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Application of Multivariate Statistics for Characterization of Sensory Properties in Pre-cooked Foods

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Abstract

Various multivariate statistics were applied to determine the relationships between sensory properties of 9 pre-cooked foods. Twelve sensory terms were selected to differentiate the food samples in stepwise discriminant analysis. Three factors accounted for 61.9% of total variation of 12 sensory attributes detected. Factor I was highly related to the qualitative sensory terms, while factor II to the quantitative ones. The principal component plot made it possible to define the relationships between sensory properties and food samples. In cluster analysis using average linkage and Ward's method, nine pre-cooked foods were classified into three clusters in terms of their sensorial similarities.

Key words: multivariate statistic, sensory property, pre-cooked food

Introduction

Commercial food products can be classified into two groups of foods, such as raw material foods and processed foods. The former group includes wheat flour, seasoning, sugar and soybean oil, etc. The latter indicates all the other foods made of raw material foods through the manufacturing treatments. Pre-cooked foods belong to a subgroup of the processed foods and represent the foods ready to eat with a simple heating, such as frozen foods, retort pouch packaged foods and microwavable foods.

The quality of food products is related to the sensory properties and nutritional value of foods. In addition, the sales price of food products is also an important factor for determining the intention of purchase. Studies in our center suggested that although some food products were reinforced with the nutritional and functional properties using specific ingredients, the purchasing intention of such foods by consumer was determined by sensory properties, sales price and nutritional levels in order of relative importance. Particularly, the food flavor, which means the combined senses of smell and taste perceived from the foods,[1] was a critical factor in determining food quality and preference of consumer.

For the sake of producing pre-cooked foods of high quality, the relationships between sensory properties of pre-cooked foods should be defined prior to setting up the final composition of products.

Sensory evaluation of food products have been repeatively performed with the quality difference test by trained panels and the preference test by untrained panels, such as consumers in industrial applications for cost reduction, new product development, quality control, stability testing, and process optimization. However, much difficulty with the prolonged time and high cost are caused by the reiteration of analytical sensory and preference test in evaluating food products with the quantitative descriptive analysis and hedonic preference scaling.

Multivariate methods have been applied to investigate the relationships among the samples using their physical, chemical, and sensory properties. Principal component analysis was used for the characterization of whiskeys based on GC profiles with accompanying discrimination between whiskey categories.[2] Heymann and Noble[3] comparatively evaluated wine sensory data by principal component analysis and canonical variate analysis. LeBlane *et al.*[5] used factor analysis to achieve a reduction of the number of chemical and physical variables in frozen fillets. Aishima and Nakai[5] established a simple and reliable method for discriminating cheese variaties (82 samples) by applying stepwise linear discriminant analysis to total GLC data. Hierarchical cluster analysis has been successfully applied in discriminating 48 samples of soy sauce on the basis of 10 peaks selected in the stepwise discriminant analysis or on the basis of 10 important peaks correlating to sensory

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scores.[6]

The ultimate purpose of a present work was to measure the relative importance of sensory properties in evaluating pre-cooked foods, to investigate the relationships among sensory terms used, and to apply several multivariate statistics for interpreting sensory properties in food products.

Materials and Methods

Food samples

The experimental samples were obtained privately from a food manufacturing company located in Kyunggido (Table 1). The characteristics of food samples used were microwavable foods (A, B, C, E, F, G, and H) or retort pouch packaged foods (D and I) which were pre-cooked, ready-to-heat and serve. Microwavable foods were reheated by a microwave oven (Camco, 1060 W, Canada) for 3 min at high power of output (700 W) and retort pouch packaged foods boiled for 3 min with a conventional oven.

Sensory analysis

Descriptive analysis was applied to determine the sensory characteristics of pre-cooked foods A through I. Ten panelists were selected from research staff in Foods R & D Center of Cheil Foods & Chemicals Inc. They had been frequently participated in testing the quality of processed foods. Initially, panelists were asked to evaluate each food samples and record appropriate descriptors representing their quality.

Descriptors were sought to assess the taste, oder, texture, size and amount of components, color and intention of purchase. Finally, sixteen descriptors were selected to evaluate the quality and preference of pre-cooked foods (Table 1). The structured 8 cm line scale on a scoresheet was used to represent the perceived intensities of sensory properties, where on the left side 1 was anchored as 'extremely dislike', 'small', 'low', 'soft', or 'not purchasing', and on the right side 9 'extremely like', 'large', 'high', 'hard', or 'everyday purchasing'. Panelists indicated their responses to the intensity of the attributes by drawing a vertical line on the horizontal line scale [7]. Marks were converted to scores by measuring the distance in cm from the left origin of the line scale. White light was applied to test the actual color of samples similarly to the conditions that the samples were consumed by the consumer. All food samples were served as a packaging unit itself after reheating. Water was provided to the panelists for mouth-cleaning between samples. If necessary, the cooked rice was sometimes served to help the evaluation of pre-cooked food samples. All food samples were determined sensorially in two replications.

Statistical analysis

Table 1. Summary of pre-cooked foods and sensory properties studied

Pre-cooked foods*

A : Food made of chicken, potato and spices, etc.(250 g)
B : Food made of tuna, Chinese cabbage and spices, etc. (280 g)
C : Food mold and made of pork, egg, onion, potato, carrot, wheat flour, tomato paste and spices, etc. (250 g)
D : Food made of curry powder, wheat flour, shortening, beef, potato, onion, carrot and spices, etc. (180 g)
E : Food fried, coated, mold and made of beef, pork, onion, carrot and egg, etc. (250 g)
F : Food made of beef, potato, carrot, tomato paste and onion, etc. (280 g)
G : Food fried, coated, mold and made of pork, potato, onion, carrot and egg, etc. (250 g)
H : Food mold and made of beef, pork, onion, potato and carrot, etc. (250 g)
I : Food made of *chunjang*, wheat flour, shortening, pork, potato, onion, carrot and spices, etc. (180 g)

Sensory properties

a : Overall odor (OO)	b : Size of meat (SM)
c : Size of other raw materials (SORM)	d : Amount of meat (AM)
e : Amount of other raw materials (AORM)	f : Amount of sauce (AS)
g : Texture of meat (TEM)	h : Texture of other raw materials (TEORM)
i : Viscosity of sauce (VS)	j : Taste of meat (TAM)
k : Taste of other raw materials (TAORM)	l : Taste of sauce (TAS)
m : Overall color (OC)	n : Amount of serving unit (ASU)
o : Overall quality (OQ)	p : Intention of purchase (IP)

*The numbers in parentheses were packaging weights of foods

Table 2. Sensory properties selected for discrimination of pre-cooked foods from stepwise discriminant analysis

Step	Properties	Partial R^2	F	p>F
1	AM	0.721	26.2	<.001
2	OC	0.669	20.2	<.001
3	VS	0.530	11.1	<.001
4	TEM	0.411	6.8	<.001
5	OQ	0.340	5.0	<.001
6	AORM	0.327	4.6	<.001
7	SM	0.301	4.1	<.001
8	TAORM	0.215	3.1	<.005
9	AS	0.182	2.0	0.054
10	TAM	0.175	1.9	0.072
11	IP	0.174	1.8	0.077
12	SORM	0.155	1.6	0.138

Table 3. Rotated factor loadings of 12 descriptive sensory properties in factor analysis

Properties	Factor analysis		
	Factor I	Factor II	Factor III
Eigenvalue	3.512	2.701	1.216
Proportion (%)	29.3	22.5	17.6
AM	0.09248	−0.80000	0.09924
OC	−0.75967	−0.09522	−0.18348
VS	−0.12198	0.81926	0.15724
TEM	0.21039	0.47954	0.27967
OQ	0.84842	0.00946	0.27256
AORM	−0.00676	0.82930	0.03692
SM	0.23956	−0.08740	0.82127
TAORM	0.80776	−0.22542	−0.04479
AS	0.05157	−0.42323	−0.74561
TAM	0.80037	0.17595	−0.17755
IP	0.74466	−0.14769	0.30100
SORM	−0.17591	0.14736	−0.00005

Statistical analyses of experimental data were conducted using SAS statistical packages.[8] Stepwise discriminant analysis (STEPDISC) with a forward stepwise procedure was applied to select the sensory attributes differentiating 9 pre-cooked food samples simultaneously. Principal component analysis (PRINCOMP) was also attempted to explain the total variation in the observed variables (sensory attributes) of food samples on the basis of the maximum variance properties of principal components.[9,10] The relationships between sensory terms was analyzed by factor analysis (FACTOR) using several options, such as principal component extraction and varimax rotation. Additionally, cluster analysis (CLUSTER) with average linkage and Ward's method[8,11] was adopted to classify 9 food samples into a few groups.

Results and Discussion

Descriptive analysis was carried out to select the descriptive terms representing the sensory attributes of pre-cooked foods. Descriptive terms of semi-trained panels were not specific. Most of terms described were 'high or low chroma', 'good or bad taste', 'good or bad smell', 'high or low amount', 'hard or soft texture', 'good or bad appearance', and 'high or low viscous'. It was assumed that sensory terms used by normal consumers were not exceeded to those described by semi-trained panels (Table 1).

All the sensory properties described were not adopted to discriminate the 9 different groups of food samples, which means some properties are not critical for differentiating the given samples (Table 2). The most-powerful discriminating sensory property was 'amount of meat' and the second 'overall color'. Other properties selected were 'viscosity of sauce', 'texture of meat', 'overall quality', 'amount of other raw materials', 'size of meat', 'taste of other raw materials', 'amount of sauce', 'taste of meat', 'intention of purchase' and 'size of other raw materials' in order of relative importance for differentiating 9 pre-cooked foods. No other sensory properties such as 'overall odor', 'texture of other raw materials', 'taste of sauce' and 'amount of serving unit' were involved because of no accomplishment of the 0.1500 significance level for entry. It was obvious from the 12 sensory properties selected that the appearence of pre-cooked foods such as 'amount of meat', 'overall color' and 'viscosity of sauce' could be used in first for the identification or discrimination of specific foods.

In factor analysis using 12 sensory properties, linear combinations of terms were calculated to form new variables called factors. Factor analysis maximizes the contribution of high loading terms and minimizes those which contribute the least by rotation methods prior to the final solution.[12,13] Three factors were extracted that explained 61.9% of the variation in the data of 12 sensory properties (Table 3). Factor I had high loadings for 'overall color', 'overall quality', 'taste of other raw materials', 'taste of meat' and 'intention of purchase'. Factor II had high loadings for 'amount of meat', 'viscosity of sauce' and 'amount of other raw materials'; and factor III had

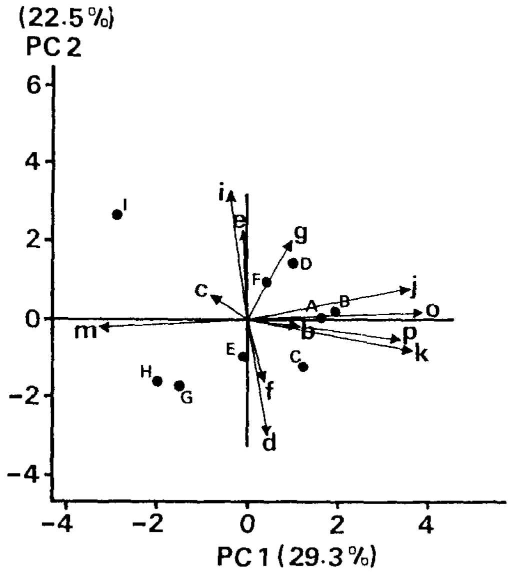

Fig. 1. Principal component plot of food samples (closed circles) and sensory properties (arrows) referred in Table 1

high loadings for 'size of meat' and 'amount of sauce'. From these results, Factor I could be renamed as a qualitative factor, whereas Factor II designated as a quantitative factor.

It was difficult to present the 9 pre-cooked foods in geometric plot using 12 sensory properties selected, because it required the 12-dimensional plot to express confidently the difference of food samples in terms of sensory properties. Principal component analysis made it possible to reduce the dimensionality of the original data set.[10]

The output from principal component analysis gave scoring coefficients that were used to calculate principal component scores of food samples from the standardized scores of the sensory attributes. Principal component scores of samples were calculated and plotted on the coordinate of principal component 1 (PC 1) and principal component 2 (PC 2). Additionally, the output from factor analysis were also presented in the same plot to elucidate the relationship between food samples and sensory preperties (Fig. 1). Both of PC 1 and PC 2 accounted for 51.8% of total variation derived from 12 sensory properties. the points of A, B, C, D, E, F, G, H and I representing 9 pre-cooked foods mean the center points of 20 observed data (2 replication×10 panels) evaluating each food sample.

There were positive relationships among 'overall quality', 'taste of meat', 'taste of other raw materials' and 'intention of purchase'. In other words, the more delicious the meat and other raw materials the higher the overall quality of pre-cooked foods, intention of purchase toward pre-cooked foods was directly related to the levels of their overall quality. Overall color that was described with respect to the chroma (low to high) or brightness (ligh to dark) had a negative effect to the overall quality of pre-cooked foods. On the other hand, the quantitative sensory terms such as 'amount of meat', 'amount of other raw materials' and 'amount of sauce' appeared to be highly related to the PC 2 and have not suggested any relationships to all the sensory properties accounted for by PC 1. It can be presumed from these results that the amount of raw materials are not critical factors compared to the sensorial and textural characters in defining final formula of pre-cooked foods that are highly acceptable to consumers. The principal component pattern of food samples represented

Table 4. Quality differences (Euclidian distances) between 9 pre-cooked foods using principal component scores derived from 12 sensory properties

	Food Samples[a]								
	A	B	C	D	E	F	G	H	I
A	0								
B	0.436	0							
C	1.677	1.673	0						
D	1.478	1.424	2.646	0					
E	1.947	2.381	1.345	2.639	0				
F	1.484	1.658	2.314	0.808	1.962	0			
G	3.569	4.001	2.803	4.056	1.624	3.278	0		
H	3.978	4.406	3.293	4.328	2.055	3.529	0.520	0	
I	5.202	5.384	5.709	4.142	4.670	3.731	4.615	4.393	0

[a]The food samples were referred in Table 1

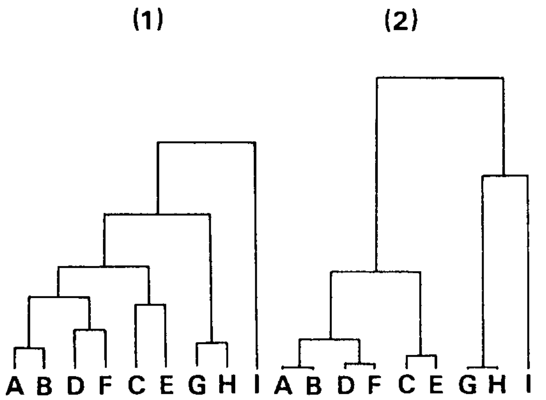

Fig. 2. Hierarchical clustering diagrams of food samples using twelve sensory properties by (1) average linkage method and (2) Ward's method

that pre-cooked foods A, B and C had similar sensory characteristics to each other, whereas food I was highly different from other 8 food samples with regard to the 12 sensory properties considered. Especially, foods A and B were located in the nearest position indicating that both showed high perceived intensities in the taste of meat and other raw materials, and received high scores in preferences and intention of purchase.

Table 4 shows the Euclidian distances between food samples in principal component plot. Foods C and I were extremely different from each other on the basis of 12 sensory properties. The categorical relationships are shown in Fig. 2 as hierarchical cluster diagrams of food samples. Two clustering methods were applied to find the similarities between 9 food samples because of the different resutls in performance according to analytical methods in most applied research.[11] Food samples were approximately classified into three groups. The first group included pre-cooked foods A, B, D, F, C and the second group foods G and H. Food I was not similar to any other food samples and hence conforms a new cluster.

In conclusion, multivariate statistics were applied to elucidate the relationships among sensory attributes and food samples with sensory data. Sensory terms on pre-cooked foods were categorized into two groups such as qualitative and quantitative groups, while 9 food samples separated into three clusters. Likewise in this study, the appropriate application of multivariate analyses would be helpful to figure out clearly the complex phonomena of experimental data.

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다변수 통계법을 이용한 조리식품의 관능특성 연구

윤희남
제일제당 가공식품개발센터

조리 식품의 관능특성을 평가하고, 다변수 통계법으로 서로의 상관관계를 조사 하였다. 시료 식품을 각각 특징지을 수 있는 12개의 관능특성을 단계적 차별 분석에 의해 선정하였으며, 요인분석에 의해 도출된 3개의 요인으로 12개의 관능 특성이 갖는 변이의 61.9%를 설명할 수 있었다. 요인 I은 질적 관능성질과 관련이 있고, 요인 II는 양적인 관능특성과 높은 상관관계를 나타내었다. 시료 식품과 관능특성을 동시에 주 성분 좌표상에 표시함으로서 서로간의 상관관계 설정이 용이하였고, average linkage 및 Ward's method을 이용한 집락분석에서 9개의 조리식품은 관능특성의 유사성에서 크게 3 개의 집락으로 분류되었다.