Functional Compounds and Ingredients from Soybean to Tofu

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Soybean (*Glycine max*) is a soybean plant whose seeds are abounding in protein. In Asia, the soybean is a native plant with oval and spherical fruits. Due to different strains, the color of the seed coat is yellow, light green, brown, and black; they are also known as soy, green, and black beans.

tofu texture component

1. Introduction

In East Asia, there is a soy product widely and commonly produced from tofu, which is made mainly from soybean. Soy is a precious source of isoflavones, which have received much attention for their anti-oxidant properties, estrogenic activity, and cancer-fighting properties [1][2]. Furthermore, the seed coat of black soybeans is black and contains more anthocyanins and isoflavones than soybeans. Several investigations have mentioned the advantageous bioactive properties of anthocyanins, including antioxidant, anti-obesity, anti-diabetic, and anti-inflammatory activities [3][4][5].

The traditional method of making tofu is to soak soybeans first, then grind them with water and strain them to make raw soybean milk. Soymilk is boiled and heat-treated for 3-10 min, then cooled to room temperature. Then, it is composed by adding acidic or salt-based coagulants, such as glucono-delta-lactone (GDL) or calcium sulfate for tofu, to heated soymilk [6][7]. Alternative natural coagulants, such as crab shell extract, eggshell, and plant-based extracts, have been proposed by several researchers to add to the health benefits of tofu [8][9][10]. There are prerequisites for making tofu, which are to dissociate, denature, and aggregate soybean proteins, inhibit microbial growth, reduce the beany odor, and inactivate biological compounds, such as lipoxygenases or trypsin inhibitors, unless performed by thermal treatment [11]. However, in traditional methods, the temperature adjustment of tofu in the production process is time-consuming and laborious. Moreover, there is improper heat treatment affected the quality of tofu. Compared with traditional technologies, ultra-high-pressure homogenization, high-pressure and ultrasonic non-thermal processing technologies have become alternatives for the food industry to re-innovate high-quality food and reduce processing time and cost [12][13][14].

The aging population is growing and resulting in increased consumer demand for food products with a variety of textures. Recently, much research has been conducted on approaches to modifying the texture of food products. For tofu preparation, there are some hydrocolloids used as gelling agents or stabilizers, such as carrageenan, chitosan, guar gum, and gum Arabic, to improve texture, water retention, or extend shelf life [15][16][17][18]. The addition of hydrocolloids might induce the agglomeration of the soy protein–isoflavone compounds and affect the structure of tofu as well [19]. There is an understanding of the mechanism of interaction among soy protein, hydrocolloids, and functional compounds, which is major in the invention potential for developing new gel textures.

In the food industry, rheology is the study of the deformation and flow of raw material, intermediate products, and final products. Additionally, there are deformation and flow laws in the final product [20]. It is important in understanding textural properties of foods and food processing. Rheological analysis of dynamic oscillation tests was used to observe general structural changes in several food systems under non-destructive conditions [21][22][23].

2. The Bioactive Components of Isoflavones in Soybeans

Isoflavones in soybean or soy products such as tofu, are free aglycones and conjugates. Recently, there have been many studies that demonstrated twelve isoflavones consisting of four chemical forms, each of which contains compounds, such as acetyl-β-glucoside, malonyl-β-glucoside, and aglycone in soybeans. They found genistein, daidzein, and glycidin, which are in the three major groups of isoflavones from soybeans. Isoflavones are classified as aglycones, including genistein, daidzein, and daidzein; β-glycosides include daidzin, genistin, and glycitin; acetylglycosides include 6″-O-acetyldaidzin, 6″-O-acetylgenistin, and 6″-O-acetylglycitin, and malonylglycosides include 6″-O-malonyldaidzin, 6″-O-malonylgenistin, and 6″-O-malonylglycitin flavin [24]. Many studies have illustrated that isoflavones from soybeans decreased cholesterol levels, thus reducing the risk of cardiovascular disease, and inhibiting cell proliferation. In addition, they have anti-cancer, anti-aging, and anti-inflammatory properties, as shown in **Table 1**.

Table 1. Major health effects brought about by isoflavones.

Soybean Content	Health Effects	References
	Decreased cholesterol levels.	[25][26]
Isoflavones	Reducing the risk of cardiovascular disease.	[27]
	Inhibiting cell proliferation.	[28]
	Anti-cancer.	[29]
	Anti-aging.	[30]
	Anti-inflammatory.	[31]

3. The Bioactive Components of Anthocyanins in Soybeans

In recent years, anthocyanins have been proven to have health-promoting properties for the human body. Anthocyanins are flavonoid polyphenols, which are common in our daily diets, particularly in yellow, red, black, purple, or blue cereals such as soybean [32]. Anthocyanins mainly exist in the shape of heterosides in nature. The aglycone modus of anthocyanins, also known as anthocyanins, is structurally based on the flaviliumion or 2-phenylbenzopyran, consisting of hydroxyl and methoxy groups in various positions [33]. More than 635 anthocyanins have been identified, based on the number and position of the hydroxyl and methoxyl moieties [34]. Anthocyanin-rich extracts from soybeans have extensive effects on human medical treatment, such as anti-oxidant, anti-diabetic, anti-obesity, and anti-inflammation activity, as well as the prevention of Alzheimer's disease and cardiovascular disease compounds, as shown in **Table 2**.

Table 2. Major health effects brought about by anthocyanins.

Soybean Content	Health Effects	References
	Anti-oxidant.	[35][36][37]
Anthocyanins	Anti-obesity.	[38][39][40]
	Anti-diabetic.	[41][42][43][44]
	Anti-inflammation activity.	[45][46][47][48]
	Prevention of Alzheimer's disease.	[49][50]
	Prevention of cardiovascular disease.	[51][52]

4. The Bioactive Components of Isoflavones in Soybean Products

In East Asia, soybeans have always been treated as an important source of protein. However, in the Western world, there is an increased interest in and consumption of soy products because of knowledge of the nutritional and functional properties of soybeans. People are looking for more nutritious and healthy products, focusing on the results of people's food choices and lifestyles [53].

In the general food industry, soy products, also known as tofu, are often used as desserts and side dishes. The production of tofu usually goes through the processes of soybean screening, soaking, grinding, filtering, boiling, coagulation, pressing, preservation, and packaging [54][55]. However, after a series of treatments in soy products, some nutrients are also affected by different processing treatments, such as protein, isoflavones, or anthocyanins [56]. Therefore, some researchers have used different processing methods to form tofu, a soft cheese curdled from heated fresh soy milk, to which calcium or magnesium salts have been added to maintain the good protein in tofu. This increased the shelf life of foods such as tofu, which is an excellent source of protein and isoflavones and stored under ambient conditions for up to 1 year [57][58]. In addition, researchers used lactic acid bacteria to ferment tofu. The results showed that the bioavailability of isoflavones in tofu after fermentation was higher than that of conventional tofu. The bioavailability of isoflavones may be affected by their chemical forms and heating processes of the food industry's manufacturing processes [59]. In tofu, both genistein and daidzein mostly exist in the form of glycosides. Then, after using tofu, isoflavones are hydrolyzed by gut microbes into unconjugated forms, namely daidzein, genistein, and glycidyl glycosides, which are estrogenic and bioavailable [60]. In addition, some research has shown that malonyl genistein is the greatest isoflavone form in soybeans, followed by malonyl daidzein, daidzein, and genistein. After using tofu, in the intestine, isoflavones are extensively metabolized; they are absorbed or transported to the liver and go through enterohepatic circulation. In the intestine, the bacterial glucosidases break down the sugar and release the biologically active isoflavones, soy zein, and genistein. Furthermore, bacteria-active isoflavones are bio-transformed into specific metabolites. [60][61].

5. The Bioactive Components of Anthocyanins in Soybean Products

Anthocyanins, a type of plant polyphenol, have received increasing attention in recent years, mainly due to their potential health benefits and applications as functional food ingredients. Soaking beans is the first step in the tofu-making process. Traditionally, however, soybeans have been soaked in water for long periods, resulting in the loss of nutrients in soybeans, such as anthocyanins [62][63][64]. Therefore, some researchers have studied the effect of soaking time on the bioactive components in soybeans, and the results have shown that long soaking times lead to the loss of nutrients in soybeans [65][66]. In addition, during tofu production, different processing conditions affected bioactive components, especially heat treatment conditions. Several researchers have investigated the effect of heat treatment conditions on bioactive components in soybean products. The results demonstrated that different processing techniques caused complex changes in the chemical composition, and heat treatment led to the degradation of anthocyanins and the release of conjugated components [67][68]. The differences in the changes of anthocyanins were induced by heat treatment in soybean due to the different distribution and content of individual phenolic compounds in the seed coat and cotyledon [69][70].

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