

Qualities of Tofu Powder as Affected by Soybean Variety, Coagulant and Drying Method

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ABSTRACT

Effects of soybean varieties and tofu powder processing on the qualities of the tofu powder was studied. Soybean varieties (CM 60, SJ 5 and ST 2), commercial coagulants (2.2% CaSO₄, 3.0% CaCl₂, 2.2% MgSO₄ and 3.0% MgCl₂) and drying methods (tray dryer, drum dryer and freeze dryer) were studied with respect to their effects on the qualities of tofu powder produced. Soybean varieties influenced the qualities of soybean and soymilk and also affected the functional properties of tofu powder. Tofu powder obtained from CM 60 gave a high yield and good functional properties. Calcium ion coagulant induced tofu powder gave a high solubility and magnesium ion induced tofu powder gave a high emulsion activity. The tofu powder which was freeze dried had a high solubility and high emulsion activity but low emulsion stability.

Key words: tofu powder, soymilk, soybean variety, coagulant and drying processing

INTRODUCTION

Soybeans are an abundant and economical source of food proteins. Soy protein isolate (SPI) is used as food ingredient especially in meat products in order to improve the functional characteristics of the system; such as water binding, textural properties and to reduce cost and fat (Lecomte *et al.*, 1993; Ho *et al.*, 1997; Ramezani *et al.*, 2003). However, SPI is imported from overseas and its manufacturing process is complicated and costly. Tofu is a soybean curd precipitated from hot soymilk with a coagulant, followed by molding and pressing to remove whey. This process is not complicated and is lower in cost than that of SPI. Tofu is high in nutrition and main protein sources. When fresh tofu was added in meat emulsion products, the products were reduced in cooking loss but weaker in internal

structure than that of the control (Jeng *et al.*, 1988; Yang *et al.*, 2007). However, tofu is quite perishable due to its rich nutrient and high moisture content. This spoilage is associated with bacterial growth. Tofu powder is the product from ground dried tofu which can be used as the ingredient in processed meat products. Ho *et al.* (1997) added tofu powder in frankfurters, it decreased fat content and increased protein and moisture content, and there was no difference in sensory attributes compared to those of the control. Panyathitipong and Puechkamut (2002) found that the emulsion made from tofu powder had good emulsion stability but the solubility of this tofu powder was very low. Chotipratoom (2003) reported that tofu powder emulsion could substitute meat emulsion by up to 90% but the products had an aftertaste and an altered flavor. The tofu powder's functionality should be improved to enhance its use.

The qualities of tofu powder are influenced by tofu powder processing which includes soybean varieties, soybean quality, processing conditions such as the coagulants used, and drying process (Cai and Chang, 1998; Panyathitipong and Puechkamut, 2002). Soybean varieties vary in chemical and physical properties consequently affected the quality and yield of tofu (Lim *et al.*, 1990; Sun and Breene, 1991; Min *et al.*, 2005). Type and amount of coagulant also affected the qualities of tofu. The most commonly used coagulants are calcium salt, magnesium salt and glucono-delta-lactone depending on tofu type and each type of coagulant has a different optimum concentration to produce each type of tofu (Lim *et al.*, 1990; Sun and Breene, 1991; Shen *et al.*, 1991; Shih *et al.*, 1997). Increasing coagulation concentration increased tofu hardness but decreased tofu yield (Hou *et al.*, 1997). Under-heat treatment could deteriorate physicochemical properties of soy protein, as a result this could affect the behavior of protein in food system. Thus drying processing could influence the properties of tofu powder. Therefore, the objective of this research was to study the effects of the three main factors, soybean varieties, types of coagulant and drying methods on the qualities of tofu powder. The optimum condition to produce tofu powder was also determined.

MATERIALS AND METHODS

Materials

The two varieties of soybean were obtained from Chiang Mai Field Crops Research Center (Chiang Mai 60; CM 60 and Sor Jor 5; SJ 5) and from Sukhothai Plan and Plant Production Material Technical Service Center (Sukhothai 2; ST 2). They had 9-10% moisture content and were cultivated during summer 2005. They were stored at 15°C before tofu processing. All coagulants were food grade reagent and other reagents were analytical grade.

Effects of soybean varieties

The chemical compositions of soybeans were analyzed by AOAC methods (1995). The three varieties of soybean were submitted to produce tofu powder as described in Figure 1. The coagulant was 2.2% (w/w) $MgSO_4$ and conventional tray dryer was used to dry tofu powder. Total solid content of the soy milk was determined by drying at 110°C in an hot air oven and the color was determined by Chroma meter (Minolta, CR-30D) by measuring the L, a and b. (lightness, redness and yellowness).

The solubility of tofu powder was determined by the modified method of Voutsinas *et al.* (1983). The solubility was determined using the absorbance measured by spectrophotometer at 260 nm.

The emulsion activity and emulsion stability of tofu powder were determined by the modified method of Uruakpa and Arntfield (2005). The tofu powder samples (0.5 g) were dispersed in 15 ml phosphate buffer pH 7.4 and 5 ml of corn oil. The dispersion was homogenized at 20,000 rpm for 1 min. Emulsion (50 μ l) was mixed with 5 ml of 0.1 % (w/v) SDS. Absorbance of the resulting dispersion was measured by spectrophotometer at 500 nm for emulsion activity. For the emulsion stability, 2 ml of emulsion was centrifuged at 8,000 rpm for 5 min. The supernatant was pipette out for 1 ml and mixed with 5 ml of 0.1 % (w/v) SDS. Absorbance of the resulting dispersion was measured by spectrophotometer at 500 nm for emulsion stability.

Effect of coagulant

Four kinds of commercial coagulant (2.2% (w/w) $MgSO_4$, 2.2% (w/w) $CaSO_4$, 3.0% (w/w) $MgCl_2$ and 3.0% (w/w) $CaCl_2$) were used. Tofu powder was prepared by the method as described in Figure 1 except the type of coagulant. The qualities of tofu powder were determined by methods as described above.

Effect of drying method

Three methods of drying, (tray dryer, drum dryer and freeze dryer) were used. Tofu powder was prepared by the method as described in Figure 1. Qualities of tofu powder were determined by the methods as described above.

Statistical analysis

A completely randomize design was used and differences among group means were analyzed by Duncan's New Multiple Range Test ($p \leq 0.05$). All the measurements were done triplicate.

RESULTS AND DISCUSSIONS

Effect of soybean varieties

The chemical compositions of three soybean varieties were shown in Table 1. The protein content of SJ 5 was higher than the others whereas the fat content of the CM 60 was the highest ($p \leq 0.05$). Soybean is the important source of food oil and food protein (Liu, 1997). The effects of soybean varieties on color and solid content of soy milk were shown in Table 2. The solid content of the soy milk from CM 60 was the highest. This may due to the high content of carbohydrate in soybean (Table 1).

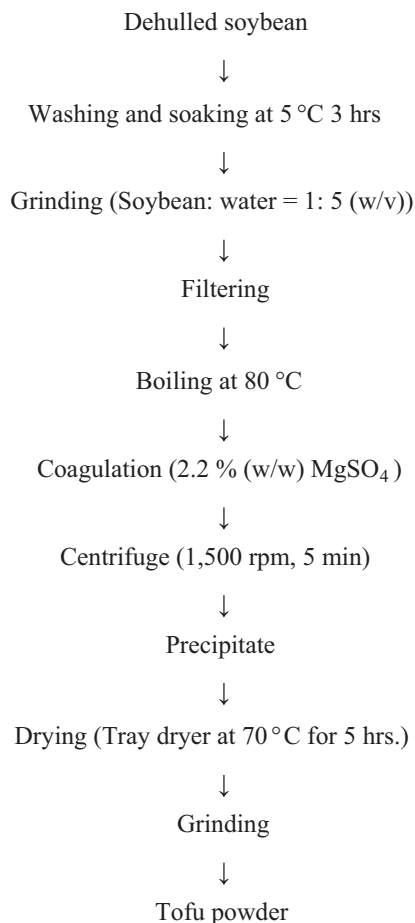


Figure 1 Flow diagram for tofu powder production.

Table 1 Chemical composition of three soybean varieties.

Varieties	Protein (%)	Fat (%)	Carbohydrate (%)	Moisture (%)
CM 60	34.27 ^c	17.02 ^a	34.67 ^a	14.04 ^a
SJ 5	37.83 ^a	14.70 ^c	33.82 ^b	13.65 ^b
ST 2	36.68 ^b	15.80 ^b	33.57 ^c	13.95 ^a

^{a-c}Different letters within the same column are significantly different at $p \leq 0.05$

Table 2 The color and solid content of soy milk prepared from three soybean varieties.

Varieties	Color			Solid content (% w/w)
	L	a	b	
CM 60	88.03 ^a	-2.01 ^b	13.47 ^a	10.20 ^a
SJ 5	86.88 ^b	-1.56 ^a	12.77 ^b	9.45 ^c
ST 2	87.91 ^a	-2.27 ^c	13.50 ^a	9.59 ^b

^{a-c}Different letters within the same column are significantly different at $p \leq 0.05$

CM 60 seeds had lighter hilum than other seeds; therefore, the soymilk had the highest L-value. There was a difference in soymilk color because of seed coat hilum (Khatib *et al.*, 2002). The different hilum color of soybean seed was due to the distribution of pigment in seed coat which could migrate to soy milk components during grinding (Khatib *et al.*, 2002). However, the color of soy milk did not affect the color of tofu powder. After tofu from three soybean varieties were dried, the color of tofu powder as pale yellow were not significant different (data not shown).

The effects of soy bean varieties on the chemical compositions of tofu powder is shown in Table 3. Tofu is curd precipitated from soy milk followed by pressing to remove whey. Most of the carbohydrate would be removed out with whey. Therefore, the main composition of tofu powder was protein. The soybeans varieties showed a significant effect on the protein content of tofu powder but non significant on the fat content and the moisture content of tofu powder (Table 3). There was a significant correlation between protein content of soybean and protein content of tofu powder ($r=0.98$), this agrees with the research conducted by Lim *et al.* (1990) and Min *et al.* (2005).

The effects of soybean varieties on functional properties and yield of tofu powder was

shown in Table 4. The functional properties of commercial soy protein isolate (SPI) were also examined. Its solubility, emulsion activity and emulsion stability were 7.856, 1.744 and 0.778, respectively. The solubility and emulsion stability of all tofu powders were significantly lower than these of SPI. However, emulsion activity of tofu powder is comparable to that of SPI. The emulsion activity is an important functionality of SPI for industrial use. Within the three types of the tofu powder, the tofu powder which was obtained from CM 60 had the highest yield and good functional properties. Therefore, CM 60 was selected to submit to the next experiment.

Effect of coagulant

Coagulation of soymilk is the most important step in tofu processing because coagulation conditions influence tofu yield and quality (Cai and Chang, 1998). In this experiment, four types of coagulants that were frequently used in the industry were studied (Table 5). CaCl_2 3.0% and MgCl_2 3.0% were usually used for firm tofu with fully removed whey and MgSO_4 2.2% and CaSO_4 2.2% were normally used for hard tofu with partially removed whey (Liu, 1997). The tofu powder which was obtained from CaCl_2 and CaSO_4 had higher solubility than that of the tofu powder obtained from the other coagulants

Table 3 Chemical compositions of tofu powder from three soybean varieties.

Varieties	Protein (%)	Fat (%)	Moisture (%)
CM 60	56.15 ^c	29.51 ^a	5.95 ^a
SJ 5	60.34 ^a	28.60 ^a	5.87 ^a
ST 2	58.40 ^b	30.58 ^a	5.83 ^a

^{a-c} Different letters within the same column are significantly different at $p \leq 0.05$

Table 4 The effects of soybean varieties on functional properties and yield of tofu powder.

Varieties	Solubility ^A	Emulsion activity ^B	Emulsion stability ^B	Yield (%w/w)
CM 60	4.69 ^a	1.59 ^a	0.47 ^a	42.74 ^a
SJ 5	2.74 ^c	1.62 ^a	0.44 ^{ab}	41.04 ^{ab}
ST 2	3.41 ^b	1.62 ^a	0.41 ^b	39.94 ^b

^{a-c} Different letters within the same column are significantly different at $p \leq 0.05$, ^Aabsorbance at 260 nm (OD₂₆₀ x dilution factor) and ^Babsorbance at 500 nm (OD₅₀₀ x dilution factor)

(Table 5). The aggregation and network structure formed by the calcium ions were not dense and had more space to trap water in the gel network (Sun and Breene, 1991). This would cause more porous in the tofu powder with enhanced their solubility. However, the emulsion activity properties of tofu powders obtained from $MgCl_2$ and $MgSO_4$ were slightly better than the other coagulants. Since the magnesium ion has a high electro-negativity, it has a great power to attract the polar proteins. Therefore, the non-polar residues are more flexible to bond with oil and this would affect the emulsion properties (Liu, 1997). Moreover, the emulsion stability of the tofu powder obtained from $MgSO_4$ was significantly higher than obtained from the other coagulants. SPI is abundantly used in emulsion meat product due to their good emulsion functionality. Therefore, $MgSO_4$ which gave good emulsion activity and stability was selected to submit to the next experiment.

Effect of drying method on tofu powder

Table 6 shows the effects of drying method on functional properties and moisture content of tofu powder. The moisture content of the tofu powder obtained from freeze dryer was

the lowest. Moreover, the tofu powder which was obtained from freeze dryer showed high solubility and emulsion activity. At high temperatures, especially from drum dryer, the tofu powder gave low solubility and low emulsion activity. Heat treatment has the effect of causing denaturation of protein which might lead to the destruction of the functional properties of tofu powder. However, the emulsion stability of tofu powder obtained from freeze dryer was the lowest compared to that of the tofu powder obtained from other drying methods. The destructive of globular conformation by heat treatment may lead to the strong film formation around oil droplet then enhance the emulsion stability (Zayas, 1997)

CONCLUSIONS

The soybean varieties, coagulants and drying methods affected the qualities of tofu powder. The correlations between protein content of soybean and protein content of tofu powder was significant ($p \leq 0.05$). The tofu powder which obtained from CM 60 showed good functional properties and yield. Different coagulants gave different qualities of the tofu powder. $CaCl_2$ and $CaSO_4$ as coagulants gave tofu powder with high

Table 5 Effects of the types of coagulants on function properties and yield tofu powder.

Coagulants	Solubility ^A	Emulsion activity ^B	Emulsion stability ^B	Yield (% w/w)
3.0% $CaCl_2$	4.42 ^a	1.58 ^{ab}	0.40 ^b	43.05 ^a
2.2% $CaSO_4$	4.17 ^a	1.41 ^b	0.39 ^c	41.67 ^{ab}
3.0% $MgCl_2$	3.74 ^b	1.70 ^a	0.30 ^d	41.96 ^{ab}
2.2% $MgSO_4$	3.68 ^b	1.62 ^{ab}	0.49 ^a	40.31 ^b

^{a-c} Different letters within the same column are significantly different at $p \leq 0.05$, ^Aabsorbance at 260 nm (OD₂₆₀ x dilution factor) and ^Babsorbance at 500 nm (OD₅₀₀ x dilution factor)

Table 6 Effects of drying methods on functional properties and moisture content of tofu powder.

Drying methods	Solubility ^A	Emulsion activity ^B	Emulsion stability ^B	Moisture (%)
Tray dry	3.56 ^b	1.70 ^a	0.40 ^b	3.43 ^b
Drum dry	3.15 ^c	1.46 ^b	0.58 ^a	4.07 ^a
Freeze dry	3.87 ^a	1.65 ^a	0.28 ^c	0.68 ^c

^{a-c} Different letters within the same column are significantly different at $p \leq 0.05$, ^Aabsorbance at 260 nm (OD₂₆₀ x dilution factor) and ^Babsorbance at 500 nm (OD₅₀₀ x dilution factor)

solubility and $MgCl_2$ and $MgSO_4$ as coagulants gave tofu powder with high emulsion properties. The drying methods affected the functional properties of tofu powder. The tofu powder obtained from low heat treatment had good solubility and emulsion activity.

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LITERATURE CITED

- AOAC. 1995. **Official Method of Analysis**. 16th ed. The Association of Analysis Chemists. Srlington, Virginia.
- Cai, T.D. and K.C. Chang. 1998. Characterisite of Production Sciale Tofu as Affected by Soymilk Coagulation Method: Propeller Blade Size Mixing time and Coagulant Concentrations. **Food Res. Int.** 31: 289-295.
- Chotipratoom, S. 2003. **Study on the Gelation of the Product from Tofu Powder and Ground Pork**. M.S. Thesis King Mungkut's Institute of Technology Ladkrabang, Bangkok.
- Ho, K.G., L.A. Wilson and J.G. Sebranek. 1997. Dried Soy Tofu Powder Effects on Frankfuter and Pork Sausage Pattied. **J. Food Sci.** 62: 434-437.
- Hou, H.J., K.C. Chang and M.C. Shih. 1997. Yield and Textural Properties of Soft Tofu as Affected by Coagulation Method. **J. Food Sci.** 62: 824-827.
- Jeng, C., H.W. Ockerman, V.R. Cahill and A.C. Peng. 1988. Influence of Substitutuing Two Level of Tofu for Fat in a Cooked Comminuted Meat-Type Product. **J. Food Sci.** 53(1): 97-100.
- Khatib, K.A., F.M.Aramounp, T.J. Herald and J.E. Boyerz. 2002. Physicochemical Characteristics of Soft Tofu Formulated from Selected Soybean Varieties. **J. Food Quality.** 25: 97-100.
- Lecomte, N.B. J.F. Zayas and C.L. Kastner. 1993. Soya Proteins functional and Sensory Characteristics Improved in Comminuted Meats. **J. Food Sci.** 53(3): 464-472.
- Lim, B.T.,L. DeMan, J.M. DeMan and R.I. Buzzell. 1990. Yield and Quality of Tofu as Affected by Soybean and Soymilk Characteristics, Calcium Sulfate Coagulant. **J. Food Sci.** 55: 1088-1101.
- Liu, K. 1997. **Soybean: Chemistry, Tecnology, and Utilization**. Chapman & Hall, New York. 532 p.
- Min, S., Y. Yu and S. St. Martin. 2005. Effect of Soybean Varieties and Growing Locations on the Physical and Chemical Properties of Soymilk and Tofu. **J. Food Sci.** 70(Nr1): C8-C12.
- Panyathitipong, W. and Y. Puechkamut. 2002. Studies on the Tofu Powder Processing for Alternative Protein Sources. **KMITL Agric. J.** 19(2): 50-59.
- Ramezani, R., M. Aminlari and H. Fallahi. 2003. Effect of Chemically Modified Soy Proteins and Ficin Tenderized Meat on the Quality Atributes of Sausage. **J. Food Sci.** 68(1): 85-88.
- Shen, C.F., L. DeMan, R.I. Buzzell and J.M. DeMan. 1991. Yield and Quality of Tofu as Affected by Soybean and Soymilk Characteristics: Glucono-delta-lactone Coagulant. **J. Food Sci.** 56: 109-122.
- Shih, M.C., H.J. Hou and K.C. Chang. 1997. Process Optimization of Soft Tofu. **J. Food Sci.** 62: 833-837.
- Sun, N. and W.M. Breene. 1991. Calcium Sulfate Concentration Influence on Yield and Quality of Tofu from Five Soybean Varieties. **J. Food Sci.** 56: 1604-1607,1610.

- Uruakpa, F.O. and S.D. Arntfield. 2005. Emulsifying Characteristic of Commercial Canola Protein-Hydrocolloids System. **Food Res. Int.** 38: 659-672.
- Voutsinas, L.P., E. Cheung and S. Nakai. 1983. Relationships of Hydrophobicity to Emulsifying Properties of Heat Denatural Proteins. **J Food Sci.** 48: 26-32.
- Yang, H.S, S.G. Choi, J.T. Jeon, G.B. Park and S.T. Joo. 2007. Textural and Sensory Properties of Low fat Pork Sausages with Added Hydrated Oatmeal and Tofu as Texture-Modifying Agents. **Meat Sci.** 75: 283-289.
- Zayas, J.F. 1997. **Functionality of Proteins in Food.** Springer, Berlin. 372 p.