

RESEARCH NOTE

## Influence of calcium chloride concentration on the physicochemical and sensory characteristics of tofu

Javier Leiva<sup>1</sup>, Valeria Rodríguez<sup>2</sup>, and Elías Muñoz<sup>2</sup>

<sup>1</sup>Programa de Doctorado en Ingeniería. Facultad de Ingeniería, Ciencias y Administración. Universidad de La Frontera. Casilla 54-D, Temuco, Chile.

<sup>2</sup>Departamento de Ciencia y Tecnología de los Alimentos. Universidad de Los Lagos. Casilla 933, Osorno, Chile.

### Abstract

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The aim of this research is to evaluate the sensory texture and influence of calcium chloride concentration on the physicochemical and sensory characteristics of tofu. Samples were prepared from reconstituted soy milk (12% total solids). Calcium chloride at two different concentrations (0.3 and 0.5%) was used as a coagulant. pH, fat content, humidity and total solids were measured. Quantitative descriptive analysis was used to evaluate the sensory properties of springiness, hardness, friability, deformability, adhesiveness and cohesiveness. Correlations were significant ( $P \leq 0.05$ ) between cohesiveness and hardness and between pH and adhesiveness. Using correspondence analysis, the panelists described tofu to be firm and elastic when using the lowest concentration of calcium and firm, adhesive and cohesive when using the highest concentration of calcium. These results indicate that the use of low calcium concentrations (0.3 and 0.5%) increase the hardness of tofu and result in a product prone to fluidity. Of these two calcium concentrations, the lower provided a higher degree of product fluidity. The physicochemical characteristics did not change significantly with the addition of calcium chloride. These results suggest that calcium chloride could be used as an additive to improve tofu fluidity.

**Key words:** Fluidity, ideal concept, soy, texture.

### Introduction

Soy protein (*Glycine max*) has gained considerable attention for its possible role in the reducing cardiovascular disease risk factors (Sacks *et al.*, 2006; Mhatre *et al.*, 2008). According to the Chilean Society of Obesity (SOCHOB), there is a high intake of fried foods, salty snacks, eggs and meat in Latin America. The Western diet

has a 35% increased risk of causing heart attacks and heart disease than other diets of the world. For this reason, the American Heart Association (AHA) recommends the inclusion of foods with soy protein and a diet low in saturated fat and cholesterol (Sacks *et al.*, 2006).

Tofu is a highly nutritious food made from soybeans, which are traditionally consumed in many Asian countries (Jayasena *et al.*, 2010). The factors limiting the consumption of tofu

are its texture and herbaceous flavor. Several studies have been conducted to evaluate sensory characteristics of tofu (Noh *et al.*, 2005). According to Yoon and Kim (2007), the application of heat to soybeans creates tofu with a firmer texture.

Lucey and Fox (1993) found that the addition of calcium increases the firmness of tofu due to a high contribution of protein particles. The use of 0.4% calcium sulfate is sufficient to obtain a firm-textured tofu, without being too hard (Prabhakaran *et al.*, 2006). The cohesiveness, adhesiveness and elasticity are sensory texture features that are used to characterize the fluidity state of cheese (Leiva and Figueroa, 2010). Reducing the level of added calcium in cheese results in a more hydrated protein matrix (Guinee *et al.*, 2002), which is prone to a more fluid state (Sheehan and Guinee, 2004).

The aim of this research is to evaluate the sensory texture to and influence of calcium chloride concentration on the physicochemical and sensory characteristics of tofu.

## Materials and methods

### *Tofu samples*

Reconstituted soy milk (1000 mL) was prepared (120 g of powdered milk in 1000 mL of water) at 12% total solids. The sample was then pasteurized at 70 °C for 20 min according to the methods of Cocio (2006). The total volume of milk was divided into two samples and heated in a water bath at 35 °C. Calcium chloride in two concentrations (A = 0.3% (3.45 g) and B = 0.5% (5.20 g)) was diluted with 10 mL of distilled water and used as a coagulating agent. The sample was then stirred gently as recommended by Liu and Chang (2003). Coagulation was carried out in a thermo-regulated oven at 37 °C for 30 min. Draining and molding was performed using a damp cloth mold at a temperature of  $20 \pm 2$  °C for 2 hours.

### *Sensory analysis*

The sensory evaluation was performed using a descriptive quantitative analysis and eight trained panelists (Anzaldúa-Morales, 1994). The samples were cube-shaped (2 cm per side), previously stabilized at  $5 \pm 1$  °C for 1 hour and presented in a Petri dish. The samples were coded with randomly chosen three digit numbers. Each sample was evaluated individually and analyzed in duplicate.

The sensory profile of texture (Castañeda *et al.*, 2007) included the following properties: elasticity (ELA), the ability of the sample to quickly recover its initial thickness after being compressed and deformed; firmness (FIR), the resistance of the sample to a small displacement of the jaws; friability (FRI), the ability to generate numerous pieces at the beginning of the chewing process; deformability (DEF), the ability of the sample to be successively deformed or stretched in the oral cavity before breaking down; adhesiveness (ADH), tongue movement to remove the sample from the palate and teeth; and cohesiveness (COH), firmness of internal connections in the sample. The intensity of perception was marked on a scale of 0 to 9 points, where 0 corresponded to non-perception and 9 to the maximum intensity of perception.

### *Physicochemical analysis*

For each cheese sample, the pH, fat content, humidity and total solids were evaluated in duplicate. The pH was measured using the potentiometric NCh 1671 Of79 (INN, 1979a) method, fat content (MAT) was calculated according to the Gerber van Gulik NCh 1016/1 Of79 (INN, 1979b) method, humidity (HUM) was determined using the thermo-gravimetric NCh 841 Of78 (INN, 1978) method and total solids (SOL) according to the 4-A (IDF/FIL, 1982) thermo-gravimetric method.

### Statistical analysis

The data were analyzed using correlation and correspondence analyses (Crivisqui, 1998; Pérez, 2004) and with the computer program Statistica 6.0 (StatSoft Inc., USA).

### Results and discussion

The physicochemical characteristics of tofu are presented in Table 1. The results were similar to those reported in other investigations. According to Kim and Han (2002), moisture in tofu varies from 80.63 to 83.40%. In a separate study examining the effect of soybean variety on tofu quality, Wang *et al.* (1983) reported humidity between 84.2 and 85.6%. According to these studies, total solids and fat content ranged from 14.4 to 15.8% and 3.8 to 4.7%, respectively. Wang and Cavins (1989) found similar values of moisture (87.3%), total solids (12.7%) and fat (4.1%). Tofu is considered a precipitated soy protein and its clotting begins at a pH of approximately 6.0 (Lu *et al.*, 1980; Knorr, 1984). In the present investigation, the pH varied between 6.13 and 6.20. Kim and Han (2002) reported a pH of 5.70 when examining clotting. The difference with respect to the optimal pH is likely due to the addition of calcium chloride (Okigbo *et al.*, 1985), because the pH can strongly affect the binding degree of Ca<sup>+2</sup>, causing hydrogen ions to compete with calcium ions for the same binding sites in the protein molecule (Kroll, 1984).

**Table 1.** Physicochemical characteristics of tofu.

Physicochemical characteristics	Tofu A	Tofu B
HUM (%)	79.30	78.21
MAT (%)	6.50	7.00
SOL (%)	20.70	21.79
pH	6.20	6.13

HUM: humidity, MAT: fat content, SOL: total solids.

The sensory characteristics of tofu are presented in Table 2. Noh *et al.* (2005) suggested that tofu

made from frozen soybeans has a firmer texture behavior, which coincides with the highest score for firmness reported in Table 2. Kim and Han (2002) reported tofu firmness values of  $6.70 \pm 1.92$ ; elasticity  $7.34 \pm 2.28$ ; and adhesiveness  $6.96 \pm 2.27$ . The same authors claimed no major differences among the sensory characteristics of tofu.

**Table 2.** Sensory characteristics of tofu.

Sensory characteristics	Tofu A	Tofu B
ELA	4.48	3.59
FIRM	2.79	4.39
FRI	3.15	4.63
DEF	5.98	4.18
ADH	3.39	3.48
COH	2.73	3.76

ELA: elasticity, FIR: firmness, FRI: friability, DEF: deformability, ADH: adhesiveness, COH: cohesiveness.

### Correlation analysis

Table 3 presents the correlation coefficients between physicochemical and sensory characteristics. Positive correlations at  $P \leq 0.05$  were significant between cohesiveness and firmness and between pH and adhesiveness. Kim and Han (2002) indicated that the pH of tofu can be significantly correlated with the textural characteristics, which was confirmed by the results of this study.

### Correspondence analysis

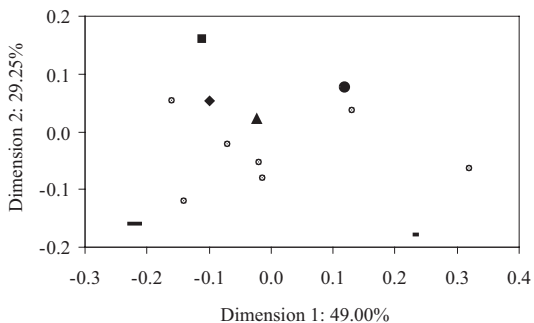
The tofu first dimension textural map (D1, Figures 1 and 2) explained 49 and 72.34% and the second dimension (D2) explained 29.25 and 15.61% of the variation in samples A and B, respectively. Leiva Figueroa (2010) previously observed sensory maps (D1, D2), which explained 81% of the variation.

Through correspondence analysis (Figures 1 and 2), it was concluded that at the lowest calcium concentration (sample A), tofu was described as

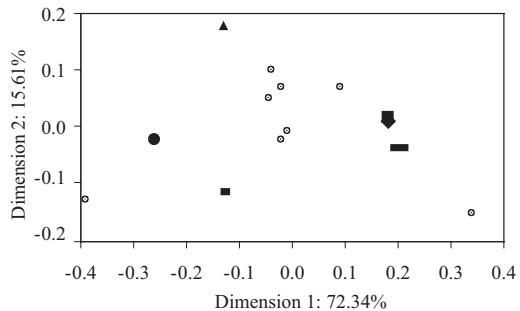
**Table 3.** A correlation coefficient matrix between the physicochemical and sensorial characteristics of tofu<sup>1</sup>.

	ELA	FIR	FRI	DEF	ADH	COH	MAT	HUM	SOL
FIR	-0.87								
FRI	-0.38	0.78							
DEF	0.25	-0.68	-0.99 <sup>1</sup>						
ADH	-0.83	0.48	-0.17	0.31					
COH	-0.82	1.00 <sup>1</sup>	0.84	-0.75	0.40				
MAT	-0.93	0.85	0.46	-0.37	0.65	0.82			
HUM	0.08	-0.44	-0.78	0.86	0.46	-0.51	-0.37		
SOL	-0.13	0.48	0.80	-0.87	-0.41	0.55	0.42	-1.00	
pH	-0.66	0.22	-0.42	0.56	0.96 <sup>1</sup>	0.13	0.46	0.65	-0.61

ELA: elasticity, FIR: firmness, FRI: friability, DEF: deformability, ADH: adhesiveness, COH: cohesiveness, MAT: fat content, HUM: humidity, SOL: total solids.  
<sup>1</sup>Significant correlation at P ≤ 0.05.



**Figure 1.** A texture map showing the influence of calcium chloride concentration on physicochemical and sensory characteristics in sample A of tofu. (■) cohesiveness, (◆) firmness, (▲) elasticity, (●) deformability, (-) adhesiveness, (-) friability, (○) panelists.



**Figure 2.** A texture map showing the influence of calcium chloride concentration on physicochemical and sensory characteristics in sample B of tofu. (■) cohesiveness, (◆) hardness, (▲) springiness, (●) deformability, (-) adhesiveness, (-) friability, (○) panelists.

firm and elastic by the panelists. With the highest concentration of calcium (sample B), the product was described as strong, adhesive and cohesive. In general, calcium salts increase the firmness of the cheese, promoting the formation of a protein matrix with a greater number of ionic interactions (Cervantes *et al.*, 1983), while the sensory characteristics of elasticity, adhesiveness and cohesiveness provide information about the status of cheese fluidity (Leiva and Figueroa, 2010). By using a low concentration of salt (sample), weak

interactions take place and water loss is reported in the protein matrix, decreasing the cohesiveness of the gel. Increasing the salt level (sample B) increases the adhesiveness, which may be due to the increased ability of proteins to interact with water and other non-protein elements (Pastorino *et al.*, 2003).

Based on the results, we can conclude that the use of low calcium concentrations (0.3 and 0.5%) increased the firmness of tofu and results in a

product with a better state of fluidity. Of the two concentrations tested, the lowest concentration of calcium provided a higher degree of product fluidity. The physicochemical characteristics do not change dramatically with the addition of calcium chloride. Therefore, the results suggest that calcium chloride could be used as an additive to improve the degree of tofu fluidity.

### Resumen

**J. Leiva, V. Rodríguez y E. Muñoz. 2011. Influencia de la concentración de cloruro de calcio sobre las características fisicoquímicas y sensoriales del queso tofu. Cien. Inv. Agr. 38(3): 435-440.** El objetivo de esta investigación es evaluar la textura sensorial e influencia de la concentración de cloruro de calcio sobre las características fisicoquímicas y sensoriales del tofu. Se prepararon muestras de queso tofu a partir de leche de soya reconstituida (12% sólidos totales). Se utilizó como agente coagulante cloruro de calcio en dos concentraciones (0,3 y 0,5%). Se midió el pH, contenido graso, humedad y sólidos totales. La elasticidad, firmeza, friabilidad, deformabilidad, adhesividad y cohesividad fueron evaluadas sensorialmente mediante análisis descriptivo cuantitativo. El análisis de correlación mostró correlaciones significativas ( $P \leq 0,05$ ) entre: cohesividad y firmeza, y entre pH y adhesividad. El análisis de correspondencias indicó que al utilizar la menor concentración de calcio, los panelistas identificaron el queso como firme y elástico. Con la mayor concentración de calcio, lo identificó como firme, adhesivo y cohesivo. Basado en los resultados se concluye que la utilización de bajas concentraciones de calcio (0,3 y 0,5%) contribuye a darle firmeza al queso y permiten obtener un producto proclive al estado de fluidez. De ellas, la menor concentración de calcio, le proporciona un mayor grado de fluidez al producto. Las características fisicoquímicas no se modifican seriamente con la adición de cloruro de calcio. Por lo tanto, los resultados sugieren que el cloruro de calcio podría ser usado como un aditivo para mejorar el grado de fluidez del tofu.

**Palabras clave:** Concepto ideal, fluidez, soya, textura.

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