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Coagulation of soymilk and quality of tofu as affected by freeze treatment of soybeans

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Abstract

The present study was carried out to investigate the effects of freezing of soybeans on the coagulation of soymilk and quality of tofu. Soymilk, prepared from frozen soybeans, was found to coagulate faster in the presence of coagulant and produced a more uniform-structured gel than that from unfrozen soybeans. Tofu, prepared from frozen soybeans, showed a more orderly and denser network structure than that from unfrozen soybeans, thereby inducing an increase in some textural parameters such as hardness, springiness, gumminess and chewiness as well as syneresis. Freezing also brought about some changes in tofu quality: lower yield, lower fat and higher protein contents. Results of sensory evaluation showed that tofu from frozen soybeans had better sensory properties in terms of flavour and mouthfeel. From these results, it was concluded that freezing promoted the coagulation process of soymilk and changed the quality of tofu in a positive way.

Keywords: Tofu; Freezing; Frozen soybeans; Texture; Sensory properties

1. Introduction

The quality and yield of tofu are influenced by cultivar of soybeans (Shen, de Man, Buzzel, & de Man, 1991; Sun & Breene, 1991), processing methods (Saio, 1979; Shih, Hou, & Chang, 1997) and type and concentration of coagulants (Lim, de Man, de Man, & Buzzell, 1990; Shen et al., 1991; Sun & Breene, 1991). Processing factors include heating rates and times (Beddows & Wong, 1987), stirring speeds and times for coagulation (Cai & Chang, 1998; Hou, Chang, & Shih, 1997; Shih et al., 1997), temperature for coagulation (Shih et al., 1997) and pressing time and weight (Gandhi & Bourne, 1988).

When a solution of soyproteins is frozen, the protein molecules become partially insoluble, due to the formation of intermolecular disulphide bonds (Hashizume, Kakiuchi, Koyama, & Watanabe, 1971). Lee, Choi, Kim, and Yun (1992) have shown that freezing is effective in improving the taste of soybeans, as well as reducing the cooking time to one-half. From these results, it can be expected that use of frozen soybeans may change the quality of soybean products. However, few researches have been carried out on the application of freezing of soybeans to modify the quality of soybean products. Some studies have been conducted to change the texture of tofu by freezing under high pressure (Fuchigami & Teramoto, 1997) and to develop a

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textured protein from frozen tofu (Hashizume, Kosaka, Koyama, & Watanabe, 1974; Hashizume, Nakamura, & Watanabe, 1974).

The present study aims to investigate how the freezing of soybeans affects the coagulation of soymilk and quality of tofu prepared by a traditional method.

2. Materials and methods

2.1. Materials

Soybean (*Glycine max* Merr., cv Jang-yeob) used for tofu making was purchased from a local grower (Chonbuk province, Korea). All chemicals used were reagent grade and purchased from Sigma.

2.2. Methods

2.2.1. Preparation of soymilk coagulum

The soybeans (approximately 150 g) were soaked in 800 ml tap water at room temperature for 10 h (soybean:water = 1:2.2). The soaked beans were placed in a basket to remove excess water, followed by freezing to −20 °C for 5 h by air-blast freezing. The frozen bean was thawed and ground with 1650 ml tap water by using a Waring blender for 4 min at high speed. After grinding, the slurry was brought to the boil with stirring and held at 95 °C for 2.5 or 5 min. Then the slurry was squeezed manually with a muslin cloth to obtain soymilk (1700 ml). An aliquot of 50 ml of the soymilk was transferred to a rheometer cell (ID: 50 mm) and coagulated with 0.02 M calcium sulfate ($CaSO_4 \cdot 2H_2O$) at 72 °C to produce the soymilk coagulum. For comparison, soymilk coagulum was prepared by the procedure described above except for the freezing of soybeans. Unless otherwise stated, freezing refers to freezing of soybeans and heating represents heating of soy slurry.

2.2.2. Preparation of tofu

The soymilk (1700 ml) from frozen or unfrozen soybeans was coagulated with 0.02 M calcium sulfate at 72 °C for 10 min. The resultant coagulum was transferred to a home-made mould (17.6 cm × 9.6 cm × 6.8 cm) lined with cheese cloth and pressed for 20 min by placing a weight of 8.120 kg to produce tofu.

2.2.3. Texture measurement of soymilk coagulum and tofu

Measurements on soymilk coagulum and tofu used a TA-XT2 Texture Analyzer (Stable Micro Systems, Goldaming, UK) fitted with a 5-kg load cell. For the soymilk coagulum, a back extrusion test was carried out. The soymilk coagulum was compressed by a plunger (D: 45 mm) until the coagulum flowed up through the annulus. The maximum force (g) required to accomplish extrusion was measured at regular time intervals. For tofu, texture profile analysis (TPA) was carried out. Cube samples of tofu (10 mm × 10 mm × 10 mm) were compressed to 80% deformation by a compression plunger (D: 25 mm). The pre-test, test and post-test speeds were set to 2, 1 and 2 mm s^{-1}, respectively. Ten replicate tests were conducted for each sample.

2.2.4. Scanning electron microscopic observation

The specimen was prepared by the method of Inoue and Osatake (1988). The tofu was cut into blocks (ca. 3 mm × 3 mm × 3 mm). To a block, 3 ml of 2.5% glutaraldehyde in 0.1 M phosphate buffer (pH 7.4) were added, pre-fixed at room temperature, and stored at 4 °C for 1 h. The pre-fixed sample was washed twice with 0.1 M phosphate buffer (pH 7.4), followed by post-fixing in 1% osmium tetroxide solution. Then the sample was dehydrated in a graded series of ethanol solutions (60%, 70%, 80%, 90%, 95% and 99.5%) and transferred to *t*-butyl alcohol. The sample in *t*-butyl alcohol was placed in a refrigerator to freeze. The frozen sample was then transferred into the bell jar of a vacuum evaporator to sublimate *t*-butyl alcohol. After sublimation, the dried sample was coated with Au–Pd to produce a specimen in an ion beam sputtering system (E-1030; Hitachi Co., Japan) using argon gas. The specimen was examined by a scanning electron microscope (model S-4700; Hitachi Co., Japan).

2.2.5. Yield and proximate analyses

Yield of tofu was expressed as weight of tofu obtained from 1700 ml of soymilk. Moisture content was determined by drying 0.9 g of fresh tofu at 105 °C in a drying oven to a constant weight. Total protein was determined by the microKjeldahl method (AOAC, 1995) and crude fat by the Soxhlet method (AOAC, 1995).

2.2.6. Syneresis

Syneresis was evaluated by employing the modified method of Amstrong, Hill, Schrooyen, and Mitchell (1994). Six pieces of tofu samples with diameter of 1.5 cm were weighed and filled into dialysis tube (D: 2.5 cm), bound and wrapped with plastic wrap to minimise evaporation. These cylinders were then tied to a wire frame placed over a 2-l beaker in a hanging position for 24 h at 4 °C. Percentage syneresis was calculated as the weight of water released from the sample in 24 h divided by the weight of sample and multiplied by 100.

2.2.7. Sensory evaluation

Ten panellists who trained to recognise and score the sensory attributes performed sensory evaluation. The attributes evaluated were colour, flavour and mouthfeel and the results were expressed on a 9-point hedonic scale (1 = excellent, 9 = not good) for each attribute.