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Effects of Defoaming and Coagulating Agents on the Physical Properties of Tofu

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SYNOPSIS

Tofu preparations were produced by a process commonly used in mechanized large-scale production from soybean. The effects of the defoaming agents (Emulgy-A, containing glycerol fatty acid ester, and Emulgy-S, glycerol fatty acid ester, soybean phospholipid, calcium carbonate, and silicone resin) and coagulating agents [synthetic nigari, calcium sulfate, and gluconodeltalactone (Maglactone-70)] on the physical properties of the tofu were examined.

The addition of the defoaming agents did not directly affect the physical properties. However, they affected the yields of soymilk and *okara*, and thus, the yield of product. A suitable a defoaming agent is highly dispersable and compatible with giving rapid and uniform adsorption to the interface during tofu preparation.

The coagulating agents directly affected the liberation of free water and thus altered the properties of the tofu.

Nigari resulted in a somewhat slow coagulation rate, poor water liberation, weak coagulation, and partial rounding of the tofu when cut. The physical properties of the products obtained were generally unsatisfactory.

Calcium sulfate resulted in rapid and uniform coagulation, a dense and glossy interior, excellent water liberation, the chracteristic feel in the mouth and when being chewed of tofu, and highly desirable physical properties. The optimum product could be achieved by the addition of 1.0% calcium sulfate, based on the weight of the soybean, of the three concentrations tested.

Maglactone-70 resulted in a low coagulation rate, nonuniform coagulation, excessive water retention, small pores in the inside, poor gloss, a rough feel when the tofu was chewed, super-coagulation, excessively high physical values, and unsatisfactory softness.

The pH variations and color of the tofu products did not directly affect their physical properties. Generally, insufficient water liberation causes excessive moisture in the product.

In the mechanized large-scale production of tofu, in which materials should be treated at high temperature within a short period of time, for the sake of efficiency, it is desirable that defoaming and coagulating agents be heat-resistant, highly dispersable, and compatible with. The agents should contain many hydrophilic and lipophilic groups. A defoaming agent containing glycerol fatty acid ester at a high concentration and a coagulation agent containing calcium sulfate at a high concentration may give desirable results.

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INTRODUCTION

Recent changes in life styles and the spread of supermarkets have promoted the mechanized mass production of tofu, a product obtained from soybeans, which was traditionaly made manually and on a small scale. The use of the procedures employed in the manual production of tofu for mass production results in certain problems, including deterioration in the physical properties of tofu products such as the characteristic texture in the mouth and while the productis being chewed. There have been few reports on the suitability and effects on the quality of tofu of various additives than can be used to control or to make use of the foaming properties of soybeans and the coagulation of soymilk examined the effects of defoaming and coagulating agents frequently used in the making of a common tofu product, fresh *momen* tofu.

MATERIALS and METHODS

Details of the procedures used in producing tofu samples (for example, the addition of a defoaming agent, coagulating agent, and water, and the temperature of heating) were those employed in mechanized large-scale production[1].

Soybeans produced in Hokkaido (Tsurunoko: *Glycine max* Merr) stored at 5°C for three months after being harvested were used. Tofu samples were produced by the process shown in Fig. 1.

Soybeans
- Washed
- Soaking in water
- Grinding

Go (mashed soybean soup)
- Boiling
- Squeezing
- *Okara*

Soymilk

Coagulating agent
- Cooling
- Molding

Tofu

Fig. 1. Production of tofu

The soybeans were immersed for 10 hr in still water (20-25°C) that weighed 2.5-3.0 times as much as the soybeans, and then ground with a multipurpose grinder at 165 rpm for 10 min. During grinding, 1.0, 2.0, or 3.0% by weight, based on the soybeans, of a governmentally approved defoaming agent was added together with water that weighed 3.5 times as much as the soybeans. The agent was either Emulgy-A, which is 97.0% glycerol fatty acid ester, pH 7.5 or Emulgy-S, which is 90.0% glycerol fatty acid ester, 5.0% calcium carbonate, 4.3% soybean phospholipid, and 0.7% silicone resin, pH 7.5 (both, Riken Vitamin Co., Ltd).

The *Go* (mashed soybean soup) thus obtained was heated to 90-95°C and pressed through a cotton bag to produce soymilk. The specific gravity and density of the resulting soymilk were adjusted with the use of a refracted densitometer to 1.2-1.3 and 13-15%, respectively, by the addition of water. Then the soymilk was heated to 95-97°C for 10 min. Separately, 0.5, 1.0, or 1. 5% by weight, based on the *go*, of a governmentally approved coagulation agent was put in a stainless steel pot. The agent was natural *nigari* (*Nigari* : Bittern), consisting of 65.0% magnesium chloride and 35.0% calcium sulfate, pH 6.9, with the solubility of 98% at 90°C ; $CaSO_4$, purity 97%, pH 6.8, and with the solubility of 98% at 90°C ; or gluconodeltalactone (Maglactone-70 : M -70), purity 70%, pH 6.6, with the solubility of 97% at 90°C.

A preliminary test showed that mixing was best when the *go* was added at one tire from position about 1.0 m above the top of the pot. The resulting mixture was allowed to cool and was left at 20-25°C. The semicoagulated product thus obtained was immediately poured into a mold (10×10×15 cm) made of Japanese cypress (hinoki), the inside of which was coated with a piece of cotton fabric. A load of 3.0 kg was left on top for 120 min, and a tofu was obtained.

Then, the following items were recorded : the period needed for defoaming, starting from the time of the addition of the defoaming agent ; the yields of the soymilk and *okara* (beancurd less), the period required for coagulation starting from the less), the period required for coagulation startings from the time of the addition of the coagulating agent : the hardness : and the following physical values[2]——the rate of penetration, elasticity, susceptibility to being cut (measured with a Digital Rheometer M-7030, Fuji Rika), color (identified with a digital hue meter ND-1001 DP, Nippon Denshoku Kogyo), pH (measured with a pH meter, Hitachi M-BE), and moisture content[3] (found by heat-drying at normal pressure).

The standard deviation and statistical significance of differences between the test lots were based on the SD was found by the X^2 test. Single asterisks in the text "*" represent a statistical significance between the test lots on the 1% level by the t-test. Each experiment was repeated a total of 25 times.

RESULTS and DISCUSSION

1. Effect on defoaming of defoaming agent

The defoaming effect was evaluated as the time (seconds) required for defoaming of 1.0 l of the *go* boiled at the temperature of 90-95°C (Table 1).

In every lot, the defoaming period shortened as amount of defoaming agent added increased. These results suggest that a higher defoaming effect can be achieved by use of a defoaming agent containing a larder amount of a glycerol fatty acid ester. Emulgy-A, containing more fatty acid ester than Emulgy-S, was significantly more effective. The effect of a defoaming agent that contains silicone resin is lower than the same agent without silicone unless the resin is thoroughly dispersed in water by, for example, being shaken[4]. However, glycerol fatty acid ester, which includes both hydrophilic and lipophilic groups, is very dispersable[5]. As a result, the intense adsorption and coordination of Emulgy-A to interfaces might lower interfacial tension, and thus increase the defoaming effect.

2. Effects on yields of soymilk and *okara* of defoaming agent

It is generally believed in the industry that yields of soymilk and *okara* in the mechanized large-scale production of tofu are approximately 63% and 15%, respectively[6]. In laboratory-scale production, higher yields can be achieved (Table 2).

In the Emulgy-A preparations, the yield of soymilk increased slightly with an increase in the amount of the defoaming agent, but in the Emulgy-S preparations, the yield decreased slightly. The yields of the preparation with 3.0% Emulgy-A and 3.0% Emulgy-S, in which the defoaming effect was large, were 73.5±2.1% and 70.9±1.1%, respectively.

Table 1. Effects of defoaming agents

Defoaming agent added*	%	Seconds needed for defoaming+
Emulgy-S§	1.0	94.5 ± 2.6
	2.0	74.6 ± 2.7
	3.0	65.6 ± 2.2
Emulgy-A¶	1.0	82.3 ± 2.6
	2.0	58.7 ± 2.4
	3.0	44.6 ± 2.7
Control	0	365.7 ± 4.6

±Standard deviation, n=25.

*Percentage of soybean weight

§Emulgy-S : glycerol fatty acid ester 90.0%, calcium carbonate 5.0%, soybean phospholipid 4.3%, silicone resin 0.7%, pH 7.5.

¶Emulgy-A : glycerol fatty acid ester 97.0%, pH 7.5

+Time needed for 1.0 *l* of *go* to became defoamed while being boiled at 90-95℃

Table 2. Effects of defoaming agents on the soymilk and *okara* yields

Defoaming agent added*	%	yield(%) Soymilk	*Okara*
Emulgy-S	1.0	73.3 ± 2.1	20.2 ± 1.3
	2.0	71.5 ± 2.6	20.7 ± 2.4
	3.0	70.9 ± 1.1	20.7 ± 1.6
Emulgy-A	1.0	70.6 ± 2.7	21.2 ± 2.5
	2.0	72.5 ± 2.4	21.6 ± 1.9
	3.0	73.5 ± 2.1	23.7 ± 1.4
Control+	0	65.0	15.0

±Standard deviation, n=25.

*Percentage of soybean weight

+From Ref. 6.

The yield of *okara* increased as the amount of the defoaming agent added increased. The *okara* yields of the 3.0% Emulgy-A and 3.0% Emulgy-S preparations were 23.7±1.4%* and 20.7±1.6%, respectively.

The total yield (soymilk yield plus *okara* yield), of the 3.0% Emulgy-A preparation was 97.1±2.1%*, and that of the 3.0% Emulgy-S prepration was 91.7±1.8%. The yield was influenced by the defoaming effect, complete defoaming would lower loss and thus elevate the yield. The glycerol fatty acid used as the defoaming agent is a surfactant that precipitates protein from soybean whey[7]. Thus, complete defoaming prevents the loss of protein, increasing the yield.

3. Effect of coagulation agents on coagulation period and hardness of coagulated

Only 3.0% Emulgy-A and Emulgy-S preparations were examined for the effects of coagulation agents on the coagulation period and hardness (Table 3).

The time needed for the soymilk to coagulate shortened as the amount of coagulation agent added increased. The time needed for coagulation of the Emulgy-A preparations was shorter than that of the Emulgy-S preparations. The coagulation time of the M-70 preparations was longer than that of the $CaSO_4$ or *nigari* preparations. The coagulation time with 3.0% Emulgy-A and 1.5% *nigari*, $CaSO_4$, or M-70 was 19.6±1.4* sec, 11.8±2.2* sec, and 45.7±2.6 sec, respectively.

The hardness of the Emulgy-A preparations was slightly greater than that of the Emulgy-S preoarations. With 3.0% Emulgy-A and 1.5% *nigari*, $CaSO_4$, and M-70, hardness was 0.75±1.4, and 1.29±1.7 dyn/mm², respectively. Hardness of ≥0.95 dyn/mm² resulted in supercoagulation, which made pouring difficult and gave unsatisfactory smoothness. The 1.0% $CaSO_4$ preparation, which gave a hardness of 0.82±1.4 dyn/mm², gave the highest workability. The results indicated that the desirable coagulation agent was one with high solubility, small particle size, and high compatibility. A coagulation agent containing a large amount of a calcium salt is highly effective, since soybean protein has a rigid high-order structure[8] and coagulates not when simply heated but when it reacts with a calcium salt[9]. However, the hardness is not proportional to the speed of coagulation ; rather it decreases as the speed of coagulation increases. The coagulation agent M-70 increased the hardness of the product, although it was labile to heat, and thus gave a low coagulation rate.

Table 3. Effects of coagulating agents on the coagulation period and the hardness of the tofu

Coagulating agent*	%	Seconds needed for coagulation		Hardness (dyn/mm²)	
		3.0% Emulgy⁺		3.0% Emulgy⁺	
		A	S	A	S
Nigari	0.5	48.2 ± 1.6	55.1 ± 1.5	0.8 ± 2.7	0.7 ± 1.7
	1.0	38.4 ± 2.1	41.5 ± 1.9	0.8 ± 3.1	0.7 ± 1.5
	1.5	19.6 ± 1.4	23.4 ± 2.3	0.7 ± 1.4	0.7 ± 2.6
$CaSO_4$	0.5	45.1 ± 1.5	50.2 ± 3.1	0.9 ± 1.9	0.8 ± 2.3
	1.0	30.9 ± 2.4	33.6 ± 2.6	0.8 ± 1.4	0.8 ± 1.7
	1.5	11.8 ± 2.2	16.5 ± 1.1	0.8 ± 1.1	0.7 ± 2.1
M-70⁺⁺	0.5	64.1 ± 2.2	68.4 ± 1.5	1.4 ± 2.1	1.3 ± 2.2
	1.0	58.2 ± 1.6	65.4 ± 2.1	1.3 ± 2.6	1.2 ± 3.1
	1.5	45.7 ± 2.6	51.4 + 1.4	1.3 ± 1.7	1.2 ± 2.2

±Standard deviation, n=25
*Percentage of soymilk weight
⁺Percentage of soymilk weight
⁺⁺Maglactone-70

4-1. Effects of coagulation agents on rate of penetration of tofu

To examine the inner density (uniformity) of the tofu preparations, their rates of penetration were measured (Table 4).

Generally speaking, the penetration rates of the preparations with 3.0% Emulgy-A were slightly higher than those with Emulgy-S. When the coagulating agents were at the same concentration, the penetration rate was lowest with *nigari*, intermediate with $CaSO_4$, and highest with M-70. The mean penetration rate of the seven commercial tofu preparations was 5.3±1.4 dyn/mm², which was close to the rate of the $CaSO_4$ preparations. The penetration rates with 3.0% Emulgy-A at 1.5% *nigari*, $CaSO_4$, and M-70 were 4.2±1.6, 5.3±1.4, and 6.9±2.1 dyn/mm²*, and all had poor internal water retention, a hard texture, and a somewhat rough and sticky feel when being chewed. By the naked eye, each preparation with *nigari* had poor integrity and was susceptible to breaking. The M-70 preparations were somewhat rough and hard, lacked gloss, and had small internal pores in some cases. The $CaSO_4$ preparations were internally uniform, and had gloss, a smooth texture, and an excellent texture when chewed, similar to that of commercial tofu.

The density of tofu depends much on the defoaming step, the coagulation rate, the coagulation strength, and the pressure used. In particular, the reaction between calcium salt in the coagulation agent and soybean protein exerts the highest possible effect. Consequently, the uniformity of tofu increases with an increase in the coagulation rate, and slow coagulation results in poor uniformity and poor liberation of free water. For satisfactory density, $CaSO_4$ was the most suitable. In the *nigari* preparations, the binding of Na ions to water molecules resulted in some water retention and the slow liberation of free water, resulting in susceptibility to being broken. In the M-70 preparations, the high solubility of M-70 in water and the rapid progress[10] of the reaction resulted in poor uniformity and the liberation of much moisture, which produced tofu with insufficient moisture and a somewhat rough and hard texture.

4-2. Effects of coagulation agents on the elasticity of tofu

In general, the elasticity of tofu is proportional to the amount of the coagulation agent added.

Table 4. Effects of coagulating agents on penetration, elasticity, susceptibility to be cut, pH, and moisture of tofu

Addition coagulating agent*	%	Em+	Penetration (dyn/mm^2)	Elasticity (dyn/mm^2)	Ability to be cut (dyn/mm^2)	pH	Moisture (%)
Nigari	0.5	A	4.1 ± 1.5	62.9 ± 1.6	69.1 ± 1.5	5.7 ± 0.1	89.5 ± 2.4
		S	4.0 ± 1.2	62.8 ± 1.5	68.0 ± 0.8	5.7 ± 0.3	89.9 ± 2.3
	1.0	A	4.2 ± 1.4	63.3 ± 1.8	70.1 ± 1.9	5.7 ± 0.4	89.5 ± 1.6
		S	4.1 ± 1.7	63.1 ± 1.3	69.2 ± 1.6	5.7 ± 0.3	89.6 ± 1.6
	1.5	A	4.2 ± 1.6	63.4 ± 1.2	71.1 ± 1.3	5.6 ± 0.2	89.0 + 2.8
		S	4.2 ± 1.1	63.3 ± 2.1	70.1 ± 1.8	5.6 ± 0.3	89.4 ± 0.8
$CaSO_4$	0.5	A	4.9 ± 1.3	64.2 ± 2.7	81.5 ± 1.2	5.7 ± 0.4	87.1 ± 2.1
		S	4.8 ± 1.1	64.1 ± 1.6	81.0 ± 1.5	5.7 ± 1.1	87.3 ± 2.4
	1.0	A	5.0 ± 2.5	64.4 ± 1.9	89.6 ± 1.4	5.6 ± 0.1	86.1 ± 2.1
		S	5.0 ± 1.6	64.2 ± 1.5	89.6 ± 1.6	5.5 ± 0.1	86.8 ± 1.5
	1.5	A	5.4 ± 1.4	65.0 ± 1.4	90.1 ± 2.1	5.6 ± 0.4	87.0 ± 2.2
		S	5.3 ± 1.8	64.4 ± 1.3	89.1 ± 2.1	5.6 ± 0.8	87.0 ± 1.2
M-70	0.5	A	6.1 ± 1.3	65.4 ± 1.3	105.1 ± 2.4	5.6 ± 0.3	84.4 ± 1.4
		S	5.9 ± 1.1	65.4 ± 1.2	105.0 ± 1.6	5.5 ± 0.2	84.4 ± 1.8
	1.0	A	6.4 ± 1.2	65.8 ± 2.1	109.1 ± 2.2	5.5 ± 0.6	84.3 ± 1.9
		S	6.3 ± 2.3	65.7 ± 1.6	109.6 ± 2.3	5.5 ± 0.5	84.4 ± 0.9
	1.5	A	7.0 ± 2.1	65.9 ± 1.4	190.8 ± 0.9	5.4 ± 0.8	84.1 ± 0.2
		S	6.9 ± 1.5	65.8 ± 1.5	108.9 ± 1.8	5.5 ± 0.3	84.3 ± 1.2
Commercial tofu++			5.4 ± 1.4	64.4 ± 2.1	89.5 ± 1.6	5.5 ± 0.7	86.6 ± 1.2

±Standard deviation, n=25
Molding Pressure by weight of 3.0 kg for 120 min
*Percentage of soymilk weight
+A, 3.0% Emulgy-A S, 1.0% Emulgy-S (Percentage of soymilk weight)
++Seven commercially available tofu preparations

The elasticity of the Emulgy-A preparations were slightly higher, by about 0.1-0.5 dyn/mm^2, than that of the Emulgy-S proparations (Table 4).

The mean elasticity of the seven commercially available tofu preparations was 64.3±2.1 dyn/mm^2, which was about the same as that with 3.0% Emulgy-A and 1.0% $CaSO_4$. The elasticity of the preparations with 3.0% Emulgy-A and 1.0% *nigari* $CaSO_4$ or, M-70 was 63.2±1.8, 64.4±1.9, and 65.7±2.1 dyn/mm^2, respectively. The differences were not significance.

Generally speaking, the *nigari* preparations were inelastic and the M 70 preparations were somewhat hard, (not resistant to impact). A product with the elasticity of around 62.5 dyn/mm^2 has insufficient resistance to impact and a rough texture; it can be released from a wood mold only with difficalty.

These results indicate that the elasticity of tofu depends on the moisture content and on its protein integrity. Much moisture makes tofu very fragile. On the other hand, little moisture content would give excessive integrity and poor flexibility. To may be caused by the difference in the integrity resulting from the reaction of soybean protein and the coagulation agent used. An excessively high or low reaction rate would cause unusual moisture liberation and poor uniformity. That is to say, when the reaction proceeds at high or low reaction rate, an intermediate density and excellent density, elasticity, and resistance to impact can be obtained[11]. Thus, a coagulation agent should have high dispersability, with constant thermal decomposition and binding to water molecules.

4-3. Effects of the coagulation agent and the ability of tofu to be cut

Table 4 shows the ability of each tofu proparation to be cut when it is about to be eaten.

Generally speaking, the ability of the preparstions to be cut increased as the amount of the coagulation agent increased. the Emulgy-A preparations cold be cut more easily less easily than the Emulgy-S preparations by about 1.0-2.0 dyn/mm^2.

The mean ability of the seven commercial tofu preparations was 89.5$\pm$1.6 dyn/mm^2. The ability of all *nigari* preparations to be cut was too low, that of the M-70 preparations was too high, and that of the $CaSO_4$ preparations was appropriate. The 1.0 or 1.5% preparations were comparable to the commercial ones. The ability to be cut of the Emulgy-A preparations with 1.0% *nigari* $CaSO_4$, and M-70 were 70.1$\pm$1.9, 89.5$\pm$1.4*, and 109.0$\pm$2.2* dyn/mm^2, respectively. The *nigari* preparations had a poor feel in the mouth and when being chewed, the M-70 preparations were somewhat sticky when being chewed, producing a rough feel in the mouth. That is to say, statistical significance ability to be cut cannot always provide sufficient texture. A value of $\leq$70.0 dyn/mm^2 or lower would give a rounded product and make cutting difficult. On the other hand, that of $\leq$95.0 dyn/mm^2 or more would give an irregular cut section and a somewhat sticky feel. Tofu with density tissue and excellent water retention shows has a value of 89.0-95.0 dyn/mm^2 when cut. This value depends on coagulation, but if the tofu is not uniform, the ability to be cut would also lach uniformity. Therefore, the coagulation agent must be thoroughly dispersed to give complete coagulation.

4-4. Effects of coagulation agents and the pH of tofu

Little difference was found in the pH of the different preparations (Table 4). The pH was about 5.5. The pH value of the soymilk shifted slightly to the neutral region, giving a pH of about 6.1$\pm$0.4, when a weakly alkaline defoaming agent was added. However, a change in the amount of this defoaming agent caused little difference in the pH. Little difference was found with the differenct defoaming agents. The mean pH value of the seven commercial tofu preparations was 5.6$\pm$0.7.

The pH of tofu of every lot was slightly shifted to the acidic region with an increase in the amount of coagulation agent added, probably because the coagulation agents were acidic. The pH of the Emulgy-A preparations with 1.0% *nigari*, $CaSO_4$, and M-70 were 5.7$\pm$0.4, 5.6$\pm$0.1, and 5.5$\pm$0.6, respectively. The pH of tofu depended on that of the coagulation agent employed. *Nigari* and $CaSO_4$ cause salt-coagulation of the soybean protein ; compared to those preparations, the pH of the M-70 preparation, which causes acid-coagulation[12], was acidic.

4-5. Effects of coagulation agents and the moisture in tofu

Generally speaking, the Emulgy-S preparations had slightly more moisture than the Emulgy-A preparations (Table 4). This might be caused by the difference in the calcium salt concentration, which has a hydrating effect.

In general, the *nigari* preparations had much moisture, the M-70 preparations had little moisture, and the $CaSO_4$ preparations had an intermediate amount of moisture. The mean moisture content of the seven commercial tofu preparations was 86.6$\pm$2.45, which was similar to that of the Emulgy-S preparations with 1.0 or 1.5% $CaSO_4$. The moisture content of the Emulgy-A preparations with 1.5% *nigari*, $CaSO_4$, and M-70 were 89.0$\pm$2.8%*, 86.6$\pm$2.2% (the optimum), and 84.0$\pm$2.6%, respectively. The *nigari* preparation had a somewhat heavy appearance and poor drainage ; the M-70 preparation was somewhat sticky, not very smooth, and with insufficient gloss. The moisture content of tofu depends much on the step of coagulation, which should proceed rapidly and uniformly. To achieve this purpose, the coagulation agent should contain a large amount of calcium salt, have a small particle size, and be highly compatible.

5. Effects of coagulation agents and surface color of tofu

The color of each tofu product was evaluated by the method of Hunter[13], with the value (L), hue (a), and chroma (b) being found and the color being calculated as $Lb/|a|$. Table 5 shows the results.

The values L of the Emulgy-A preparations were somewhat higher than those of the Emulgy

Table 5. Effects of coagulation agents on the surface tone and color of tofu

Coagulating agent*	%	Em⁺	Hunter color values⁺⁺ L	a	b	Lb/∣a∣
Nigari	0.5	A	82.1	−1.5	12.6	662.2 ± 2.1
		S	81.6	−1.4	12.2	711.0 ± 2.4
	1.0	A	82.5	−1.5	12.2	671.0 ± 2.5
		S	81.7	−1.4	12.4	723.6 ± 2.5
	1.5	A	82.7	−1.5	12.3	678.1 ± 2.7
		S	81.6	−1.4	12.8	746.0 ± 3.1
$CaSO_4$	0.5	A	82.2	−1.5	12.5	685.0 ± 2.8
		S	81.8	−1.4	12.7	730.3 ± 3.9
	1.0	A	83.1	−1.5	12.5	692.5 ± 3.2
		S	81.9	−1.4	12.8	748.8 ± 3.4
	1.5	A	83.2	−1.5	12.6	698.8 ± 3.1
		S	82.1	−1.4	12.8	750.6 ± 3.5
M-70	0.5	A	99.6	−1.7	12.3	720.6 ± 2.6
		S	91.1	−1.5	12.2	740.9 ± 2.6
	1.0	A	101.4	−1.5	12.2	748.2 ± 3.5
		S	92.0			
	1.5	A	108.2	−1.8	12.5	751.3 ± 3.6
		S	94.4	−1.5	12.0	755.2 ± 4.1
Seven commercially available tofu			83.7	−1.4	11.6	693.5 ± 1.4

±Standard deviation, n=25

*Percentage of soymilk weight

⁺Preparation (percentage of soybean weight) 3.0% Emulgy-A, 1.0% Emulgy-S

⁺⁺Hunter color values: L=value, a=hue, b=chroma Method of calculation of tone of color=Lb/|a|

-S preparations. The hues were similar. The chromas of the Emulgy-S preparation were generally somewhat higher in value than those of the Emulgy-A preparations, although the preparations with Emulgy-A and M-70 were slightly higher in chroma than the preparations with Emulgy-S and M-70.

A tofu product with a value L of 75 is opaque white to the naked eye. A hue of 10-3 give a product that is almost opaque white ; a chroma of 0-5 makes it opaque white but somowhat less glossy.

The values, hues, and chromas of the *nigari* and $CaSO_4$ preparations were almost that same. The values and hues of the M-70 preparations were somewhat higher than those of the two other kinds of preparations, although the difference could not be detected with the naked eye. When observed with the naked eye, each M-70 preparation had a somewhat yellowish color and poor gloss, which are undesirable in tofu. This tendency became obvious when the Lb/|a| value exceeded 720. The mean Lb/|a| value of the seven commercial products was 69.3±1.4, which was about the same as the Emulgy-A preparation with 1.0% $CaSO_4$. The Lb/|a| values of the Emulgy-A preparations with 1.0% *nigari*, $CaSO_4$, and M-70 were 671.0±2.5, 692.5±2.2, and 733.6±4.1*, respectively. The calculated results did not always agree with observations by the naked eye. It may be the coagulation rate or the liberation of free water that affects the color, transparency, and gloss of tofu.

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豆腐の食品物性への消泡剤と凝固剤の影響

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摘　　要

機械化による大規模製造法を基準としたダイズ原料による豆腐製造を行い，消泡剤（エマルジーA：グリセリン脂肪酸エステル，エマルジーS：グリセリン脂肪酸エステル，ダイズリン脂質，炭酸カルシウム，シリコン樹脂混合剤）と凝固剤（合成ニガリ，硫酸カルシウム，グリコノデルタラクトン：マグラクトン-70）の使用が豆腐物性におよぼす影響を検討した．

消泡剤添加は直接に豆腐物性に影響せず豆乳，おからの歩留りに影響し，製品歩留りを左右するために，分散，混合性に秀れ，親水性，親油性に富み，界面での吸着性が敏速で平均的であることが重要である．

凝固剤は離水性を左右して豆腐物性に直接影響する．

ニガリは凝固速度が緩慢で，離水性に欠けて凝固度が弱く，一部型くずれするものが認められ，全般的に物性度が不足した．

硫酸カルシウムは凝固速度が敏速で平均的で豆腐内面も緻密で光沢を有し，離水性に富み豆腐特有の舌ざわりと咀しゃく感を呈し，物性度は良好となり，豆乳重量に対して1.0%添加が最良である．

マグラクトン-70は凝固速度が緩慢で均一性に欠け，離水過多となり，内面に小孔を有し，光沢性に欠け，咀しゃく感が粗雑で凝固過多となり，物性度が高く豆腐特有のソフト感に欠けることが認められた．

pH および色調は直接豆腐物性に影響しない．

水分含有量は豆腐物性に顕著に影響をおよぼし，全般的に離水性が不足すれば水分過多の原因となる．

機械化大規模製造法は高温，短時間処理が多用されることから，消泡剤，凝固剤は耐熱性を有し，分散，混合性，親水および親油性に富むことが重要で，消泡剤はグリセリン脂肪酸エステル純度が高く，凝固剤は硫酸カルシウム純度の高いものが最適である．