Mechanisms of Aburage (Fried Soy Curd) Formation

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Introduction

Aburage is one of the most popular traditional and domestic foods of Japan produced from soybean seeds and is a kind of fried soy curd. The name of Aburage can be divided into Abura and Age, and Abura means oil and Age does frying in Japanese. Aburage is a golden-colored brick and the common one sizes 16 × 8 × 1.2 cm. Chemical composition of Aburage is listed in Table 1[1]. Water content of Aburage is lower than, but the oil content is higher than that of Tofu (soy curd). The reasons for these differences are ascribed to the lower water content of original Tofu and oil absorbed by the Tofu during the frying. The lower water content of Aburage contributes to prolongation of the shelf life and the decrease of its weight, and it gives easiness of conveyance and storage of Aburage compared with those of Tofu.

About 500 thousands tons of soybean seeds are consumed for Tofu and Aburage in Japan every year. One third of the consumption is for Aburage. From 1 kg of soybean seeds, 1–1.2 kg of Aburage is produced and 300 g of oil is consumed for the frying. Aburage of good quality is a well-expanded fried Tofu with its surface area increased more than three times that of the original Tofu during the frying, and the inner side of Aburage has the fine and homogenous spongy structure.

The preparation method of Aburage has been developed based on the trials and experiences of many professionals from ancient times. But the method was not scientifically explained. When a new problem arises, even though the method is thought to be complete, the scientific explanation of the method might give an important clue without many trials which had been done by ancient people. We here describe firstly the outline of the Aburage preparation method and secondly the expansion mechanism of Aburage which is most important for producing high quality Aburage, and finally food items of Aburage.

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Table 1. Chemical composition of Tofu and Aburage (%)

	Water	Protein	Lipid	Carbohydrates: Non-fibrous	Carbohydrates: Fiber	Ash
Tofu	86.8	6.8	5.0	0.8	0	0.6
Aburage	44.0	18.6	33.1	2.8	0.1	1.4

Procedure to prepare Aburage

1) *Outline of the preparation method of Aburage*

The process of preparing Aburage is shown in Fig. 1. Soybean seeds are firstly soaked and ground homogeneously, and the mash called Go is then heated and filtered to separate Okara (residue). Appearance of the filtrate is similar to cow's milk and it is called Tounyu (soy milk). Coagulant is added to the soy milk and the soy milk becomes gel which is called Tofu (soy curd). Finally the Tofu is fried to Aburage. Among the steps to pre-

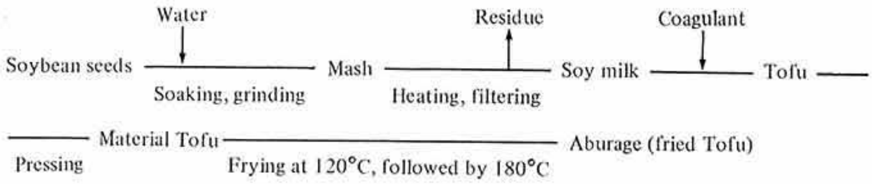


Fig. 1. The process of making Aburage

pare Aburage, the gelation of soy milk (heating and coagulation) and the frying are important for preparing Aburage of high quality.

2) Essential procedure for Aburage making

(1) Preparation of the Tofu for Aburage

The procedure for preparing Tofu, which is a starting material of Aburage, is almost the same with that for preparing Tofu as a food item. The different points between the two procedures are the period of heating time of Go, a kind of coagulant, and condition of the coagulation.

The heating time for Tofu for Aburage (Aburage-Tofu) is shorter than that for Tofu for dishes (food-Tofu). For the food-Tofu, Go is prolongably heated to ensure to form the smooth Tofu gel having good water-holding capacity. On the contrary, for Aburage-Tofu it is important to avoid overheating of Go. Practically heating of Go is stopped just before the boiling or some water is added to the Go just after the boiling started and stopped heating. After the heating, the Go is filtered to separate Okara (residue) from the filtrate (soy milk). As contamination of fine residues to the filtrate causes poor expansion of Aburage, the filtration should be carefully done.

Coagulant for preparing Tofu for Aburage is calcium sulfate. Although coagulation of the food-Tofu is done stationarily in order to form smooth and homogeneous gel, that of the Aburage-Tofu is done with vigorously stirring the milk to form low water-content gel. The Tofu is pressed to reduce the water content to about 70%. For preparing Aburage it is important to prepare carefully the original Tofu, otherwise the Aburage is poorly expanded and insufficiently developed its spongy structure, resulting in poor quality of Aburage[2].

(2) Frying condition of the Tofu

The pressed Tofu is then fried in a process described below. At the first period of the frying, the Tofu is fried at relatively low temperature (about 120°C) to expand the Tofu and develop the spongy structure. Then the temperature is raised to about 180°C by changing the frying pot for baking the surface of the Tofu to change the color gold and to decrease the water content in the skin. When the Tofu is fried at high temperature from the start of frying, the change of the surface of Tofu precedes the expansion of Tofu and the Tofu does not expand well.

The method to prepare Aburage is more complicated than that of food-Tofu, and sometimes poorly expanded Aburage of low quality is produced in commercial factories. This instability of the product quality comes from the complex procedure to make Aburage and many factors relate to the quality of the product. Thus it should be noted that for making Aburage of high quality it is important how to prepare original Tofu and control the frying condition.

Expansion mechanism of the Tofu during the frying

1) Minimum temperature necessary for the expansion

The Tofu is firstly fried at temperature slightly higher than 100°C in a factory. For determining the minimum temperature necessary for the expansion, the Tofu was fried under reduced pressure in an oil bath at the temperature set to be 5°C higher than the

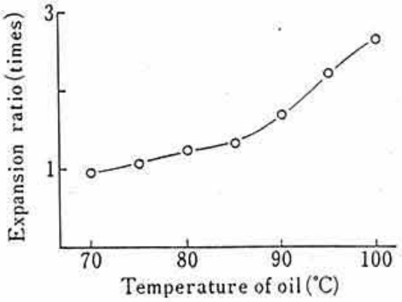


Fig. 2. Expansion of Aburage as affected by frying temperature under reduced pressure

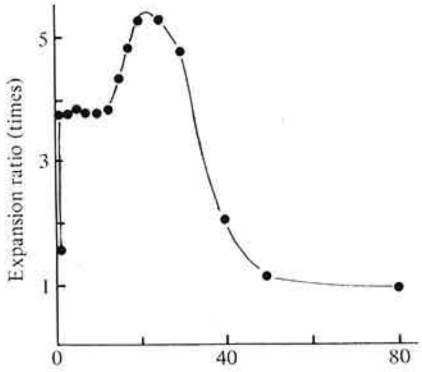


Fig. 3. Expansion of Aburage as affected by sulfhydryl content of protein

boiling point of water under the reduced pressure between the temperature 70° and 100°C[3]. As shown in Fig. 2, the Tofu did not expand at the frying temperature range between 70° and 85°C (boiling point of water ranged from 65° to 80°C). At frying temperature 90°C (boiling point of water was 85°C), the Tofu expanded well. This result indicates that even if the water vapor is present in Tofu gel, the Tofu did not expand at the temperature below 85°C and temperature higher than 85°C is essential for the expansion. This temperature is consistent with the temperature at which soy protein starts to be denatured, and it suggests the supply of energy to disrupt noncovalent bonds between molecules of protein. As the boiling point of water is 100°C under normal condition, which is higher than the temperature necessary for denaturing the soy protein, the Tofu can easily expand well.

2) *Importance of exchange reaction between -SH and S-S in the Tofu during the frying*

It is well-known that formation of disulfide bond (S-S) between protein molecules sustains the gel formation of soy protein. Contribution of the S-S bond formation to the expansion of Tofu during the frying was examined[4]. The Tofu prepared from soy milk which was treated with N-ethylmaleimide to mask -SH residue of proteins in the milk did not expand completely. This shows that the SH residue is essential to the expansion of Tofu and this residue plays an important role in the mechanism of the expansion. One preparation of soy protein solution was treated with dithiothreitol (DTT) to convert S-S bonds in the milk to free SH residues, and it contained 8.2×10^{-5} mols of SH residue per 1 g of protein. Another preparation of soy milk was treated with potassium bromate to convert SH residue in the milk to S-S bonds, and it contained 0.5×10^{-6} mols of SH residue per 1 g of protein. Tofu samples were prepared by mixing these two milk fractions in varying ratios and fried (Fig. 3). A Tofu sample prepared from soy milk containing less SH residues poorly expanded, and other Tofu samples prepared by mixing the two kinds of soy milk, containing less and rich SH residues respectively, in the ratio of -SH to S-S between 1 : 27 and 1 : 3 were expanded well. Samples with the ratio of -SH to S-S between 1 : 2.2 and 2 : 3.1 expanded abnormally, and further increase of SH residues in Tofu decreased the expansion of Tofu. These results indicated that there are optimum contents of SH and S-S residues in the soy milk for the expansion of Tofu. It showed that both of the SH and S-S residues are essential for the expansion, and it also suggested that the exchange of SH and S-S residues occurred during the expansion. Heated soy milk which was prepared according to the commercial method contained 4×10^{-6} mols of SH residues per 1 g of soy protein[5], and this amount of SH residue is enough for the S-S, SH exchange reaction.

3) Role of air in the Tofu for Aburage making

It has been observed that Tofu prepared from prolongably heated Go did not expand well during the frying. Heating of liquid usually releases dissolved air in the liquid to the atmosphere. It was examined whether the dissolved air in the soy milk contributes to the expansion of the Tofu[3]. The soy milk was heated for 3 to 30 min and then fried. The relationship between the degree of the expansion and heating period was measured. Prolongation of the heating time decreased the degree of the expansion and heating for more than 10 min completely depressed the expansion (Fig. 4). When such prolongably heated soy milk was aerated after it cooled, the Tofu prepared from this soy milk expanded well. Soy milk preheated for 3 to 20 min was mixed with water, after the amount of air dissolved in that water was determined, and fried (Fig. 5).

The amounts of the added air necessary for the expansion of the Tofu increased with the prolongation of the heating time of the soy milk. The soy milk which did not contain dissolved air required 12.2 ml of air per 1 *l* of the soy milk for the expansion of the Tofu irrespective of the length of the heating time. These results clearly show that the decrease of the degree of expansion of Tofu with heating time is caused by the decrease of dissolved air in the soy milk.

What is a role of dissolved air in the soy milk during the expansion? Minimum volume of the air for the expansion is 12.2 ml per 1 *l* of soy milk as shown above, and this value is more than the solubility of air at 70°C. During the gelation of soy milk (formation of Tofu gel) some of the dissolved air formed bubbles inside the Tofu. These bubbles may work like a boiling stone in boiling water during the frying and the growing bubbles serve to expand the interspaces of protein gel, resulting in the well-expanded Aburage (Fig. 6). Low content of dissolved air results in few bubbles which act as a boiling stone, and bumping occurs inside the Tofu. The

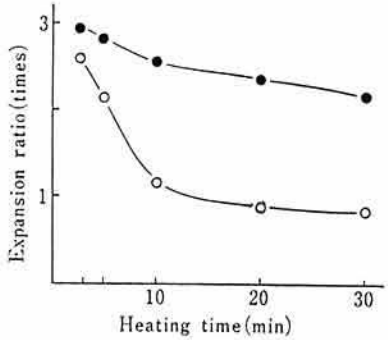
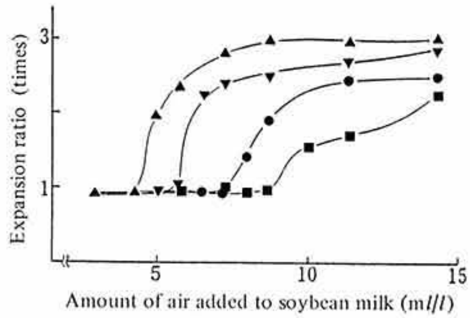


Fig. 4. Expansion of Aburage as affected by heating time and aeration
○ Heated at 100°C.
● Heated at 100°C and then aerated.



Heated at 100°C for 3 min. (▲), 5 min. (▼), 10 min. (●), 20 min. (■).

Fig. 5. Expansion of Aburage as affected by heating time and the amount of air added to soybean milk

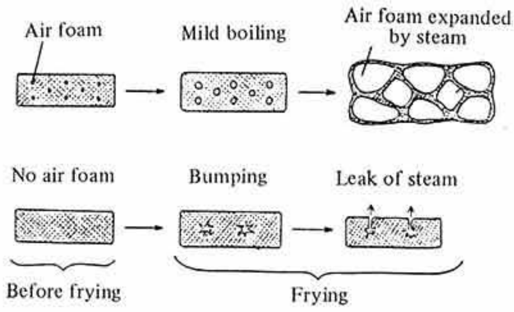


Fig. 6. The role of air foam on the expansion of Aburage

water vapor generated leaks with the bumping, resulting in poorly expanded Aburage.

Availability of Aburage as a food material and items of Aburage

Even though the Aburage is a fried product of Tofu, the texture of the Aburage is quite different from that of Tofu. Gannmodoki, which is one of Aburage items and the name means a food similar to meat of wild geese, is a kind of ancestor of the texturized soy protein recently developed. Aburage is available for many Japanese style dishes as a material of soups and stews after being cut into pieces, or as a material to make Inari-sushi (seasoned boiled rice packed inside the Aburage, an edible envelope).

Briefly presented is the mechanism of Aburage formation clarified by our food chemical studies. Such basic explanation on the change of food chemical properties of soy protein in preparing food items may give a clue to create a new field of food processing industry.

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(Received for publication, October 3, 1986)