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NaCl 첨가 및 평가 온도에 따른 천연조미소재의 감각적 특성

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Effects of NaCl and Temperature on the Sensory Characteristics of Natural Flavor Enhancers

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Abstract The objectives of this study were to evaluate the sensory properties of various natural flavor enhancers (NFEs) and to understand the effects of NaCl and temperature on the sensory characteristics of these NFEs. Descriptive analysis was conducted to evaluate six types of NFEs: yeast extract-based NFE, three; fish sauce-based NFE, one; soy sauce-based NFE, one; and hydrolyzed peptide NFE-based, one. The effects of NaCl (no addition vs. addition) and temperature (20°C vs. 55°C) were also evaluated. The results showed that the overall flavor intensity and sensory properties of the NFEs differed greatly depending on the NFE source. Two of the yeast extract-based NFEs elicited higher umami intensity than the other NFEs. Addition of NaCl increased some of the savory-related flavors and the perceived viscosity of the sample. Aroma intensities, in general, were enhanced at the higher temperature, whereas flavor, aftertaste, and mouthfeel attributes were perceived to be stronger at the lower temperature.

Keywords: natural flavor enhancer, NaCl, temperature, descriptive analysis

Introduction

Glutamate-based monosodium glutamate (MSG), nucleotide-based inosine monophosphate (IMP), guanosine 5'-monophosphate (GMP), and adenosine 5'-monophosphate (AMP) are the most widely used flavor enhancers in Asian cuisine. However, due to consumers' preferences for natural products, the demands for natural flavor enhancers (NFE) that can substitute MSG and nucleotide-based enhancers are growing strongly (1).

NFEs such as hydrolyzed vegetable protein (2), hydrolyzed animal protein (3), and yeast extracts (4) are some of the currently available NFEs that have been successfully developed. Currently, the search for new flavor enhancers, especially umami and koku substances, is very active. “Umami” can be translated as delicious flavor while “kokumi” is translated as complex, heavy, thick, and continuity flavor. Winkel et al (5) gave an update on new umami substances. Traditionally known umami (enhancing) substances other than MSG are theanine, succinic acid, gallic acid, theogallin, and some amino acids. New umami substances such as the condensation products of alanine and creatinine, products of the maillard reaction, several tripeptides, lactoyl amides of amino acids, and amides of GMP have also been introduced in the literature.

The common goal of flavor researchers is finding new umami substances by selecting a food source rich in protein (6) or which has undergone an extensive maillard reaction (7,8). The water-soluble portion of the substances is then fractionated based on its molecular size and the fraction that carries the most umami or koku characteristics is identified. Although discovering a pure single compound that can sufficiently substitute for MSG would be meaningful, extracting a cocktail of umami substances from a food source that already contains an abundance of such compounds would be more time and cost saving. The traditional Asian condiments such as soy sauce, fish sauce, and fermented soy bean paste are rich sources of umami and taste-enhancing substances due to the presence of proteineous ingredients that promote fermentation and maillard reaction during the ripening process. Thus, the flavor substances produced from these materials are also strong NFE candidates.

Umami eliciting NFE materials are often applied to savory food systems. These food systems vary in optimal serving temperature, matrix type, flavor composition, etc. which all interact and affect the final sensory characteristics of the target food system. The change in perceived intensity and threshold of

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tastants such as sucrose and NaCl in different temperature conditions are well known example (9). Taste-taste and taste-odor interaction are also critical in determining the sensory quality of foods (9).

Numerous NFEs have been developed and introduced for application to a wide range of savory food systems. Reliable evaluation methods for measuring the flavor-enhancing functionality of NFEs are of great interest to NFE developers and marketers. However, care must be taken since the flavor-enhancing functionality of NFEs may vary depending on the physico-chemical conditions of the food system. The objectives of this study were to evaluate the sensory properties of various types of NFEs using a generic descriptive analysis method and to understand the effects of NaCl addition and temperature on the sensory characteristics of NFEs in an aqueous system.

Materials and Methods

Panel

Ten female panellists, who were selected based on their sensitivities to five basic tastants (sweet, salty, sour, umami, and bitter), participated in the descriptive analysis.

Samples and sample preparations

Six types of NFEs were investigated for their sensory characteristics. The NFE samples consisted of three yeast extract-based (YA, YB, YC), one fish sauce-based (FS), one soy sauce-based (SS), and one hydrolyzed peptide-based (PTD) samples. The detailed sample description is provided in Table 1. Yeast extract samples varied in nucleic acid contents and types of vegetable extract mixed together. The fish sauce-based and soy sauce-based samples had undergone deodorization and desalinization processes by the manufacturer. PTD sample was produced by fermenting wheat protein with koji. The samples were diluted to 1% (w/w) aqueous solution for evaluation. All the samples were provided by CJ Cheiljedang (Seoul, Korea). The samples were diluted as the manufacturer suggested.

Experimental design

Effects of NaCl addition and temperature on the sensory characteristics of six NFE samples were investigated. The six NFE samples were evaluated under two levels of NaCl and two levels of temperature conditions. The samples were either evaluated upon no addition of NaCl or addition of NaCl to a concentration of 0.5% in the 1% diluted sample. As seen in Table 1, the original NaCl content of the 6 samples varied. Therefore, different amounts of NaCl (Samchun Pure Chemical Co., Ltd., Seoul, South Korea) were added so that the final NaCl concentration of each sample was equilibrated to 0.5% of the diluted samples. Additionally, these samples were evaluated either at 20 or 55°C. Table 2 summarizes the experimental design of the sample treatment. Each block represents a combination of NaCl and temperature conditions applied to the six NFE samples. Each block was evaluated separately. The evaluated orders of the four blocks were randomized among the subjects in order to balance the learning effect that may be present during the course of evaluation.

Descriptive analysis procedure

The descriptive analysis consisted of training sessions and main experiment sessions. The descriptive analysis experiment took approximately 6 weeks in total. In the training sessions, panellists generated and defined the sensory attributes for characterizing the NFE samples. Corresponding reference standards were established and the intensity of each reference standard was assigned when possible. Eight odor (O), 17 taste/flavor (F), 6 aftertaste (A), and 6 mouthfeel/texture attributes (T) were developed. The list of sensory attributes is shown in Table 3. Since the major functionality of NFEs is to exhibit and to enhance umami related attributes, umami taste was divided into (pure) umami taste (reference standard=MSG 0.3%), beef umami taste (reference standard=beef broth), and seafood umami taste (reference standard=clam broth). Panellists were trained to evaluate the intensity of each attribute on a 15-point category scale. The anchor words at the left and right ends were “not detectable” and “very strong”, respectively.

In the main experiment session, the intensities of the attributes developed in the training session were evaluated for each sample using the 15-point intensity scale. The samples were evaluated under red light to remove the possible bias that may exist due to the color intensity of the samples. The serving orders of the samples within each block were determined based on randomized complete block design. The samples were served in sequential monadic order. Spring water was used to rinse the palate between sample evaluations. All the samples were replicated three times.

Table 1. Information of 6 natural flavor enhance samples

Sample	NaCl content (%)	Information
YA	31.9	70% yeast extract (containing 6% natural nucleic acid) mixed with 30% vegetable extract (mixture of onion, garlic, cabbage, shitake mushroom, black pepper)
YB	31.9	70% yeast extract (containing 6% natural nucleic acid) mixed with 30% vegetable extract (mixture of onion, garlic, cabbage, shitake mushroom, black pepper, ginger)
YC	26.5	Yeast extract with 12% natural nucleic acid
FS	38.9	Deodorized and desalinated fermented anchovy juice
SS	14.6	Desalinated Korean style soy sauce
PTD	0	Wheat protein fermented with Koji resulting in 12% natural glutamic acid

Table 2. Outline of the experimental design to investigate the effect of NFE type, NaCl addition, and temperature

Experimental block	Types of natural flavour enhancer	Addition of NaCl	Temperature	code
I	YA	No addition	55°C	YA_N_H
	YB			YB_N_H
	YC			YC_N_H
	SS			SS_N_H
	FS			FS_N_H
	PTD			PTD_N_H
II	YA	No addition	20°C	YA_N_L
	YB			YB_N_L
	YC			YC_N_L
	SS			SS_N_L
	FS			FS_N_L
	PTD			PTD_N_L
III	YA	Addition	55°C	YA_S_H
	YB			YB_S_H
	YC			YC_S_H
	SS			SS_S_H
	FS			FS_S_H
	PTD			PTD_S_H
IV	YA	Addition	20°C	YA_S_L
	YB			YB_S_L
	YC			YC_S_L
	SS			SS_S_L
	FS			FS_S_L
	PTD			PTD_S_L

Statistical analysis

In order to analyze the effects of NFE type, NaCl addition, and temperature on the sensory characteristics of the samples, Analysis of Variance (ANOVA) using General Linear Model (GLM) was conducted. The GLM model was as follows: [NFE type+NaCl addition+temperature+panellist+NFE type×NaCl addition +NFE type×temperature+NFE type×panellist+NaCl addition ×temperature]. The significance level was α=0.05. Duncan's multiple range test was conducted whenever a NFE type showed significant difference. Additionally, Principal Component Analysis (PCA) was conducted to visually summarize the relationships between samples and their sensory characteristics. GLM and PCA were conducted using PASW statistics 18 (Chicago, IL, USA) and XLSTAT (Paris, France), respectively.

Results and Discussion

Sensory characteristics of natural flavor enhancers

When ANOVA was conducted to analyze the effect of NFE type on the sensory characteristics of the samples, all of the attribute intensities except for smoothness (p=0.504), slippery (p=0.216), and viscosity (p=0.592) showed significant differences among the NFE samples.

Table 4 shows the mean attribute intensities of the 6 NFE samples evaluated at 55°C with no NaCl addition. Concerning the odor characteristics, yeast extract-based NFE samples YA and YB exhibited distinct vegetable and black pepper odors. In contrast, yeast extract-based YC sample was rated relatively low for most of the odor attributes, except for raw bean and *gusoo* (boiled roasted barley) odor. *Gusoo* and soy sauce odor were the main characteristics of the short peptide-based NFE sample PTD. Fish sauce-based FS sample was characterized as having the strongest fishy and vegetable odor, although the sample had gone through deodorization by the manufacturer. Soy sauce-based SS sample was rated average among the samples regarding most of the attributes.

Taste and flavor characteristics also varied depending on the NFE type. Yeast extract-based YA and YB samples showed relatively strong intensity for umami, beef umami, MSG, vegetable, and black pepper flavors. YC was rated moderate to high intensity for umami, sweet, and cooked bean flavors. However, compared to other samples, YC was rated low regarding other taste and flavor attributes. Fish sauce-based FS exhibited a relatively strong umami and seafood umami taste. Soy sauce-based SS was rated low for most of the taste and flavor intensities. Peptide-based PTD was characterized as having strong soy sauce flavor as well as bitter and sour taste. The aftertaste and mouthfeel texture of YA and YB were rated high for salty, hot, MSG, taste retention in mouth, mouth coating, biting, and

Table 3. Definitions and reference standards of odor, flavour, and mouthfeel attributes used in the descriptive analysis of NFEs

Categories	Descriptors	Definitions	Reference sample
Odor/Aroma	FishyO	Aromatics associated with fishy smell	20 g Dried anchovy (13)
	Raw BeanO	Complex Aromatic associated with raw bean, cut grass	30 g Grinded raw bean (7)
	MushroomO	Aromatics associated with mushroom such as Pyogo	30 g Pyogo mushroom boiled with 400 mL water for 20 min (13)
	VegetableO	Aromatics associated with vegetable stock	3 g Dried vegetable powder boiled with 400 mL water for 20 min (7)
	MetallicO	Aromatics associated with metal, iron and copper	Not applicable
	Black pepperO	Aromatics associated with black pepper	5 g Black pepper powder (13)
	GusooO	Aromatics associated with barley tea	30 g Barely tea extracted with 400 mL water for 20 min (10)
	Soy sauceO	Aromatics associated with soy sauce	Soy sauce dilute with water (1:1) (13)

Table 3. Continued

Categories	Descriptors	Definitions	Reference sample
Flavor/Taste	SweetT	Typical taste of sucrose	0.5% sugar solution (5)
	SaltyT	Typical taste of sodium chloride	0.5% NaCl solution (7)
	BitterT	Typical taste of caffein	0.05% caffein solution (5)
	SourT	Typical taste sensation stimulated by acid	0.05% citric acid solution (9)
	UmamiT	Typical taste of monosodium glutamate	0.5% MSG solution (7)
	Beef umamiF	Flavor associated with beef stock	200 g Eye Round boiled with 500 mL water for 20 min (10)
	Seafood umamiF	Flavor associated with seafood stock	200 g shellfish boiled with 500 mL water for 20 min (7)
	MSGF	Typical taste of MSG	0.5% MSG solution (7)
	Dried fishF	Flavor associated with dried fish such as dried anchovy	20 g Dried shrimp (6)
	FishyF	Flavor associated with fish	20 g Dried anchovy (13)
	Fish sauceF	Flavor associated with fish sauce	Fish sauce dilute with water (1:1) (14)
	Cooked beanF	Flavor associated with cooked bean	30 g Grinded cooked bean (7)
	MushroomF	Flavor associated with mushroom such as Pyogo	30 g Pyogo mushroom boiled with 400 mL water for 20 min (13)
	VegetableF	Flavor associated with vegetable stock	3 g Dried vegetable powder boiled with 400 mL water for 20 min (7)
	Black pepperF	Flavor associated with black pepper	Black pepper powder 5 g (13)
	Soy sauceF	Flavor associated with soy sauce	Soy sauce dilute with water (1:1) (13)
	MetallicF	Flavor associated with metals, iron and copper	Not applicable
Aftertaste	SweetA	After taste associated with typical taste of sucrose	N/A
	SaltyA	After taste associated with typical taste of sodium chloride	N/A
	HotA	After taste associated with typical taste of chili pepper	N/A
	MSGA	After taste associated with typical taste of MSG	N/A
	FishA	After taste associated with fish	N/A
	Taste retention	The feeling which remainder of flavor	N/A
Texture/ Mouth feel	Mouth coatingT	Mouthfeel when thin oil layer covers the tongue	Not applicable
	AstringencyT	The feeling which rough the tongue associated with tannins	Green Tea (7)
	BitingT	The feeling which shrivel the tongue associated with garlic	Not applicable
	MintyT	Mouthfeel associated with mint	Polo (13)
	SlipperyT	Mouthfeel associated with jelly	Petitzel (13)
	ViscousT	Degree of thickness of the fluid	Not applicable

minty. YC, SS, and FS samples exhibited strong mouth coating and flavor retention in mouth. Astringency was rated high in the PTD sample.

Overall, it was observed that the sensory characteristics of the NFE samples varied widely depending on the source ingredients. Although all of the NFE samples consisted of umami substances such as glutamate, amino acids, and short peptides, as well as other taste substances (7,10,11), the samples were also composed of various odor active volatile compounds. Umami substances are known to influence various taste and flavor qualities in a food system. The synergistic effect of MSG and sodium salts of ribonucleotides on the umami taste intensity is widely known (12). Several studies have investigated the effect of MSG on other tastants. Bitterness is generally suppressed by the addition of umami substances (13,14), whereas sweetness and saltiness are enhanced by the addition of MSG (13-16). The amount of taste and odor active compounds in the NFE samples combined with their perceptual interaction between the compounds will strongly affect the sensory profiles for each NFE sample. Therefore, application of these NFEs to a food system should be determined carefully based on how well their sensory characteristics and functionalities blend with the target food system. For example,

Table 4. Mean attribute intensities of 6 NFE samples evaluated at 55°C without NaCl addition

Sample	Aroma/odor								Taste				
	FishyO	Rawbean O	Mushroom O	Vegetable O	MetallicO	Black pepperO	GusooO	Soy sauceO	Sweet	Salty	Bitter	Sour	Umami
YA	3.8^{b}	3.7^{a}	3.7^{b}	5.7^{bc}	3.0^{b}	4.9^{c}	4.3^{a}	3.0^{b}	3.9^{ab}	4.9^{cd}	3.8^{a}	3.6^{bc}	5.1^{cd}
YB	4.0^{b}	4.0^{ab}	3.6^{b}	5.8^{bc}	2.7^{b}	4.4^{c}	4.9^{b}	3.1^{b}	4.1^{b}	4.9^{cd}	3.6^{a}	3.4^{bc}	5.4^{d}
SS	3.7^{b}	4.1^{ab}	4.0^{bc}	3.8^{ab}	3.2^{b}	2.3^{b}	5.1^{bc}	3.3^{bc}	3.5^{a}	2.8^{a}	3.8^{a}	3.0^{a}	3.8^{a}
FS	5.0^{c}	4.2^{ab}	4.1^{bc}	6.0^{c}	3.1^{c}	2.7^{b}	4.8^{b}	3.9^{c}	4.2^{b}	5.4^{d}	3.4^{a}	3.8^{c}	4.9^{bc}
PTD	4.1^{b}	4.0^{ab}	4.3^{c}	3.5^{a}	3.9^{b}	2.6^{b}	5.5^{c}	5.0^{d}	3.4^{a}	4.5^{c}	5.2^{b}	6.3^{d}	3.6^{a}
YC	2.7^{a}	4.4^{b}	3.1^{a}	4.2^{abc}	2.2^{a}	1.7^{a}	5.0^{bc}	2.2^{a}	4.4^{b}	3.5^{b}	3.4^{a}	3.3^{ab}	4.6^{b}

Sample	Flavor											
	Beef umamiF	Seafood umamiF	MSGF	Dried seafoodsF	FishyF	Fish sauce F	Cooked bean F	Mushroom F	VegetableF	Black pepperF	Soy sauceF	MetallicF
YA	4.5^{c}	3.8^{b}	5.6^{d}	3.1^{b}	2.9^{b}	2.5^{b}	3.6^{a}	3.2^{a}	5.4^{c}	5.5^{c}	2.7^{a}	3.1^{b}
YB	5.0^{c}	4.0^{b}	5.8^{d}	3.0^{b}	2.8^{b}	2.2^{ab}	3.6^{a}	3.3^{a}	5.2^{c}	5.4^{c}	2.6^{a}	3.0^{b}
SS	2.9^{a}	2.7^{a}	2.9^{a}	2.4^{a}	2.3^{a}	2.5^{b}	3.5^{a}	3.4^{a}	3.0^{a}	1.8^{a}	3.3^{b}	3.4^{b}
FS	3.8^{b}	4.2^{b}	4.3^{c}	3.2^{b}	3.5^{c}	3.4^{c}	3.7^{a}	3.3^{a}	3.9^{b}	2.6^{b}	3.7^{b}	2.9^{ab}
PTD	2.7^{a}	3.2^{a}	3.9^{bc}	2.8^{ab}	2.8^{b}	4.0^{d}	3.5^{a}	3.5^{a}	3.1^{a}	2.5^{b}	4.8^{c}	4.6^{c}
YC	3.9^{b}	3.8^{b}	3.4^{ab}	2.7^{ab}	2.3^{a}	1.9^{a}	4.4^{b}	3.3^{a}	3.8^{b}	1.6^{a}	2.2^{a}	2.4^{a}

Sample	Aftertaste						Mouthfeel/texture						
	SweetA	Salty A	HotA	MSGA	FishA	Taste retention	Mouth coatingT	Astrin-gencyT	BitingT	MintyT	SmoothT	SlipperyT	ViscousT
YA	$2.9^{a1)}$	4.1^{cd}	5.1^{c}	4.8^{c}	2.7^{a}	6.6^{c}	5.7^{b}	4.5^{a}	5.1^{d}	4.0^{c}	4.3^{a}	3.3^{a}	3.2^{a}
YB	3.4^{b}	4.2^{d}	5.1^{c}	4.7^{c}	2.8^{a}	6.6^{c}	5.7^{b}	4.3^{a}	4.9^{d}	4.0^{c}	4.4^{a}	3.4^{a}	3.3^{a}
SS	2.9^{a}	2.4^{a}	1.9^{b}	2.5^{a}	2.8^{a}	4.2^{a}	4.8^{a}	3.9^{a}	2.1^{ab}	2.4^{a}	4.7^{a}	3.4^{a}	3.4^{a}
FS	3.4^{b}	4.3^{d}	2.0^{b}	3.7^{b}	3.7^{c}	5.3^{b}	5.1^{ab}	4.0^{a}	2.4^{bc}	2.3^{a}	4.4^{a}	3.6^{a}	3.4^{a}
PTD	2.9^{a}	3.6^{bc}	2.1^{b}	3.2^{b}	3.5^{bc}	6.9^{c}	5.5^{b}	5.3^{b}	2.8^{c}	3.4^{b}	4.5^{a}	3.4^{a}	3.7^{a}
YC	3.5^{b}	3.3^{b}	1.3^{a}	3.4^{b}	3.1^{ab}	5.1^{b}	5.1^{ab}	3.9^{a}	1.8^{a}	2.1^{a}	4.8^{a}	3.0^{a}	3.2^{a}

[1)]Mean values within the same column sharing the same letter superscripts are not significantly different (p>0.05).

YC and SS samples may be appropriate for a bland food system since these were relatively mild compared to other NFE samples. In contrast, FS sample may be more suited for a seafood-based product, and PTD sample may fit well into a food matrix having intense and complex flavors.

Effect of NaCl addition on the sensory characteristics of NFE samples

Table 5 shows the list of attributes that were significantly affected by NaCl addition, NaCl addition×NFE type, temperature, and temperature×NFE type at α=0.05 level. The addition of NaCl to the NFE samples suppressed fishy odor, vegetable odor, bitter, and sour taste but increased salty and other savory related attributes such as seafood umami, MSG, and dried seafood flavor (Fig. 1A). Perceived viscosity was also increased with NaCl addition (Fig. 1B). Although several attributes were significantly affected by NaCl addition or NaCl addition and NFE type interaction, the magnitude of the effects was less than 0.7 point (data not shown).

It was observed that NaCl addition suppressed fishy odor, vegetable odor, bitterness, and sour taste but increased salty and other savory related attributes such as seafood umami, MSG, dried seafood flavor, and etc (14). The suppression of sour and bitter tastes by salt has been reported in other studies (15). Despite a sufficient amount of research on the effects of NaCl on sweet, sour, and bitter tastes, there has been only limited investigation concerning the effect of NaCl on umami-related flavors. Omission test studies in a model seafood system showed that removal of Na^{+} ion or Cl^{+} ion from the matrix decreases the intensities of umami, sweet, and sour tastes (16-18), indicating that Na^{+} ion or Cl^{-} ion may enhance these attributes. In our study, NaCl enhanced savory-related flavors, which may be explained by the fact that congruent flavors show a synergistic effect (19). Additionally, it is worth noting that the perceived viscosity increased with NaCl addition (Fig. 1B), which may have been due to a halo effect or actual increase in perceived viscosity. NaCl seems to differentially affect the perceived viscosity depending on the food matrix. In pure water matrix, Na^{+} ion is known to increase the viscosity of water, whereas Cl^{-} distorts the water structure and thus reduces the viscosity (20). The perceived viscosity decreases as the NaCl concentration increases, in the case of sodium carboxymethylcellulose solution matrix (21). On the contrary, NaCl increases the physical and perceived viscosity of an emulsion matrix (22).

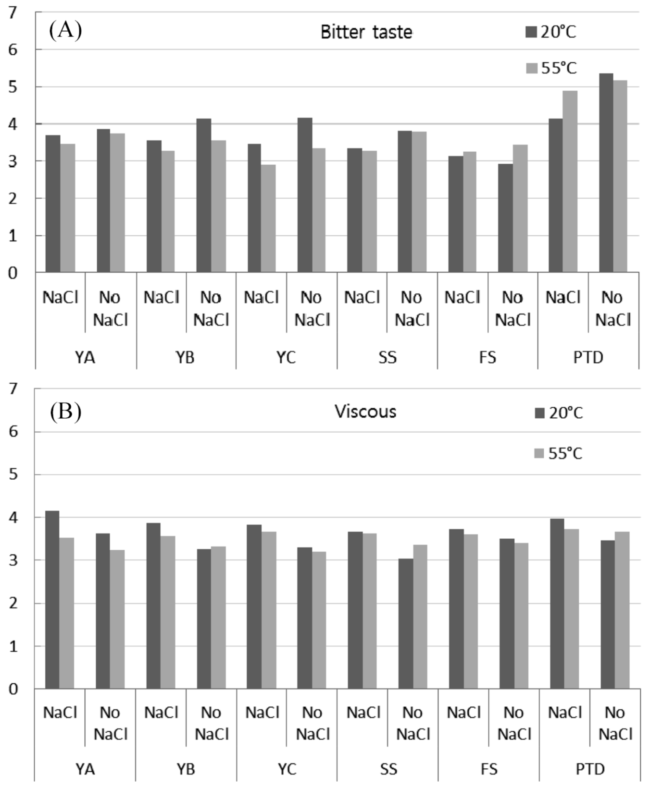

Fig. 1. Effect of NaCl on the bitter taste (A) and viscous intensities (B) of samples.

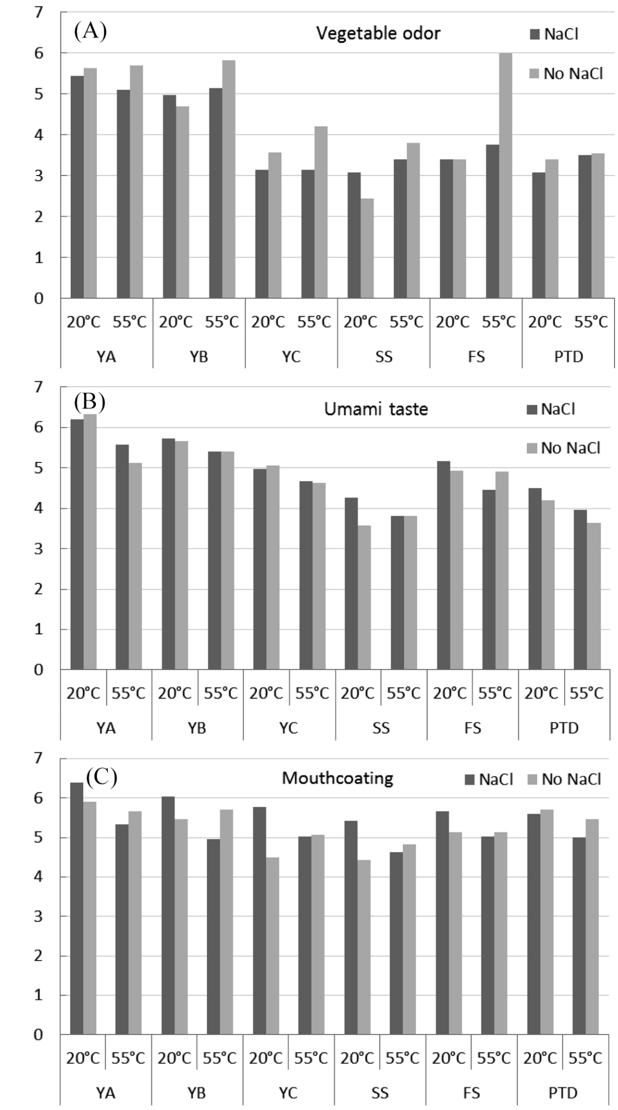

Fig. 2. Effect of temperature on vegetable odor (A), umami taste (B), and mouth coating (C) intensities of samples.

Effect of temperature on the sensory characteristics of NFE samples

The effects of temperature on the sensory characteristics of the samples were relatively stronger than the effects of NaCl addition. Twenty-seven attributes among the 38 total attributes were significantly affected by the temperature conditions. The intensities of odor attributes such as raw bean, vegetable, and *gusoo* were increased as the temperature increased (Fig. 2A). However, taste/flavor and mouth feel/texture attributes, in general, were perceived to be stronger at room temperature than at high temperature (Table 5, Fig. 2B).

The intensities of odor attributes, in general, increased as the temperature increased (Table 5). Many studies have reported that temperature critically affects the aroma, taste, and flavor intensities of food. However, even with the same taste/flavor substance, the results varied widely depending on the experimental design, testing method, and evaluation conditions. In this study, the increased odor intensities at higher temperature can be easily explained by the increased odor-active volatile release from the food matrix (9,23). However, concerning taste/flavor and mouthfeel/texture attributes, the intensities were perceived stronger at 20°C than at 55°C (Fig. 2C). Studies have shown that the threshold for NaCl was the lowest in the range of 22-37°C (24-26). When intensities were measured based on rating methods at the suprathreshold level, increment of intensity was commonly observed until the temperature reached 35°C for NaCl and the other tastants (27). The inconsistency between these previous findings and the present results may be due to the strong odor/aroma elicited at 55°C, which masked the flavor and taste perception of the samples. That is, the low volatility at 20°C may have brought out the flavor and taste attributes of the samples.

The impact of NaCl addition and temperature conditions on sensory intensities varied depending on the NFE type. SS, FS, and PTD samples were more influenced by NaCl and temperature conditions than the yeast extract based samples. For the SS and FS samples, overall odor intensities were stronger for the no NaCl addition and 55°C conditions than the other conditions. In the case of the PTD sample, seafood-related attributes such as seafood umami, dried seafood, and fishy flavor were rated distinctly stronger at 20°C.

Principal Component Analysis of NFE samples varied depending on NaCl addition and temperature conditions

PCA was conducted to visually summarize the sensory

Table 5. List of attributes that showed significant effect by NaCl addition, NaCl addtion×NFE type, temperature, temperature× NFE type at α=0.05 level

NaCl addition[1)]	NaCl addition× NFE type	Temperature[2]	Temperature× NFE type
FishyO↓	Salty T	Raw beanO↑	MetallicO
VegetableO↓	Salty A	VegetableO↑	Black pepperO
SaltyT↑		GusooO↑	GusooO
BitterT↓		UmamiT↓	Soy sauceO
SourT↓		Beef umamiF↓	SweetT
Seafood umamiF↑		Seafood umamiF↓	BitterT
MSGF↑		Dried seafoodF↓	SourT
Dried seafoodF↑		FishyF↓	FishF
FishyF↑		MushroomF↓	Fish sauceF
Fish sauceF↑		SweetA↓	Black pepperF
Soy sauceF↑		FishyA↓	Soy sauceF
SaltyA↑		Mouth coatingT↓	MetallicF
Viscous T↑		AstringencyT↓	MSGA
		MintyT↓	MintyT
		SmoothT↓	
		ViscousT↓	

[1)]denotes the significant increase (↑) and decrease (↓) of sensory attribute intensity when NaCl was added to the NFE sample.
[2)]denotes the significant increase (↑) and decrease (↓) of sensory attribute intensity when the temperature of the sample was increased to 55°C.

characteristics of the 24 samples (six types of NFE×two levels of NaCl×two levels of temperature) (Fig. 3A and 3B). Approximately 60% of the total variance was explained by PC 1 (37.25%) and PC 2 (23.23%). The attributes of salty, vegetable flavor, umami, MSG, black pepper, mouth coating, and minty were strongly loaded in positive PC1. Yeast extract-based samples YA and YB showed high correlation with these attributes. The attributes of soy sauce, metallic, fish sauce flavor, and mushroom odor were loaded positively in PC2, and PTD showed high correlation with these attributes. YC and FS samples were characterized as smooth, sweet, and umami, which were loaded in negative PC2. SS sample was rated as relatively weak for most of the attributes.

Conclusion

The present study investigated the sensory properties of various NFE samples and the effects of NaCl and temperature on the sensory characteristics of NFEs. Addition of NaCl increased some of the savory-related flavors and the perceived viscosity of the sample. Aroma intensities, in general, were enhanced at higher temperature, whereas flavor, aftertaste and mouthfeel attributes were perceived stronger at lower temperature. It was observed that the type of NFE determined the flavor direction of each sample. When choosing NFE for food application, the flavor characteristics of the target food system should be taken into account. In order to reliably measure the flavor-enhancing functionality of NFEs, a model system should include all of the key conditions present in the real food system to which the NFE is applied.

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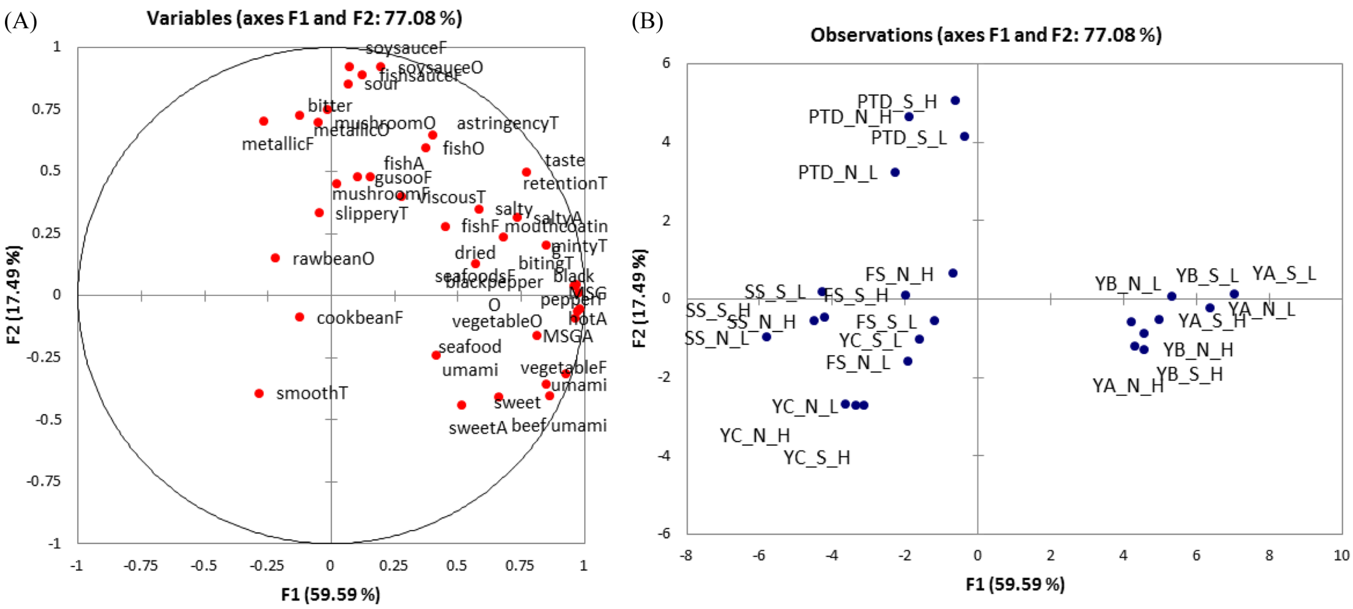

Fig. 3. Principal component loadings of sensory attributes (A) and scores of samples (B).

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