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Texture and Storage Stability of Tofu Incorporated with *Rhynchosia volubilis*

Jun Ho Lee† and Mi Jung Ahn

Department of Food Science and Engineering, Daegu University, Gyeongbuk 712-714, Korea

Abstract

The effects of *Rhynchosia volubilis* (*yakong*) incorporation (0%, 10%, 20%, and 30%, w/w of soybeans) on quality and shelf life of tofu were investigated. Moisture content of tofu increased slightly with the increase in the level of *yakong* incorporation from 10% to 30% and no apparent relationships between *yakong* incorporation and the yield were found. Turbidity of soybean whey tended to increase with increased level of *yakong* incorporation where the values of 20% and 30% samples were significantly different from those of control and 10% sample ($p<0.05$). The different levels of *yakong* incorporation were found to have significant influence ($p<0.05$) on all the color characteristics of tofu. Tofu texture varied with the level of *yakong* incorporation in consistent pattern; however, there was no significant difference ($p>0.05$) in most cases. Tofu incorporated with *yakong* (10～30%) had a shelf life of above at least 1 day longer than that of the control tofu.

Key words: tofu, *yakong*, *Rhynchosia volubilis*, texture, shelf life

INTRODUCTION

Soybean contains high amount of protein (35～40% on a dry weight basis), which provides a relatively inexpensive protein source for human consumption (1). In addition to their nutritional benefits, isoflavones (genistein, daidzein, and glycitein) in tofu have several health-promoting functions like anti-carcinogenicity, lowering blood cholesterol and sugar (2), and reducing the risk of cardiovascular disease (3). Soybeans have been utilized into various forms of foods, among which tofu being the most widely accepted (4). As a traditional soybean food, tofu has been an important staple of the human diet in most countries of Asia (5,6).

Various types of food ingredients have been incorporated in the preparation of tofu. For example, fruit juices of *Schizandra chinensis* R. and *Prunus mume* (7), chitosan (8), herb (9), *Rubus coreanus* (10), small black soybean (11), turmeric (12), *Capsosiphon Fulvescens* powder (13), and water dropwort powder (14) were incorporated into tofu to improve quality and extend the shelf life successfully. *Rhynchosia volubilis* seeds, also known as *yakong*, have traditionally been used to cure or prevent various diseases such as neuralgia, kidney disease, senile dementia, and postmenopausal osteoporosis (15,16). *Yakong* contains higher amount of isoflavone as compared with *hwanggumkong* and *huktae* cultivars (17).

In this study, tofus were prepared with different levels of *yakong* and their physicochemical properties and storage stability were evaluated.

†Corresponding author. E-mail: leejun@daegu.ac.kr
Phone: +82-53-850-6535, Fax: +82-53-850-6539

MATERIALS AND METHODS

Materials

Soybeans (*Glycine max* L.) and *yakong* (*Rhynchosia volubilis* Lour.) were procured from Orga Whole Foods (Seoul, Korea). The coagulant used was food grade magnesium chloride and purchased from Daesan Trading Co., Ltd. (Incheon, Korea).

Preparation of soymilk

The soybeans (500 g) were washed and soaked in 5000 g distilled water for 12 hr at room temperature. The hydrated beans were drained, rinsed and ground with distilled water, using a food mixer (MX2000, Linaset AS, The Czech Republic) for 3 min at high speed. The ratio of water to bean was 10:1 unless otherwise specified. Raw soymilk was heated to boil on a stove with constant stirring and maintained for 10 min, followed by filtering with a muslin cloth to obtain the cooked soymilk.

Preparation of filled tofu

A 4000-mL portion of cooked soymilk was mixed with 200 mL of 5% $MgCl_2$ solution and held for 10 min to coagulate for control. $MgCl_2$ was chosen as a coagulant due to the facts that it tended to reduce the dissolution time during the preparation of solution, as well as coagulation time as compared with other coagulants such as glucono-δ-lactone, $CaSO_4$, and $CaCl_2$ from the preliminary experiments. The other samples were made by incorporating 10～30% (w/w, based on the total weight of the soybeans) of *yakong*. For example, 500 g of soybeans and 50 g of *yakong* were hydrated to prepare the soymilk in the beginning of the process to make 10% *yakong* tofu. The curd was gently transferred to a specially designed, perforated mould (10 cm×11 cm×10 cm) lined with cheese cloth and pressed for 30 min using bricks weighing 3.0 kg. The tofu was immersed in the running tap water for 30 min, drained for 15 min to remove excess moisture, then all the measurements except for storage tests were done in same day.

Moisture content and turbidity determination

Moisture content of tofu was determined by drying a weighed amount of samples to a constant weight at 105°C in an oven for 24 hr (18). Turbidity of filtered soybean whey using a Whatman No. 5 filter was measured at 600 nm using a spectrophotometer (Optizen 2120UV Plus, Mecasys Co., Ltd., Daejeon, Korea). All measurements were done in triplicate and mean values were compared.

Yield and color analysis

The yield of tofu was calculated as fresh weight of tofu obtained from 4000 mL of soymilk. Color characteristics, expressed in CIE L^*, a^*, b^* values, 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 samples (3 cm×3 cm×2 cm) for each treatment. The measurements were replicated thrice and six times for yield and color determination, respectively and the mean values were compared.

Textural properties measurement

Texture profile analysis of tofu was carried out using a computer-controlled Advanced Universal Testing System (LRXPlus, Lloyd Instrument Limited, Fareham, Hampshire, UK) at room temperature. A test speed of 1.0 mm/s and 1.2-cm diameter stainless steel cylinder probe was used for this purpose. The individual tofu samples (3 cm×3 cm×2 cm) were compressed to 30% deformation. Nine replicate tests were carried out for each condition.

Storage test of tofu

The tofu was placed in a polypropylene container with 100 mL of sterilized distilled water as an immersion solution and stored at 10°C for 12 days. The tofu and immersion solution were homogenized and the above supernatant was diluted with 0.1% peptone water. Plate count agar was used for the determination of total viable counts. All plates were triplicated, incubated at 30°C for 48 hr, and viable cell numbers were determined as colony forming units (CFU) per g.

Statistical analysis

The statistical analyses including Pearson correlation matrix, analysis of variance, and Duncan's multiple range test were performed using the SAS 9.1 statistical package for Windows (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Moisture content, yield, turbidity, and color of *yakong* tofu

Characteristics of tofu influenced by *yakong* incorporation are presented in Table 1. The moisture content of tofu samples ranged from 78.33% to 80.24%. The values are in good agreement with the moisture content of tofu made by incorporating selected seaweeds (19). It appeared that the addition of *yakong* from 10% to 30% increased the moisture content slightly; however, the different incorporation levels of *yakong* were found to have no significant difference ($p>0.05$) on the moisture content of tofu.

Yield of tofu in this experiment was of the order: control tofu> 30% *yakong*> 20% *yakong*> 10% *yakong*. Statistical analysis indicated no apparent relationships between *yakong* incorporation and the yield. Similar effect of yield value on the chitosan incorporation was reported, in which their values ranged from 1.45 to 1.60 (g/g bean) (20). Values in this experiment varied from 1.47 to 1.56 (g/g bean). Lee (11) also indicated that level of small black soybean up tp 60% did not influence the

Table 1. Effect of *yakong* incorporation on the moisture content, yield, turbidity, and color of tofu

	Level of *yakong* incorporation (%)			
	0	10	20	30
Moisture content (%)	79.56±1.16[a]	78.33±2.69[a]	79.13±0.96[a]	80.24±0.74[a]
Yield (g)	783.26±6.26[a]	733.52±20.58[b]	737.86±18.84[b]	756.06±10.74[ab]
Turbidity	0.048±0.007[b]	0.050±0.008[b]	0.063±0.004[a]	0.065±0.005[a]
CIE color				
L^*	90.49±0.57[a]	83.52±0.83[b]	73.39±2.43[c]	71.33±0.90[d]
a^*	-4.56±0.02[d]	-2.50±1.05[c]	-1.76±0.05[b]	-0.25±0.06[a]
b^*	17.38±0.30[a]	13.76±0.67[b]	11.93±0.61[c]	9.58±0.59[d]

Like superscripts in the same row do not differ significantly at 5% level of significance.

Table 2. Effect of *yakong* incorporation on the textural properties of tofu

	Level of *yakong* incorporation (%)			
	0	10	20	30
Hardness (kg_f)	0.382±0.019[a]	0.388±0.053[a]	0.394±0.033[a]	0.411±0.027[a]
Cohesiveness	0.480±0.018[a]	0.474±0.024[a]	0.471±0.018[a]	0.466±0.014[a]
Springiness (mm)	5.246±0.078[a]	5.218±0.075[ab]	5.206±0.084[ab]	5.158±0.029[b]
Chewiness (J)	0.010±0.001[a]	0.010±0.002[a]	0.009±0.001[a]	0.009±0.001[a]
Gumminess (g_f)	177.769±19.14[a]	180.868±17.99[a]	182.195±24.92[a]	184.016±13.74[a]
Adhesiveness (N·mm)	0.134±0.024[a]	0.084±0.010[b]	0.040±0.020[c]	0.036±0.009[c]
Stiffness (N/mm)	0.714±0.082[a]	0.722±0.049[a]	0.751±0.153[a]	0.769±0.045[a]

Like superscripts in the same row do not differ significantly at 5% level of significance.

yield. The high moisture content accounted for a higher tofu yield (21) but this is not the case in this experiment. The yield of tofu generally affected by not only the moisture content but also directly related to the soluble protein and lipids contents of soybeans (22).

Turbidity of soybean whey tended to increase with increased level of *yakong* incorporation where the values of 20% and 30% samples were significantly different from those of control and 10% sample ($p<0.05$). Turbidity values may indicate the degrees of the aggregation of protein molecules or dispersion of color pigments due to the ingredients incorporated in the tofu formulation. The increase in the turbidity values in this experiment is probably due to the small dispersed color pigments of *yakong* in the whey, which were not engaged in protein aggregation and resulted in increase in the turbidity. Similar increases in the turbidity values were observed for tofu coagulated by fruit juice of pomegranate (23), tofu prepared with turmeric (24) and *omija* extract (25).

With regard to color, white or light-yellow color is generally considered good quality (4,26). All the control sample prepared in this study had a light yellow or creamy white color. As expected, the color of tofu became darker with increased level of *yakong* incorporation. The L^* values of tofus ranged from 71.33 to 90.49 while a^* and b^* values ranged from -0.25 to -4.56 and 9.58 to 17.38, respectively. The different levels of *yakong* incorporation were found to have significant influence ($p<0.05$) on all the color characteristics of tofu. Similar increases in a^* values and decreases in L^* and b^* values were also reported for tofu coagulated by fruit juice of pomegranate (23), tofu containing small black soybean (11) and *omija* extract (25). It is probably due to anthocyanin color pigments leaching from *yakong* whose color characteristics are distinctively different from those of soybeans (11), L^* and b^* values of black soybeans are lower than those of soybeans while a^* value is the other way around (27).

Textural properties of *yakong* tofu

The textural properties of tofu is an important quality attribute that affects the consumer acceptability. Results of texture analysis of tofu incorporated with *yakong* are shown in Table 2. The textural properties were analyzed using force-time curve.

Texture varied with the level of *yakong* incorporation in consistent pattern although the mean values were not significantly different at 5% level of significance in most cases. Hardness, gumminess, and stiffness increased with increasing level of *yakong* incorporation while springiness, cohesiveness, and adhesiveness decreased. Chewiness of tofu slightly decreased with increased in the level of *yakong* incorporation. Statistical analysis showed that only springiness and adhesiveness of 30% sample were significantly lower than those of control ($p<0.05$). This suggests that incorporation of *yakong* up to 30% in tofu formulation would not change most of the textural properties and even improved the eating quality by reducing springiness and adhesiveness. Similar increases in hardness and gumminess were observed for green tea tofu (28), tofu coagulated with apricot juice (29), and tofu coagulated by fruit juice of pomegranate (23). In contrast to our findings, Min et al. (24) reported decreases in hardness and gumminess with the incorporation of turmeric up to 0.015% in tofu formulation. This is probably due to different materials and level of incorporation used, which suggests that the cross-linking between protein molecules may have been affected by them.

Correlation analyses among different physicochemical properties

The correlations among different physicochemical properties of tofus incorporated with different levels of *yakong* are given in Table 3. Pearson correlation analysis provided a range of significant correlation coefficients (*r*) (from 0.952 to 0.999) for the relationship between several parameters obtained from the different analyses performed. Statistically significant positive correlation coefficients were found between level of *yakong* incorporation and a^* (r=0.985, $p<0.05$), hardness (r=0.961, $p<0.05$), gumminess (r=0.984, $p<0.05$), and stiffness (r=0.980, $p<0.05$) while b^* (r=-0.990, $p<0.05$),

Table 3. Pearson correlation coefficients among different physicochemical properties of tofus incorporated with different levels of *yakong*

	Yakong	Yield	Moisture	Turbidity	*L**	*a**	*b**	Hardness	Springiness	Gumminess	Cohesiveness	Chewiness	Adhesiveness
Yield	-0.442												
Moisture	0.458	0.593											
Turbidity	0.946	-0.343	0.524										
*L**	-0.974*	0.531	-0.358	-0.974*									
*a**	0.985*	-0.547	0.335	0.882	-0.949								
*b**	-0.990*	0.555	-0.334	-0.906	0.967*	-0.998*							
Hardness	0.961*	-0.231	0.623	0.871	-0.877	0.940	-0.933						
Springiness	-0.970*	0.336	-0.527	-0.858	0.891	-0.969*	0.959*	-0.993**					
Gumminess	0.984*	-0.582	0.302	0.894	-0.963*	0.998**	-0.999***	0.922	-0.953*				
Cohesiveness	-0.993**	0.508	-0.383	-0.903	0.957*	-0.998**	0.998**	-0.953*	0.976*	-0.996**			
Chewiness	-0.894	0.292	-0.534	-0.991**	0.944	-0.813	0.845	-0.808	0.786	-0.830	0.839		
Adhesiveness	-0.952*	0.650	-0.218	-0.932	0.988*	-0.949	0.966*	-0.830	0.861	-0.967*	0.949	0.895	
Stiffness	0.980*	-0.298	0.590	0.980*	-0.963*	0.931	-0.943	0.952*	-0.940	0.931	-0.950	-0.949	-0.916

*, **, and *** means the correlations are significant at $p<0.05$, $p<0.01$, and $p<0.001$ levels, respectively.

springiness (r=-0.970, $p<0.05$), cohesiveness (r= -0.993, $p<0.01$), and adhesiveness (r=-0.952, $p<0.05$) were negatively correlated with the level of *yakong* incorporation.

Correlations between color parameters and textural parameters were observed. *L** value had high positive correlations with cohesiveness and adhesiveness but negative correlations with gumminess and stiffness ($p<0.05$). *a** value was positively correlated with gumminess ($p<0.01$) but negatively correlated with springiness ($p<0.05$) and cohesiveness ($p<0.01$). On the other hand, *b** value was highly correlated with springiness ($p<0.05$), cohesiveness ($p<0.01$), and adhesiveness ($p<0.05$) positively but negative high correlation with gumminess ($p<0.001$). These results indicate that level of *yakong* incorporation, color, and textural parameters would have a significant role in tofu quality in a set of different kind of samples as evidenced by the good correlations observed in this study. In addition, due to the low insignificant correlation coefficients yield and moisture content did not play major role in establishing color and textural quality of tofu.

Storage test of *yakong* tofu

Fig. 1 shows the changes of the viable microbial counts of tofu incorporated with *yakong* and a control tofu prepared with single use of $MgCl_2$ during storage at 10°C for 12 days. Initial bacterial concentrations of tofus varied from 1300 CFU/g to 2500 CFU/g at 0 day for storage. These values are close to the initial concentrations reported for tofu prepared with red soybean (30), green tea powder (28), fruit juice of pomegranate (23), and *mesangi* (*Capsosiphon Fulvescens*) powder (13). Total viable counts of all the tofu samples increased exponentially during storage. However, it can be also seen that the viable microbial counts of the control tofu increased more rapidly than those of tofu prepared with *yakong* during longer storage periods.

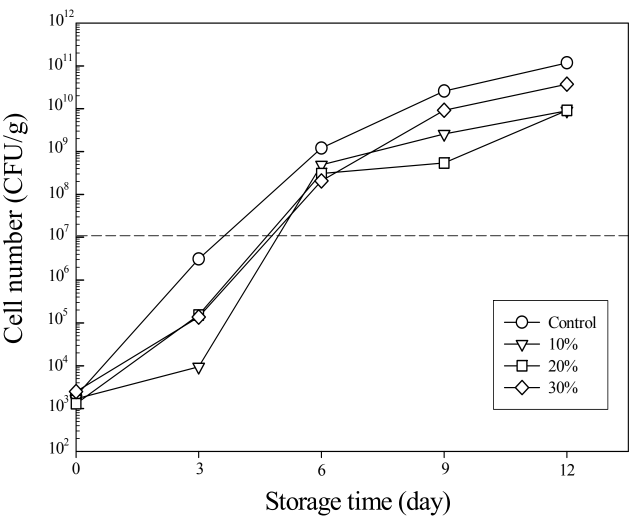

Fig. 1. The effect of *yakong* on total microbes of tofu.

With the postulation that tofu spoilage would start when viable counts were above 10^7 CFU/g (28,31,32), incorporation of *yakong* in the range of tested concentrations can extend the shelf life of tofu. Tofu incorporated with *yakong* (10～30%) had a better shelf life which was at least 1 day longer than the control tofu. This was probably due to the antimicrobial activities of phenolic compounds contained in *yakong* (11). Such extension effect on shelf life of legume-based tofu was also reported by others (11,30,32).

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