

Physical Characteristics and Consumer Acceptance of Tofu as Influenced by Water Dropwort

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Abstract

The effects of water dropwort on the physical characteristics of tofu were investigated and consumer acceptance test was conducted. pH decreased significantly with increasing water dropwort concentration from 0 to 3%, whereas titratable acidity showed the reverse trend ($p < 0.05$). The amount of water dropwort did not significantly influence the moisture content up to 2% substitution ($p > 0.05$). Turbidity increased significantly with increasing water dropwort concentration ($p < 0.05$). A significantly lower moisture content in 3% water dropwort tofu may be attributed to the denser structure and hardness of that was significantly higher than those of the other samples ($p < 0.05$). Even though a^* -values of 3% water dropwort tofu was lower than that of control, a^* -values increased significantly with increasing water dropwort content ($p < 0.05$). On the contrary, b^* -values decreased significantly with increasing water dropwort content ($p < 0.05$). 2% water dropwort tofu was found to be the best with respect to its overall acceptability score.

Key words: physical characteristics, consumer acceptance, water dropwort, tofu

INTRODUCTION

The soybean (*Glycine max* (L.) Merrill), originated in East Asia, and has been grown as a food crop for thousands of years and continues to be an important component of the traditional popular diet in these regions (1). Soybeans have been utilized into various forms, among which tofu is the most widely accepted (2). Moreover, isoflavones in tofu have been credited with performing several health-promoting functions, like lowering the incidence of several types of cancer (3,4), and reducing the risk of cardiovascular disease (5), and menopausal symptoms. The results from animal and human studies have indicated that an increased intake of isoflavones improves the retention of bone or increases the bone mass (6-8).

Various attempts have been made in the preparation of tofu to improve functional properties with fruit juices (9-11), basil water extracts (12), ginseng (13), green tea (14), chitosan (15), carrageenan (16), chlorella (17), garlic (18) and seaweeds (19). Water dropwort (*Oenanthe javanica* DC.) is a perennial herb with a distinctive aroma and taste due to its characteristic essential oil content (20), and grows wild in fresh water marshes and swampy fields, canals, and streams in Asia and Australia. It is a member of the umbelliferae family (along with coriander, caraway, fennel, and cumin) and as a very

important commercial crop, the stems and leaves are used as a garnish in soups and stews in Korea. Also water dropwort has been widely used as a medicinal food in East Asia for treatments of jaundice, hypertension, and polydipsia diseases for many years (21,22) and has sometimes been employed as a treatment for pneumonia in folk medicine. Essential oils from plants are a promising source of novel natural anti-microbial agents (23).

The objective of this study was to investigate the effect of water dropwort addition on the physical quality of tofu and the consumer acceptance.

MATERIALS AND METHODS

Materials

Soybeans were purchased from Orga Whole Foods (Seoul, Korea). Magnesium chloride, the coagulant, was reagent grade and purchased from Daesan Trading Co., Ltd. (Incheon, Korea). Samples of water dropwort were obtained from Cheongdo, Gyeongsbuk, Korea and thoroughly cleaned to remove the impurities with distilled water.

Preparation of tofu

Cleaned water dropwort was cut into 6.0 ± 0.5 cm pieces and excess water was removed using a salad spinner (WD23-210, Myeongmoon LC Corp., Gyeonggi, Korea). Water dropwort juice was then extracted using

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Table 1. Formulation of tofu with water dropwort juice

Ingredients	Concentration of water dropwort juice			
	0%	1%	2%	3%
Soybean milk (mL)	4000	3960	3920	3880
Water dropwort juice (mL)	0	40	80	120
Coagulant (g)	200	200	200	200
Total	4200	4200	4200	4200

a commercial juicer (model DO-9001, Dong-a Osca, Co., Busan, Korea). Washed soybeans were soaked in tap water at room temperature for 12 hr. The hydrated beans were placed in a basket to remove excess water and ground with 5000 mL distilled water in a blender for 3 min at high speed, followed by straining through a muslin cloth and pressing to obtain soymilk. Soymilk (4000 mL) was heated to a boil and mixed with 200 mL of 5% MgCl₂ and held for 10 min to coagulate for control. The other samples were made by substituting 1~3% (based on the total weight of the soybean milk and water dropwort juice) of water dropwort juice according to the formulation given in Table 1. The curd was gently transferred to a specially designed, perforated mould (10×11×10 cm depth) lined with cheese cloth and pressed for 30 min using bricks weighing 3.5 kg.

pH and titratable acidity measurement

Ten grams of sample mixed with 40 mL distilled water was prepared to measure the pH of water dropwort tofu with a pH meter (PHM210 Standard pH meter, Radiometer Analytical, Lyon, France) at room temperature. The titratable acidity was determined as the titration volume in mL of 0.1 N NaOH needed to bring the pH to 5.3 after homogenization. All measurements were done in triplicate and mean values were compared.

Moisture content and turbidity

Moisture content was determined by drying a weighed amount of samples to a constant weight at 105°C in an oven for 24 hr (24). Turbidity of filtered soybean whey using a Whatman No. 5 filter was measured using a spectrophotometer (Optizen 2120UV Plus, Mecasys Co., Ltd., Daejeon, Korea). All measurements were done in triplicate and mean values were compared.

Color assessment

Color characteristics (CIE *L**, *a**, *b**) were measured using a Minolta Chroma Meter (Model CR-200, Minolta Co., Osaka, Japan) calibrated with a calibration plate using $Y=94.2$, $x=0.3131$, and $y=0.3201$. Color was measured at the same location (six sides of each cube) using 10 tofu cubes (3×3×2 cm) for each treatment. The re-

sults reported in this paper are the mean values of samples accompanied by their standard deviations.

Textural properties

Textural characteristics were evaluated by 30% compression of individual sample (3×3×2 cm) with a computer-controlled Advanced Universal Testing System (LRXPlus, Lloyd Instrument Limited, Fareham, Hampshire, UK) at room temperature with a 1.2-cm diameter stainless steel cylinder probe. A 100-Newton (N) load cell was used, and the crosshead speed was 60 mm/min. Nine samples for each replication were tested, and their mean values were compared.

Consumer test

Tofu with water dropwort was evaluated by 30 consumer panelists. Four samples were presented in random order and they were asked to evaluate the consumer attributes of color, dropwort flavor, beany flavor, chewiness, texture, and overall acceptability. Consumers expressed judgments about samples using a structured numeric scale of five points (7-point hedonic scale), where 7=like extremely, 6=like strongly, 5=like moderately, 4=neither like or dislike, 3=dislike moderately, 2=dislike strongly, and 1=dislike extremely, for each attribute evaluated. Each sample (*ca.* 5 g), randomly coded using a three-digit number, was evaluated in each session. Consumers received a tray containing the samples, a glass of water, and an evaluation sheet.

Statistical analysis

The statistical analysis was done using the SAS for Windows version 8.1 (SAS Inst. Inc., Cary, NC., USA). The means were compared with Duncan's multiple range test at 5% level of significance.

RESULTS AND DISCUSSION

pH and titratable acidity

pH and titratable acidity of tofu with different concentrations of water dropwort are shown in Fig. 1. pH values of 2 and 3% water dropwort tofu were significantly lower than that of control and 1% water dropwort tofu. These are probably due to the low pH of water dropwort juice. Im et al. (12) reported the average pH of typical tofu is in the range of 5.2~6.2 and pHs of water dropwort tofu were 6.13~6.26. Similar results were reported by Kim et al. (17) with chlorella soybean curd. However, these were higher than that of tofu with basil water extracts (12), with green tea powder (14), with chitosan (15), and with fruit juice of pomegranate (9). Titratable acidities of water dropwort tofu were 3.13~3.55 mL/g. There were significant differences in titratable acidities

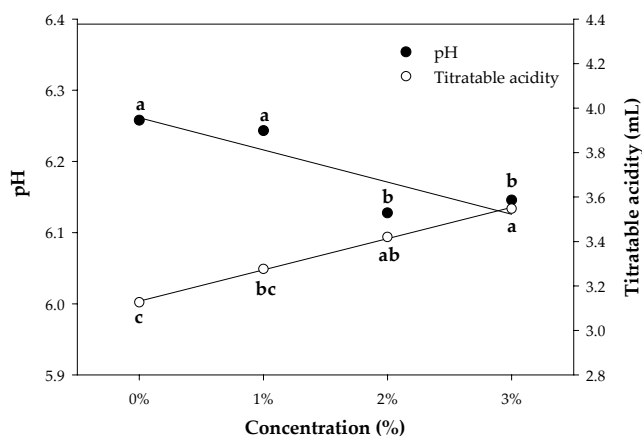


Fig. 1. Effects of water dropwort juice on the pH and titratable acidity of tofu. Means within the same property bearing unlike letters are significantly different ($p < 0.05$).

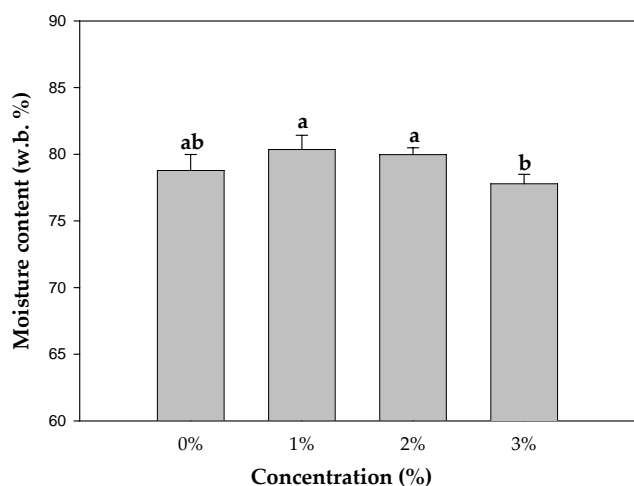


Fig. 2. Effects of water dropwort juice on the moisture content of tofu. Means bearing unlike letters are significantly different ($p < 0.05$).

among water dropwort tofus with various water dropwort concentrations. With increasing water dropwort concentration, titratable acidity increased significantly. Titratable acidity of water dropwort tofu was considerably higher than that of tofu with basil water extracts (12).

Moisture content and turbidity

Changes in moisture content are shown in Fig. 2. Moisture contents of water dropwort tofu were 77.78~80.35%. Even though moisture contents were not significantly changed ($p < 0.05$) with increasing water dropwort concentration up to 2% substitution, moisture content of water dropwort tofu consistently decreased as the water dropwort concentration increased. Water dropwort tofu prepared with magnesium chloride gave clear whey, indicating that the level of coagulants added was sufficient for complete coagulation of soy proteins. Lower moisture content of water dropwort tofu with higher amount of water dropwort may be ascribed as denser

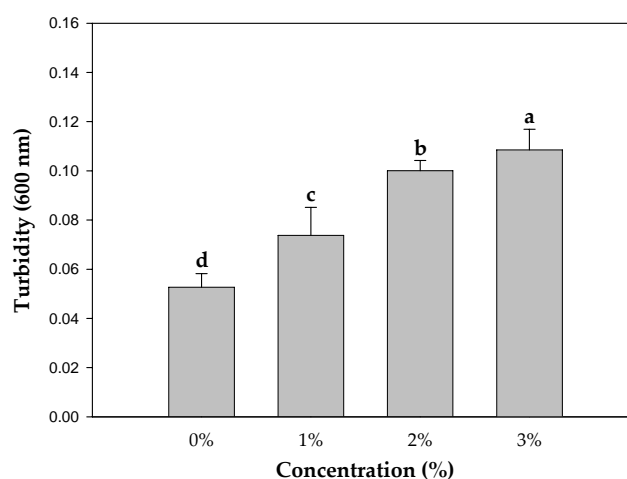


Fig. 3. Effects of water dropwort juice on the turbidity of tofu. Means bearing unlike letters are significantly different ($p < 0.05$).

and with a more compact structure, which made water easily release from the curd during pressing.

Turbidity of water dropwort tofu increased significantly with increasing water dropwort concentration (Fig. 3). In general, the solids in whey are mostly sugars and low molecular weight proteins (25). The increase in turbidity with increasing water dropwort juice concentration was probably due to the fiber and color component in the water dropwort juice which was prepared by simple extraction without clarification. The yield of tofu was calculated as the weight of fresh tofu obtained from a 100 mL of the soymilk used for its preparation. Use of water dropwort extract in preparation of tofu did not significantly influence the yield of tofu, which were 19.57~20.06 g/100 mL of soymilk.

Color changes

Tristimulus colorimetry of water dropwort tofu was used to assess the extent of color change with different water dropwort concentrations (Table 2). L^* -value of control is comparable to that of tofu with oyster shell powder reported by Kim et al. (2) and Lee et al. (15), where chitosan was used as a coagulant. However, there are several findings showing lower L^* -values than ours, for example, Karim et al. (16) with carrageenan, Kim et al. (17) with chlorella, Kim et al. (26) with cow's milk, and Kim and Park (9) with fruit juice of pomegranate. Substituting water dropwort had a significant effect ($p < 0.05$) on the lightness of tofu. A significant decrease ($p < 0.05$) in lightness with increasing water dropwort concentration was observed and these are due to the darkish green color of water dropwort. A similar decrease in lightness was also reported by Kim et al. (2) with oyster shell powder from 0 to 0.2% of soy milk, by Kim et al. (13) with ginseng from 0 to 0.5

Table 2. Color characteristics of tofu as affected by water dropwort juice

Characteristics	Concentration of water dropwort juice			
	0%	1%	2%	3%
<i>L</i> *-value	89.78 ± 1.02 ^a	84.94 ± 1.26 ^b	85.13 ± 1.07 ^b	83.48 ± 1.23 ^c
<i>a</i> *-value	-4.21 ± 0.25 ^a	-8.11 ± 0.96 ^b	-6.78 ± 1.30 ^b	-4.68 ± 3.15 ^a
<i>b</i> *-value	16.57 ± 0.61 ^c	19.59 ± 1.57 ^a	18.25 ± 1.28 ^b	17.45 ± 0.57 ^{bc}

^{a-c}Means(± standard deviation) within the same row bearing unlike letters are significantly different (p<0.05).

%, by Kim et al. (17) with chlorella from 0 to 2.0%, by Jung and Cho (14) with green tea powder from 0 to 1.0%, by Kim and Park (9) with fruit juice of pomegranate, from 0 to 5%, and by Choi et al. (27) with various natural materials, with carrot from 0 to 8%, cucumber from 0 to 12%, spinach from 0 to 1.5%, and green tea from 0 to 0.1%.

*a**-value significantly increased with increasing water dropwort concentration. Kim et al. (13) showed similar results with ginseng, Choi et al. (27) with carrot, and Kim and park (9) with fruit juice of pomegranate. These are due to the colorants of each material, for example, pomegranate has pelargonin. On the other hand, a decrease in *a**-value was also reported by Jung and Cho (14) with green tea powder, Kim et al. (17) with chlorella, Choi et al. (27) with cucumber, spinach and green tea, and Karim et al. (16) with carrageenan using calcium sulfate as a coagulant.

*b**-values of water dropwort tofu were significantly higher than that of control and as the water dropwort concentration increased, *b**-values consistently decreased (p<0.05). Interestingly, Kim and park (9) also showed *b**-values of pomegranate tofu were significantly lower than that of control, but as the pomegranate juice concentration increased, *b**-values consistently increased (p< 0.05). Kim et al. (2) showed *b**-values of oyster shell powder tofu increased with the increasing shell powder concentration, Choi et al. (27) also with carrot, Kim et al. (13) with ginseng, Jung and Cho (14) with green tea powder, and Kim et al. (17) with chlorella.

Textural properties

The middle portion of tofu, which has a homogeneous texture, was analyzed for textural characteristics imparted by water dropwort tofu. Substituting 3% of water

dropwort significantly hardened the texture of tofu and significantly increased springiness, and chewiness while cohesiveness decreased significantly (Table 3). Increased hardness in tofu was also observed with carrageenan (16) and chlorella (17). These are mainly due to the increased fiber content with increasing water dropwort concentration. The hardening of tofu can be affected by the way protein interacts with coagulants and other constituents, e.g. phytic acid, in soy milk and anions to form the microstructure into gel. During the process of gelation, the intermolecular interaction of soy protein is somewhat slowed by water dropwort and resulted in a more homogeneous and regular network and final result is a stronger tofu structure (28,29). Tofu with greater hardness means harder and firmer. Tofu with higher springiness possesses higher elasticity. Tofu with lower yield contained less water and would be harder, which was well observed in the case of 3% water dropwort tofu.

Consumer acceptance

Tofu samples were evaluated by a panel for color, flavor, taste, texture, and overall acceptability on a 7-point scale. Fig. 4 presents the spider charts on several attributes including color, water dropwort flavor, beany flavor, chewiness, texture, and overall acceptability. In terms of color, beany flavor, beany smell, chewiness, and texture, there were no significant differences among the samples. Increasing water dropwort concentration resulted in increased water dropwort flavor scores, 1 and 2% water dropwort substitution did not significantly increase the water dropwort flavor, but not in 3% water dropwort tofu. The overall acceptability scores ranges from 3.86 to 5.38. Highest scores were given to 2% water dropwort tofu. 2% water dropwort tofu was found to be the best with respect to its overall acceptability

Table 3. Mechanical characteristics of tofu as affected by water dropwort juice

Concentration	Texture characteristics				
	Hardness	Cohesiveness	Springiness (mm)	Chewiness (N/mm)	Stiffness (N/mm)
0%	3.7920 ± 0.5777 ^b	0.473 ± 0.029 ^a	5.211 ± 0.068 ^b	0.009 ± 0.001 ^b	0.707 ± 0.111 ^b
1%	3.7330 ± 0.9393 ^b	0.459 ± 0.039 ^a	5.157 ± 0.101 ^c	0.009 ± 0.002 ^b	0.707 ± 0.194 ^b
2%	4.0223 ± 0.5522 ^b	0.467 ± 0.020 ^a	5.213 ± 0.182 ^b	0.010 ± 0.002 ^{ab}	0.730 ± 0.100 ^b
3%	5.2466 ± 1.0167 ^a	0.444 ± 0.027 ^b	5.223 ± 0.167 ^a	0.012 ± 0.002 ^a	1.001 ± 0.226 ^a

^{a-c}Means(± standard deviation) within the same column bearing unlike letters are significantly different (p<0.05).

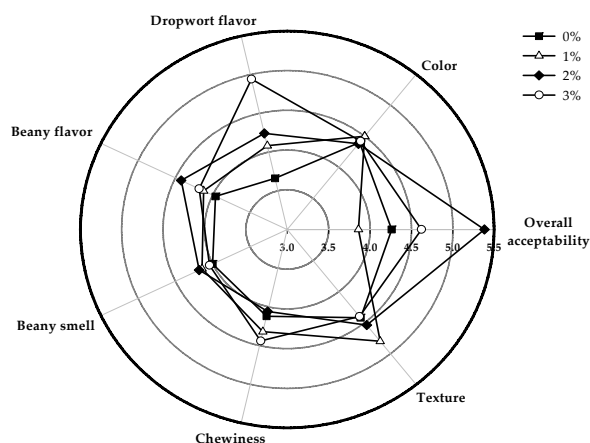


Fig. 4. Spider chart for consumer test as influenced by water dropwort juice.

and water dropwort flavor.

REFERENCES

- Koury SD, Hodges RE. 1968. Soybean proteins for human diets? *J Am Diet Assoc* 52: 480-483.
- Kim YS, Choi YM, Noh DO, Cho SY, Suh HJ. 2007. The effect of oyster shell powder on the extension of the shelf life of tofu. *Food Chem* 103: 155-160.
- Messina MJ, Persky V, Setchell KDR, Barnes S. 1994. Soy intake and cancer risk: a review of the in vitro and in vivo data. *Nutr Cancer* 21: 113-131.
- Mousavi Y, Adlercreutz H. 1993. Genistein is an effective stimulator of sex hormone binding globulin production in hepatocarcinoma human liver cancer cells and suppresses proliferation of these cells in culture. *Steroids* 58: 301-304.
- Anderson JW, Johnstone BM, Cook-Newell MB. 1995. Meta analysis of the effects of soy protein on serum lipids. *New Engl J Med* 332: 276-282.
- Mei J, Yeung SSC, Kung AWC. 2001. High dietary phytoestrogen intake is associated with higher bone mineral density in postmenopausal but not premenopausal women. *J Clin Endocr Metab* 86: 5217-5221.
- Somekawa Y, Chiguchi M, Ishibashi T, Aso T. 2001. Soy intake related to menopausal symptoms, serum lipids, and bone mineral density in post menopausal Japanese women. *Obstet Gynecol* 97: 109-115
- Morabito N, Crisafulli A, Vergara C, Gaudio A, Lasco A, Frisina N, D'Anna R, Corrado F, Pizzoleo MA, Cincotta M, Altavilla D, Lentile R, Squadrito F. 2002. Effects of genestein and hormone-replacement therapy on bone loss in early postmenopausal women: a randomized double-blind placebo-controlled study. *J Bone Miner Res* 17: 1904-1912.
- Kim JY, Park GS. 2006. Quality characteristics and shelf-life of tofu coagulated by fruit juice of pomegranate. *Korean J Food Cult* 21: 644-652.
- Jung GT, Ju IO, Choi JS, Hong JS. 2000. Preparation and shelf life of soybean curd coagulated by fruit juice of *Schizandra chinensis* RUPRECHT (Omija) and *Prunus mume* (maesil). *Korean J Food Sci Technol* 32: 1087-1092.
- Lee SJ, Chung ES, Park GS. 2006. Quality characteristics of tofu coagulated by apricot juice. *Korean J Food Cookery Sci* 22: 825-831.
- Im JG, Park IK, Kim SD. 2004. Quality characteristics of tofu added with basil water extracts. *Korean J Soc Food Cookery Sci* 20: 144-150.
- Kim KT, Im JS, Kim SS. 1996. A study of the physical and sensory characteristics of ginseng soybean curd prepared with various coagulants. *Korean J Food Sci Technol* 28: 965-969.
- Jung JY, Cho EJ. 2003. The effect of green tea powder levels on storage characteristics of tofu. *Korean J Soc Food Cookery Sci* 18: 129-135.
- Lee KS, No HK, Meyers SP. 2001. Effect of chitosan as a coagulant on shelf-life of tofu prepared in commercial scale. *Food Sci Biotechnol* 10: 529-533.
- Karim AA, Suelebele GA, Azhar ME, Ping CY. 1999. Effect of carrageenan on yield and properties of tofu. *Food Chem* 66: 159-165.
- Kim SS, Park MK, Oh NS, Kim DC, Han MS, In MJ. 2003. Studies on quality characteristics and shelf-life of chlorella soybean curd (tofu). *J Korean Soc Agric Chem Biotechnol* 46: 12-15.
- Park YJ, Nam YL, Jeon BL, Oh NS, In MJ. 2003. Effects of garlic addition on quality and storage characteristics of soybean curd. *J Korean Soc Agric Chem Biotechnol* 46: 329-332.
- Kim Dh, Lim MS, Kim YO. 1996. Effects of seaweeds addition on the physicochemical characteristics of soybean curd. *J Korean Soc Food Nutr* 25: 249-254.
- Rhee HJ, Koh MS, Choi OJ. 1995. A study on the volatile constituents of the water dropwort (*Oenanthe javanica* DC) - according to extraction methods, parts and heating methods. *Korean J Soc Food Sci* 11: 386-395.
- Lee JM, Kim NJ, Cho DH, Chung MY, Hwang KT, Kim HJ, Jun WJ, Park CS. 2006. Ethanol extracts of *Oenanthe javanica* modulates inflammatory response by inhibition NF-kB mediated cyclooxygenase-2 expression in raw 264.7 macrophage. *Food Sci Biotechnol* 15: 303-307.
- Noh HJ, Song KB. 2001. Isolation of an angiotensin converting enzyme inhibitor from *Oenanthe javanica*. *Agric Chem Biotechnol* 44: 98-99.
- Shin SW. 2004. *In vitro* inhibitory activities of essential oils from *Oenanthe javanica* DC against *Candida* and *Streptococcus* species. *Top Curr Chem* 10: 325-329.
- AOAC 2000. *Official methods of analysis*. 17th ed. Association of official analytical chemists, Washington, DC.
- Lee KH, Azhar ME, Noryati I. 2000. Effect of thermal treatments on texture of soy protein isolate tofu. *J Food Proc Preserv* 24: 275-286.
- Kim TY, Kim JM, Cho NJ. 1994. Effect of coagulants on the quality of soybean curd added with cow's milk. *Agric Chem Biotechnol* 37: 370-378.
- Choi YO, Chung HS, Youn KS. 2000. Effects of various concentrations of natural materials on the manufacturing of soybean curd. *Korean J Postharvest Sci Technol* 7: 256-261.
- Bernal VM, Smadja CH, Smith JL, Stanley DW. 1987. Interactions in protein/polysaccharide/calcium gels. *J Food Sci* 52: 1121-1125, 1136.
- Lim BT, de Man JM, de Man L, Buzzel RI. 1990. Yield and quality of tofu as affected by soybeans and soymilk characteristics. Calcium sulphate coagulant. *J Food Sci* 55: 1088-1092, 1111.