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Developing Sensory Lexicons for Tofu

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ABSTRACT The objective of this study was to develop sensory lexicons that can be utilized for various types of tofu such as pressed, unpressed, and tofu made from germinated soybeans, using generic descriptive analysis. In the first phase of the experiment, trained descriptive panelists developed and defined the appearance, aroma, flavor, and texture attributes that are commonly present in tofu. Then, the sensory characteristics of seven types of tofu were analyzed using the sensory lexicons established in the initial stage of the experiment. Four appearance, 6 odor/aroma, 6 flavor/taste, 7 texture, and 4 aftertaste attributes were identified, and reference standards were established for most of the terms in order to facilitate the understanding of the attribute definitions. The intensities of the sensory attributes were measured on a 15-point scale. Statistical analyses, including analysis of variance and principal component analysis, were used for the data. The seven tofu samples showed significant differences in the intensities of 22 attributes. The unpressed tofu samples were generally rated as being high in moistness, easy to cut, silky, and easy to swallow. The pressed tofu, on the other hand, was salty, astringent, beany, hard, and rough in texture. The tofu made with germinated soybeans was characterized as having a strong cooked bean flavor, salty and astringent aftertaste, and hard texture. Overall, the attributes of moistness, easy to swallow, and silkiness showed strong positive correlations; hardness and sticks to teeth were also positively correlated to each other.

KEYWORDS: Tofu, descriptive analysis, sensory lexicon

INTRODUCTION

Recently, as consumers are strongly seeking healthier ways of eating as well as health-oriented lifestyles, soybeans and soy products, which are proven to offer various functional health properties, have gained immense popularity. Tofu, which is a coagulated product of soymilk, is a typical soybean product that has been one of the most favorable ingredients of Korean and many East Asian style cuisines for several centuries. Traditionally, tofu was made at the home-scale level (unpackaged style tofu); but today, production is quickly shifting towards industrial scale (packaged style tofu). Innovative processing methods and soybean ingredients are being applied to create new tofu products. And these new types of tofu are being aggressively introduced to consumers, causing product variation to proliferate due to the significant increase in market share for packaged style tofu as well as the competitive market environment.

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In order to meet these demands, countless research efforts have been aimed at tofu production, including examinations of processing (Kim and Lee 1992, Kim et al 1995, Baik et al 1996, Cai and Chang 1998), types of soybeans for manufacture (Chang et al 1990, Han and Hwang 1992, Ku and Kim 1994, Ku et al 1994), and the addition of ingredients (Park and Hwang 1994, Kim et al 1996, Kim et al 2000, Obatolu 2008). Although it is essential to verify how such production changes and new innovations affect the sensory characteristics of tofu, many studies fail to provide solid data. Even when sensory analyses have been performed, the experiments are frequently poorly conducted by using inappropriate panelists, vague sensory descriptors, or by confusing use of hedonic and attribute intensity measurements. Seo et al. (2001) developed and defined the sensory attributes of pressed tofu using Korean descriptors. They also provided reference standards for some of the attributes. However, since their study only developed sensory lexicons for pressed tofu, the lexicons do not fully cover the wide varieties of tofu products that are currently on the market. The objective of this study was to use generic descriptive analysis to develop sensory lexicons that can be used for various types of tofu, including pressed, unpressed, and tofu made from germinated soybeans.

Table 1. Brand, processing method, and bean type of the 7 evaluated tofu samples

Brand	Type	Soy type	Sample code
A	Unpressed	Regular	AUR1
A	Unpressed	Regular	AUR2
B	Unpressed	Regular	BUR1
B	Pressed	Regular	BPR2
C	Unpressed	Germinated	CUG1
C	Pressed	Regular	CPR2
D	Pressed	Regular	DPR

MATERIALS AND METHODS

Materials

As shown in Table 1, seven types of tofu products from five different manufactures were purchased from local supermarket in Seoul, Korea. The samples selected for this study covered a wide range of tofu types, which varied in product brand, processing method (pressed vs. unpressed), and type of soybean (ungerminated vs. germinated).

Descriptive Analysis

Sample Preparation: The tofu samples were cut into 222 cm cubes. Approximately 30-40 g of each sample was put into a white plastic cup (53 cm) and covered with a lid. All of the tofu samples were labeled with a 3-digit random code, and were served at 8-10°C throughout the descriptive analysis sessions.

Panel: Six volunteers were recruited as the sensory panel from the campus of Seoul Women's University, Seoul, Korea. The same panelists participated throughout the entire training and main experiment sessions.

Training and Main Experiment: A generic descriptive analysis (Chung and Chung, 2007), which consisted of the training and main experiment sessions, was conducted to analyze the sensory characteristics of the seven types of tofu. The sensory attributes of the tofu samples were developed and defined, and corresponding reference standards were established during the training sessions (Table 2). The training sessions were held four times and each session took approximately 60~90 min.

In the main experiment, the sensory characteristics of the seven types of tofu were evaluated using the attributes developed during the training sessions. The intensity of each attribute was rated on a 15-point category scale. The anchor words of the intensity scale were as follows: 1=extremely weak, 8=moderate, 15=extremely strong. Two sessions were held per day in order to complete one replicate evaluation of the samples. Four and three samples were served during the first and second sessions, respectively. A randomized complete block design was applied to determine the serving order of the samples. The serving order was randomized within each replication. The samples were served monadically and the panelists were asked to rinse their palates with water, carrots, and crackers between the samples. The samples were evaluated in two replications.

Statistical Analysis

Using the tofu samples and panelist factors as the main effects, two-way analysis of variance (ANOVA) was conducted to test for their effects on the intensities of the attributes. When the sample effect ($p<0.05$) showed significance, Duncan's multiple comparison test was carried out to test whether significant differences existed among the samples in their attribute intensities. Principal component analysis (PCA) (covariance matrix and no rotation) was performed on the mean attribute intensity values of the tofu samples to visually summarize the sensory characteristics of the seven samples and to understand the correlation between the sensory attributes. ANOVA and PCA were performed with SPSS (Chicago, IL, USA) and XLSTAT (Paris, France) statistical software, respectively.

RESULTS AND DISCUSSION

The sensory characteristics of the seven tofu samples, which varied in brand, processing method, and ingredients, were analyzed using the generic descriptive analysis method. A total of 27 attributes, consisting of 4 appearance, 6 odor/aroma, 6 taste/flavor, 4 aftertaste, and 7 texture attributes, were identified and defined for the tofu samples. Table 2 lists the established Korean descriptors, translated English descriptors, definitions, and reference standards for each attribute. Compared to the study by Seo et al. (2001), the number of descriptors increased and the aroma/odor and aftertaste categories were newly included in this study.

When ANOVA was conducted to analyze the product effect on the intensities of the 27 sensory attributes, most of the attributes (except for whiteness, yellowness, green odor, raw bean odor, and bitter aftertaste) showed significant differences among the seven tofu samples. The mean intensity values of the samples are shown in Table 3. Although color was not significantly different among the samples, visual roughness and moistness did differ significantly. The unpressed tofu samples (AUR1, AUR2, BUR, and CUG) were rated significantly higher in roughness and moistness than the pressed tofu samples (BPR, CPR, and DPR).

Regarding the odor/aroma, taste/flavor, and aftertaste attributes, some sensory characteristics were affected by the processing methods, but other characteristics were simply product dependent. The pressed tofu samples tended to have stronger intensities of cooked bean odor; salty and umami taste; and salty, cooked bean, and astringent aftertaste, than the unpressed tofu samples. However, unlike the other

Table 2. Definitions and reference standards of appearance, odor/aroma, flavor/taste, and texture/mouth feel attributes used in the descriptive analysis

Categories	Korean Descriptors	English translated Descriptors	Abbreviation.	Definitions	Reference Standards
Appearance attributes	하얀정도	whiteness	whA	Degree of white intensity	-
	노란정도	yellowness	ylA	Degree of yellow intensity	-
	거친정도	roughness	rghA	Degree to which surface is uneven[1]	-
	촉촉한정도	moistness	mstA	Degree of moisture on the tofu surface	-
Odor/Aroma attributes	풋내	green	grnO	Aromatic associated with green grass	Cut grass
	비린내	raw soy	rbeanO	Aromatic associated with raw soybean	Hydrated raw soybean (ground)
	쉰내	dirty socks	dscksO	Aromatics associated with wet dirty socks	Wet old dishcloth
	고소한내	cooked bean	cbeanO	Aromatics associated with boiled soybean	Boiled soybeans (ground)
	짠내	briny	brinyO	Aromatics associated with brine	Wet kelp
	락스냄새	chlorine	chO	Aromatics associated with chlorine	1% Diluted Chlorox“ solution
Flavor/Taste attributes	고소한맛	cooked bean	cbeanF	Typical flavor of boiled soybeans	Boiled soybeans (ground)
	비린맛	raw bean	rbeanF	Typical flavor of raw soybeans	Hydrated raw soybeans (grinded)
	짠맛	salty	sltyT	Typical taste of NaCl	0.5% NaCl solution
	단맛	sweet	swtT	Typical taste of sucrose	1% sucrose solution
	감칠맛	umami	umiT	Typical taste of MSG	0.5% MSG solution
	쓴맛	bitter	bitrT	Typical taste of caffeine	0.1% Caffeine solution
Texture/ Mouth feel attributes	탄력성	springiness	sprTX	Degree to which sample returns to original shape after a certain period[1)]	Acorn gel
	경도	hardness	hrdTX	Force required to bite through[1]	Cheddar cheese block
	치아으깨짐	easy to cut	etcTX	Easiness to cut through the sample with teeth	Jello
	치아부착성	stickiness	stckTX	Amount of product that adheres to the tooth surface	Sticky rice cake
	매끄러움정도	silkiness	slkTX	Smooth texture sensation in mouth	Jello
	목넘김	easy to swallow	etsTX	Easiness to swallow after masticating	-
	수분정도	moistness	mstTX	Amount of wetness felt from the sample	Apple
Aftertaste attributes	쓴맛A	Bitter	bitAF	Typical aftertaste of caffeine	0.1% Caffeine solution
	짠맛A	salty	sltAF	Typical aftertaste of NaCl	0.5% NaCl solution
	고소한맛A	cooked bean	cbnAF	Typical aftertaste of boiled soybeans	Boiled soybeans (ground)
	텁텁한정도	astringent	astrAF	Complex mouthfeel associated with dry, roughness, lingering residual after swallow in mouth.	Soymilk

[1)]Adapted from Meilgaard et al. 1991

Table 3. The mean intensities of 27 sensory attributes of the 7 tofu samples

Product	whA	ylA	rghA	mstA	grnO	rbeanO	dscksO	cbeanO	brinyO
AUR1	8.3^{a}	7.2^{a}	2.8^{a}	10.7^{cd}	8.5^{a}	6.2^{a}	4.4^{ab}	5.8^{a}	5.3^{ab}
AUR2	8.2^{a}	5.8^{a}	2.3^{a}	11.5^{cd}	8.0^{a}	6.4^{a}	6.0^{cd}	6.6^{ab}	4.2^{a}
BUR	8.8^{a}	5.8^{a}	2.4^{a}	12.4^{d}	9.3^{a}	6.3^{a}	4.3^{a}	6.7^{ab}	5.8^{ab}
BPR	8.8^{a}	6.0^{a}	10.5^{c}	7.3^{ab}	9.2^{a}	8.3^{a}	5.8^{bcd}	7.0^{ab}	6.2^{ab}
CUG	8.3^{a}	6.8^{a}	8.4^{b}	9.3^{bc}	9.8^{a}	6.7^{a}	4.9^{abc}	7.3^{ab}	4.6^{a}
CPR	8.4^{a}	6.9^{a}	10.8^{c}	5.4^{a}	9.3^{a}	6.3^{a}	4.9^{abc}	7.3^{ab}	5.4^{ab}
DPR	8.8^{a}	7.3^{a}	10.5^{c}	6.4^{a}	8.8^{a}	7.1^{a}	6.6^{d}	7.9^{b}	6.8^{b}

Product	chO	cbeanF	rbeanF	sltyT	swtT	umiT	bitrT	sprTX	hrdTX
AUR1	4.1^{a}	6.4^{ab}	5.8^{a}	5.1^{a}	6.1^{ab}	5.3^{ab}	5.9^{c}	10.4^{bc}	6.5^{bc}
AUR2	4.2^{a}	8.6^{c}	7.4^{a}	5.0^{a}	6.4^{b}	5.2^{ab}	4.1^{ab}	10.2^{bc}	5.5^{ab}
BUR	4.2^{a}	5.9^{a}	6.7^{a}	4.2^{a}	5.9^{ab}	4.8^{a}	3.9^{ab}	11.5^{c}	3.3^{a}
BPR	5.8^{b}	7.0^{abc}	7.7^{a}	5.8^{ab}	4.8^{a}	6.7^{bc}	5.6^{bc}	7.3^{a}	9.2^{d}
CUG	4.4^{a}	7.8^{abc}	6.6^{a}	7.8^{bc}	6^{ab}	6.1^{abc}	3.3^{a}	8.5^{ab}	9.2^{d}
CPR	4.2^{a}	7.8^{abc}	6.3^{a}	5.8^{ab}	6.1^{ab}	6.8^{bc}	5.3^{bc}	6.5^{a}	8.7^{c}
DPR	5.3^{ab}	8.1^{bc}	6.5^{a}	9.3^{c}	5.1^{ab}	7.3^{c}	3.1^{a}	7.0^{a}	10.2^{d}

Product	etcTX	stckTX	slkTX	etsTX	mstTX	bitAF	sltAF	cbnAF	astrAF
AUR1	10.5^{bc}	5.6^{b}	11.4^{c}	11.3^{c}	11.3^{b}	6.7^{a}	5.0^{abc}	5.8^{ab}	5.6^{ab}
AUR2	9.1^{abc}	3.2^{a}	10.6^{c}	11.5^{c}	10.1^{b}	5.7^{a}	3.1^{a}	5.8^{ab}	4.5^{a}
BUR	10.8^{c}	2.8^{a}	12.0^{c}	13.2^{c}	12.1^{b}	5.7^{a}	3.6^{ab}	5.2^{a}	6.4^{bc}
BPR	6.9^{a}	8.1^{c}	6.7^{ab}	6.4^{a}	6.3^{a}	7.2^{a}	5.4^{bc}	6.9^{ab}	8.4^{d}
CUG	8.4^{ab}	7.3^{c}	9.3^{bc}	8.8^{b}	9.8^{b}	6.3^{a}	5.8^{b}	7.0^{ab}	7.4^{cd}
CPR	6.8^{a}	8.0^{c}	6.2^{a}	5.2^{a}	5.8^{a}	5.8^{a}	6.0^{b}	6.6^{ab}	8.7^{d}
DPR	6.8^{a}	9.1^{c}	5.8^{a}	6.0^{a}	6.2^{a}	4.9^{a}	8.6^{d}	7.1^{b}	8.1^{cd}

[1)]Mean values within the same column with the same letter superscripts do not differ significantly (p>.05).

unpressed tofu samples, the CUG sample made with germinated soybeans showed a strong cooked bean odor, salty and umami taste, and astringent aftertaste. AUR1 was characterized as having a relatively mild odor and flavor; however, it had a sweet and bitter taste. The AUR2 sample had the same brand and processing method as AUR 1, and therefore, was relatively more similar to AUR1 than the other samples. However, AUR2 was rated high for dirty socks odor as well as cooked bean and raw bean flavor. Among the 7 samples, BUR exhibited the lowest intensities for most of the odor and taste characteristics. The BPR and DPR samples were characterized as having relatively strong intensities for odors such as dirty socks, briny, and chlorine as compared to the other samples. The CPR sample tended to have more sweet and astringent aftertaste than the other pressed tofu samples, but it showed similar characteristics for the other attributes.

Unlike the odor and flavor attributes, the texture

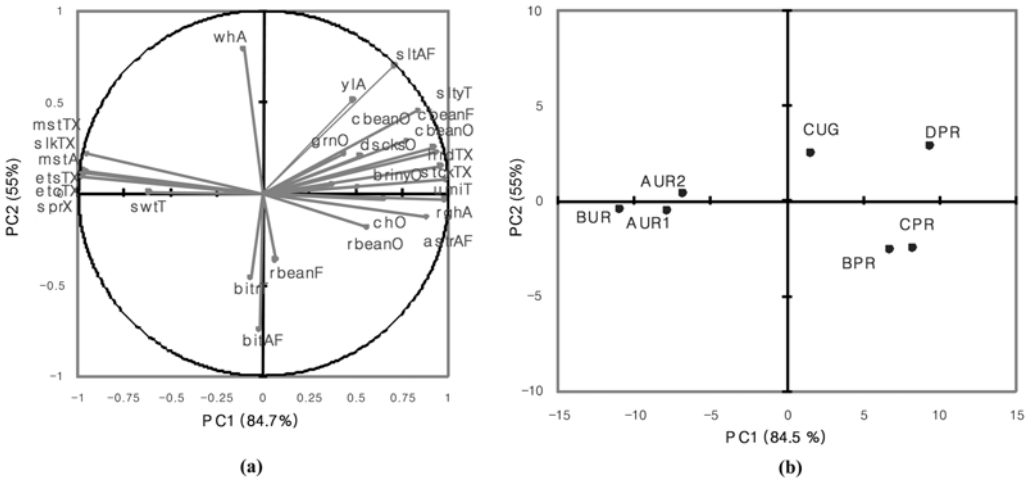

Fig. 1. PC 1 and 2 loadings and scores of the sensory attributes (a) and tofu samples (b) by descriptive analysis in a PCA plot.

characteristics of the tofu were more distinctly affected by the pressed and unpressed processing methods. The unpressed tofu samples were significantly more springy, easy to cut with teeth, silky, easy to swallow, and moist in texture than the pressed tofu samples. The pressed tofu samples were more hard and sticky than the unpressed tofu samples.

In order to visually summarize the sensory characteristics of the seven tofu samples, PCA was performed on the mean attribute intensity values of the samples (Fig. 1.). Most of the variation was explained by the first principal component (84.5%). The first principal component axis was defined mostly by the pressed and unpressed processing methods. The pressed samples DPR, CPR, and BPR, which were located on the positive axis, were characterized by the attributes of rough appearance, briny odor, umami taste, astringent aftertaste, and hard and sticky texture; whereas the unpressed tofu samples AUR1, AUR2, and BUR were strongly correlated with the attributes of moistness, silky, easy to cut, easy to swallow, and springy texture. The second principal component, which explained 5.5% of the total variation that separated the samples, was based on whiteness as well as salty taste and after taste on the positive axis, and raw bean flavor and bitter taste and aftertaste on the negative axis.

SUMMARY

In this study, the sensory characteristics of seven types of tofu were analyzed using sensory lexicons that were established by performing generic descriptive analysis. Four appearance, 6 odor/aroma, 6 flavor/taste, 7 texture, and 4 aftertaste attributes were identified, and reference standards were established for most of the terms to facilitate the understanding of the attribute definitions. The sensory characteristics of the tofu samples varied depending on brand, processing method, and type of soybean used in manufacture. The unpressed tofu samples were generally rated as being high in moistness, easy to cut, silky, and easy to swallow. The pressed tofu, on the other hand, was salty, astringent, beany, hard, and rough in texture. The tofu made with germinated soybeans was characterized as having a strong cooked bean flavor, salty and astringent aftertaste, and hard texture.

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