin solution (not shown in this figure). The two aglycones (genistin and daidzein) are very thermally stable, although daidzein is slightly more stable than genistin (Figure 2B vs. Figure 2A). In addition, the malonyl forms are the least thermally stable, being converted to the acetyl forms. Although heat causes changes in the isoflavone profiles, it does not produce a significant decrease in total isoflavones in a product.

**Background reading**


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