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Development of Food Kansei Model and Its Application for Designing Tastes and Flavors of Green Tea Beverage

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The Food Kansei Model has been developed to formulate the causal relationships between the analyzed characteristics and perceived quality of food products. It was applied to correlate the physicochemical properties with the food perception, preference and pleasantness quantitatively. The model was applied to the practical design of flavor- and taste-active components in green tea beverages. Instrumental analyses using gas chromatography and high performance liquid chromatography were carried out for test samples of green tea beverages. Sensory evaluation was also performed by three consumer groups belonging to different social categories. The perception of tastes and flavors was summarized in new sets of uncorrelated sensory factors by applying principal component analysis to sensory data. Preferences were indicated by regression coefficients estimated to correlate hedonic ratings with the sensory factors. The relationships among the green tea components and the sensory factors were analyzed by the use of an artificial neural network. The preferable intensities of sensory factors and the concentration ratio of the components were estimated for each consumer group. Relatively high levels of roasted and sweet flavor components were found to cause higher smoothness that was preferred by female students. In contrast, female and male office workers preferred the samples containing a greater amount of flowery flavor and total amino acid, which offered greater thickness and fragrance.

Keywords: Food Kansei Model, green tea beverage, principal component analysis, artificial neural network, consumer preference, product development

Introduction

Kansei engineering was founded 30 years ago as an ergonomics and consumer-oriented technology for new product development (Nagamachi, 2002). Recently, the specified paradigm and methodology of Kansei engineering related to foods has been proposed as "Food Kansei Engineering" by Sagara (2001). The measurement methods of intrinsic food attributes concerning food palatability have been proposed for each of the five senses, however, the approach of psychophysical relationships among physicochemical food characteristics and perceived quality is scarce for complex food products. Thus the development of models has been desired to correlate these physicochemical attributes and food perception quantitatively based on the causal association.

Sijtsema gave an overview of conceptual models about factors influencing food choice, acceptance or preferences (Sijtsema *et al.*, 2002). The need for food in relation to its function in groups of people is studied by anthropologists, psychologists, sociologists, marketers and economists who place food in a societal perspective. In psychology, most literature about food that deals with eating concerns quantity: regulation of food intake, and disorders related to food intake, such as obesity, anorexia nervosa, and bulimia. The cultural aspects of food and the function of food in a group were first studied by anthropologists. Recently, sociologists also started to study the differences of food use and choice in different countries, though, in those studies, research that analyzes the linkage of physicochemical characteristics to quality attributes is scarce.

The psychophysical literature contributes to the fundamental insight into the relationship between physical product characteristics and consumer perceptions (Steenkamp and Van Trijp, 1996). A serious limitation of traditional psychophysical research, however, is that the overwhelming majority of these studies involve at most a couple of narrowly defined physicochemical characteristics. Therefore, the psychophysical functions obtained from these studies have limited practical relevance for complex foods. Since the tastes and flavors are dependent upon a number of natural components, the quality prediction in food processing is difficult, especially from the viewpoints of consumer-oriented design. Quality recognition in humans is thought to be generally unsupervised pattern recognition. The sensory attributes can originate through the interactions of complex nonlinear physical and chemical properties that can individually be quantified only by instruments.

Artificial neural network (ANN) was developed almost four decades ago as a tool that has the ability to handle information-processing problems (Ni and Gunasekaran, 1998). ANN has recently gained more attention because of advanced technology in computer hardware and software

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(Bomio, 1998). ANN was capable to generalize and deduce essential characteristics from inputs containing chaotic data, and handle complex nonlinear, and even unknown, relationships. The ANN has been used as an effective method for constructing a highly accurate model of relationships between instrumental measurements and sensory evaluations (Wilkinson and Yuksel, 1997; Ni and Gunasekaran, 1998; Bomio, 1998; Wailzer *et al.*, 2001; Boccorh and Paterson, 2002; Tominaga, 2002). The ANN models could be used to predict the intensities of tastes and flavors immediately, however, these represent little about the interactions among perceived quality and preference for the flavors. On perceptual levels, the models generated in these studies cannot be classified as causative in terms of the determinants influencing food perception and preferences. It seems that it is important for consumer-oriented product development to integrate the preferences for tastes and flavors into the model, which are considered to be different among individuals.

Since food perception is an abstract construct and is of a multi-dimensional nature, the development of mensuration scales is a question of vital importance (Jover *et al.*, 2004). Many authors recognize the interest of scales directed to a product, suggesting that quality is specific to a single good or service. The fact that the intrinsic attributes are specific to each product means that choosing one specific product is recommendable. Recently, many types of tea beverages have been produced and consumed in Japan, including green tea, oolong tea, black tea and scented tea (Kobayashi, 1995). In the marketing of tea beverages, the development of new methodologies to design taste and flavor adapted to consumer preference is desired for creating new demand and an advance in sales performance. We have chosen green tea beverage as a specific case, for the reasons mentioned and due to the fact that it is one of the products which is enjoyed in household consumption allowing different preferences among individuals.

The objectives of this study are (a) to develop the Food Kansei Model to correlate the physicochemical properties of food with the food perception, preference and pleasantness quantitatively, and (b) to predict preferable taste and flavor design of green tea beverages for consumer groups from varying social backgrounds.

Theoretical

Factors affecting food preference and pleasantness In the study of factors influencing food preferences by Randall and Sanjur, three groups of characteristics: food, individual, and environmental, were clearly divided (Sijtsema *et al.*, 2002). The characteristics of food deal with taste, appearance, texture, cost, food type, method of preparation, form, seasoning, and food combinations. On the other hand, The characteristics of the individual are represented in terms of age, sex, education, income, nutritional knowledge, cooking skills and creativity, and attitudes toward health as well as the role of food. The characteristics of environment refer to season, employment, mobility, degree of urbanization, size of household and stage of family. The variables were selected based on the criteria of the frequency with which they were isolated in past studies and/or the strength of the proposed association with food preference (Sijtsema *et al.*, 2002). The variables in the three characteristics, for which operation or measurement can be available in the process of product development, should be incorporated into the present model.

Except for the characteristics of the environment because of their impossibility to control, the other two causal factors of pleasantness could be classified broadly into three categories, viz., perceptual, appetitive and cognitive factors (Fig. 1), based on the classification of factors relating to the mechanism of affective response (Fiske, 1982; Ito, 1994). Perceptual factor represents external stimuli caused by physicochemical characteristics of food such as components, structure, temperature and appearance. They contribute materially to sensory pleasantness by the perception of taste, flavor and texture through sensory organs. Appetitive factor represents internal motivation and attitudes, the characteristics of the individual, which include hunger, preference, knowledge, wish and demands for a food product. Cognitive factor represents the external stimuli from the information about the food product indicating price, manufacturer, calorie and health-promoting benefits, which are also included in the characteristics of food. These influence the pleasantness through cognition and judgment of benefits at the time of the food consumption.

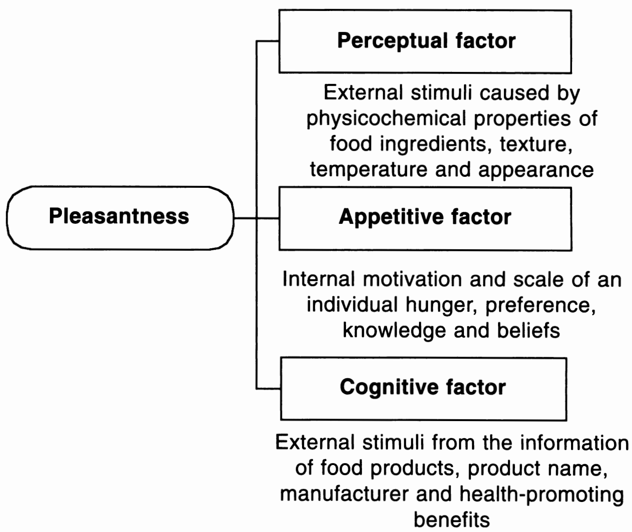

Fig. 1. Three factors affecting the pleasantness of food ingestion.

Food Kansei Model The "Food Kansei Model" (Fig. 2) is primarily intended to formulate the causal relationships between the characteristics and perceived quality of food products. The model integrates the key factors and causal relationships discussed above. In the model, the food product was assumed to have "intrinsic" and "extrinsic" attributes. Intrinsic attributes work as perceptual factors, which represent the characteristics of food such as chemical components and physical structure analyzed instrumentally by gas chromatography – mass spectrometry (GC-MS),

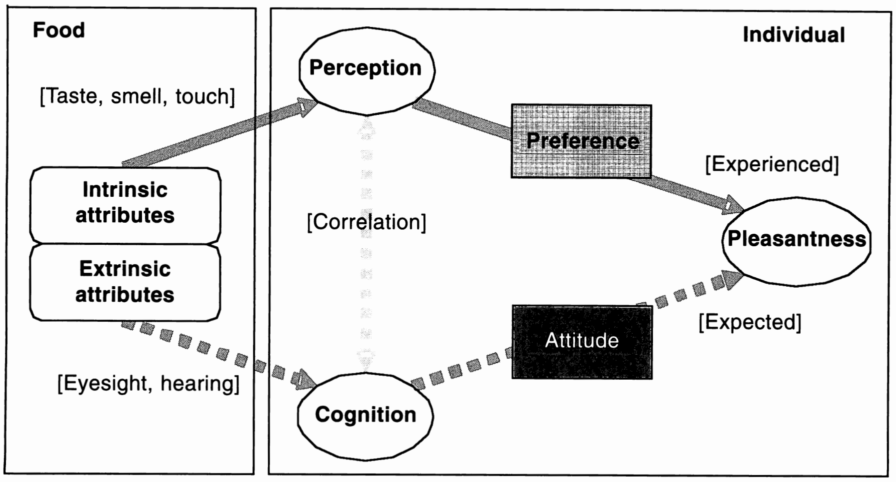

Fig. 2. Food Kansei Model. Source: own elaboration based on Ito (1994).

high performance liquid chromatography (HPLC) and texture measurement. On the other hand, extrinsic attributes deals with the contents described on packages and advertisements such as product name, manufacturer and health-promoting benefits work as cognitive factors of pleasantness.

The upper routes of the model represent the causal relations between intrinsic attributes, perception and pleasantness. Perception represents perceived quality of taste, flavor and texture felt by tongue, nose and teeth, respectively. The intrinsic attributes of a food are perceived firstly as taste, flavor and texture through sensory organs. The link between physicochemical characteristics and the perceptions is generally referred to as a psychophysical relationship (Steenkamp and Van Trijp, 1996). It is assumed that these perceived qualities are converted to pleasantness based on the preference. Preference shows the hedonic scale for perceived quality of tastes and flavors, acquired through biological inheritance, dietary habit and aging process. It works as an appetitive factor in the determination of pleasantness for perceived taste and flavor during a brief period of tasting food. The pleasantness through sensory perceptions, which is determined at the moment of ingestion, is regarded as experienced pleasantness.

In a similar fashion, the lower routes represent the way extrinsic product characteristics are related to pleasantness through quality cognition. Cognition indicates mental image in the mind caused by the recognition of extrinsic attributes through eyesight and hearing. Parallel to the upper procedure, extrinsic attributes of the product are recognized as imaginary which subsequently evokes the pleasantness (Fiske, 1982). Attitude is also an appetitive factor providing criteria for the images, evaluating the benefits of the food product. The pleasantness resulting from the images based on extrinsic attributes is referred to as expected pleasantness, which is expected at the point of purchase and consumption. Both procedures are presumed not to be independent but correlated to each other. Sensory quality of taste and flavor might be assimilated by the expectation of high quality from extrinsic attributes of food products (Cardello, 2003). It should also be mentioned that the overall pleasantness for food consumption is demonstrated to be the result both of the experienced and the expected pleasantness (Accebron and Dopico, 2000).

Materials and Methods

Test samples Eight green tea samples were prepared: one standard sample (std.), three taste- and four flavor-controlled samples, namely T1~T3 and F1~F4, respectively, by brewing the green tea and adding natural extracts and materials differently. The flavor component of T1~T3 was designed to be the same as F4. These were filled and sealed mechanically in 500 ml plastic bottles, preserved at room temperature for a few weeks. For sensory evaluation, the chilled samples in the refrigerator were poured and served in translucent disposable plastic cups.

Instrumental analyses Volatile compounds of flavor-controlled samples were analyzed with a gas chromatograph (GC, Agilent 6890) to determine the absolute concentrations of the odor-active compounds in green tea. Gas chromatography/olfactometry (GC/O) was also conducted to identify the characteristics of odor. A sniffer, an expert sensory technician, sat at the GC outlet and recorded the characteristics of each flavor released in the stream of purified and humidified air at a linear velocity. Non-volatile compounds including amino acids and catechins of the eight samples were analyzed by high performance liquid chromatography (HPLC, Shimadzu LC-10Avp; Waters AccQTag™ Amino Acid Analysis System 2690 xe). These characteristics are generally used in the field of chemical studies to measure the quality of tea beverages, taking multiple measures of standardized procedures.

Human sensory evaluation Sensory evaluation was performed by a panel of 240 consumers, 80 female senior high school or university students, 80 female office workers in the age group of 20–39 yrs and 80 male office workers in the age group of 20–59 yrs. The panel size is sufficient for the evaluation of the consumer response to the product samples (Poste *et al.*, 2001). The panel, who were neither hungry nor sleepy, profiled the samples using a sensory 7-

point descriptive analysis after being informed about the test. Both sniffing and tasting were performed in order to allow evaluation of odors, flavors and tastes. After the preliminary studies we found that we could measure the perceived quality of green tea beverage using 17 items. The samples were described and discriminated by the following 17 sensory attributes: fragrance intensity of green, floral and roasted, taste intensity of bitter, sweet, aftertastes, authentic and ten other attributes (shown in Table 1). Hedonic ratings were obtained from an overall impression of each sample. Each of the 240 consumers performed the evaluation of 4 samples in a fully randomized order.

Table 1. Configuration matrix of high factor loadings for sensory attributes.

Items	Rotated components 1	2	3	4
Appropriate to the food	0.81			
Good to gulp down	0.79			
Well-balanced	0.75			
Refreshing	0.75			
Authentic		0.77		
Leave the clear impression		0.72		
Aftertaste		0.71		
Intensly flavored		0.71		
Distinctive		0.67		
Astringency, acerbity		0.66		
Roasted fragrance			0.78	
Floral fragrance			0.77	
Green fragrance			0.72	
Sweet				0.80
Soft				0.65
Percent	19.7	23.8	14.1	10.4
Cum Percent	19.7	43.5	57.7	68.1

Application of Food Kansei Model Since no differences in the appearance were presented among samples, the influence of extrinsic attributes for pleasantness through cognition, the lower routes of the model, was neglected in this study. As shown in Fig. 3, the upper routes of the Food Kansei Model were applied to specify the causal relationships between intrinsic attributes, perception, preference and pleasantness. It contains both food perception and acceptance phases, which express the causal effects of intrinsic attributes on perception and the effects of perception on pleasantness through preference, respectively. The concentrations of volatile and non-volatile components were characterized as the variables of intrinsic attributes, while the described tastes and flavor intensities in sensory analysis were assumed to be the variables of perception.

In Fig. 4, an instance of causal relationship in the model was illustrated from the aspect of quantity. In our empirical application, the relationship of food perception phase was estimated on the use of ANN in consideration of the presumed multiple and synergistic effects in the sensory perception, which have been observed in the relationship between perceived and actual intensity of many stimuli (Wilkinson and Yuksel, 1997). The latter relationships of food acceptance phase were estimated by multiple regression analysis (MRA) for the empirical linearity among the ratings of sensory intensity and hedonic impression. In the food acceptance phase, the gradient of hedonic ratings was defined as preference for perceived quality, which facilitates the understanding of the different preferences among consumer groups. It seems advantageous to combine ANN and MRA from the viewpoint of product development.

Statistical analyses Given the theoretical evidence that consumers' information processing capacity is limited and that they generally use only three or four more general dimensions in judging products (Steenkamp and Van Trijp, 1996), a principal component analysis (PCA) was performed on the sensory data to condense the evaluated response into simple and few variables. The principal components (PC) show the directions of greatest variance in the data. Additionally, in order to form orthogonal combinations of these principal components, rotated components were obtained by the method of varimax rotation, which is the same method traditionally used in factor analysis. These analyses were carried out using commercially available software called JMP 5 (SAS Institute Inc.).

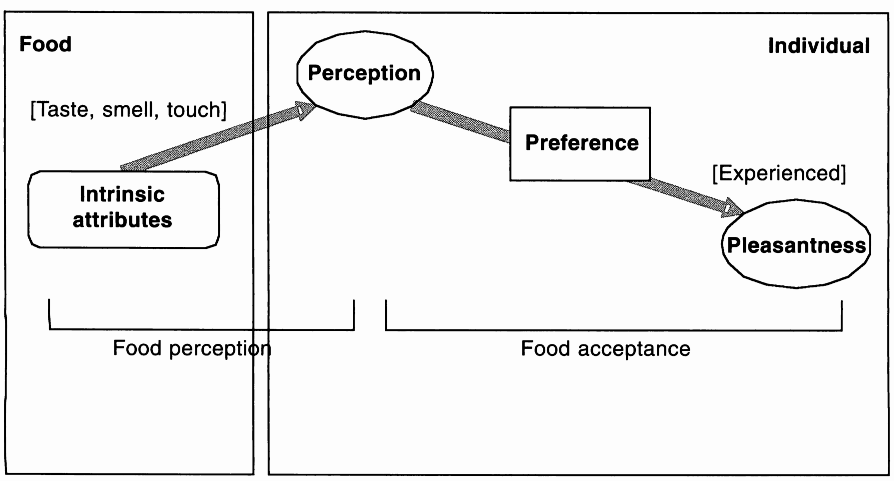

Fig. 3. Simplified Food Kansei Model dealing with intrinsic attributes.

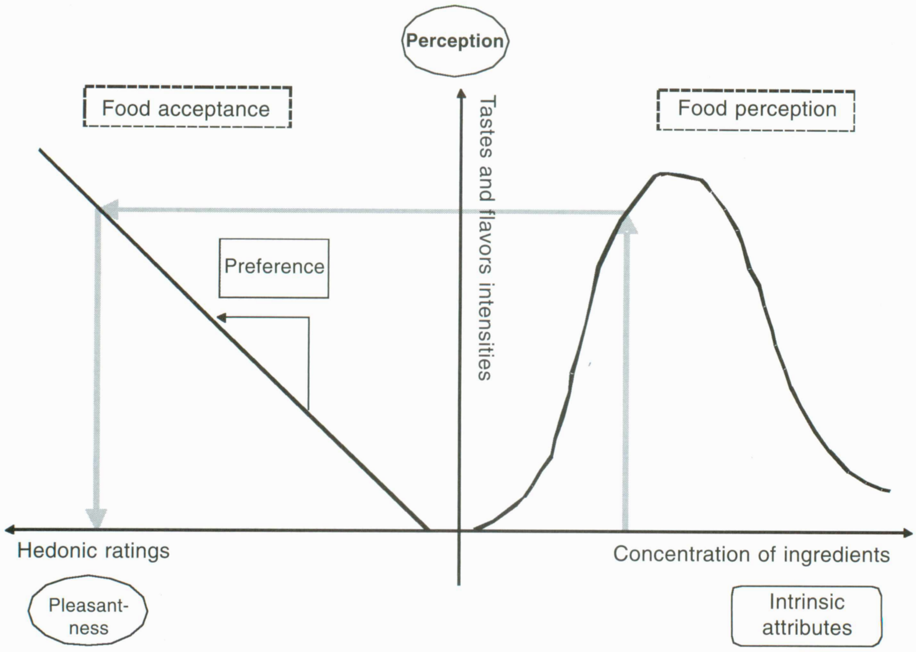

Fig. 4. Causal relationship among intrinsic attributes, perception and pleasantness in quantity.

Using the rotated PC scores and the hedonic ratings data, the relationships described in the preceding sections as food acceptance have been analyzed by means of MRA for each consumer group. The hedonic ratings were used as the dependent variables and rotated PC scores used as the independent variables. One of the assumptions of multiple regression is that there is no linear relationship between any of the independent variables in the model (Accebron and Dopico, 2000). If such a relationship does exist, variables are co-linear, which sometimes leads to instability of estimated coefficients. Since the rotated PC scores are orthogonal with each other, then the correlations among independent variables do not exist in this case. The regression coefficients were used to investigate preference for the perceived quality.

An ANN modeling was carried out to elucidate food perception on the dataset obtained by instrumental and sensory analysis, using JMP software package. This network has the architecture of a characteristic multilayer perception (MLP) network. This consists of one hidden layer between the input and output layers (Fig. 5), modules of which use an error back propagation algorithm for weight adjustment, determining the contribution of each weight to prediction error. The weights are then adjusted by a fixed proportion of that contribution using the gradient descent method. To avoid finding local minima, several runs were carried out with different sets of initial weights.

In ANN modeling, the whole dataset was used in calibration for the shortage of evaluated samples to be used for cross validation. Number of nodes in input layer of each network was set to the number of extracted components by GC/O and HPLC. In the output layer, the number of nodes was same as the number of optimal PC factors. For other network parameters, an over fit penalty was set to avoid the erroneous solution by holding down the weight estimates. The root mean square error (RMSE) and coefficients of determination were used to evaluate prediction performance of the models.

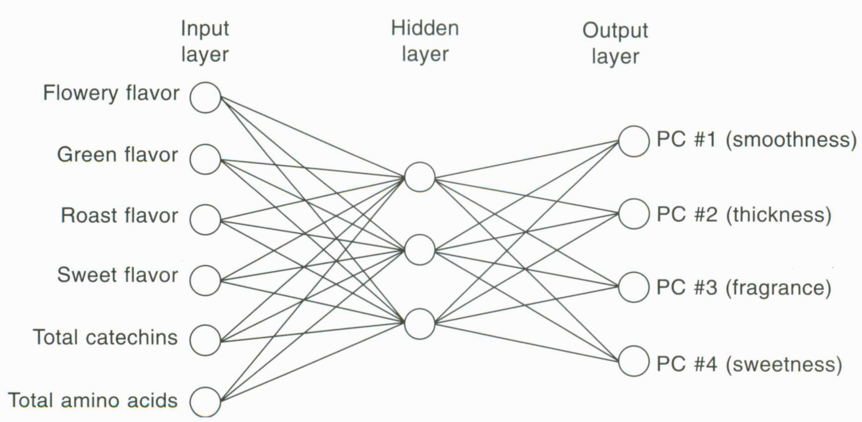

Fig. 5. An example of 3-layer artificial neural network (ANN).

Estimations of perceived quality The estimations of perceived quality were performed to determine the most preferable concentration ratio of components using the ANN model. Geometrical average of PC scores weighted with their coefficients to hedonic ratings was calculated repeatedly in order to explore which combination of components gives the perceived quality preferred by each consumer group, leading to the greatest pleasantness for them. It determines the most appropriate design of intrinsic attributes and perception within the limits of evaluated samples for consumer groups having different social backgrounds.

Results and Discussion

Sensory analysis Using the normalized sensory data for each attribute, the PCA revealed four principal components which accounted for 68.1% of the variance in the dataset, where PC #1, PC #2, PC #3 and PC #4 accounted for 34.4, 22.1, 5.9 and 5.5% of the variance, respectively, while PC #5 accounted for 4.0%. Table 1 shows the configuration matrix of high factor loadings for sensory attributes, obtained by applying the method of varimax rotation. The first rotated component showed factor loadings on the items of "appropriate to the food", "good to gulp down", "well-balanced" and "refreshing". Thus the first perceptual dimension was identified as *smoothness* which accounts for 19.7% of the variation in the data. Similarly, the following basic perceptual factors were uncovered: *thickness* (authentic, leaves a clear impression, aftertaste, intensely flavored and distinctive), *fragrance* (roasted, green and floral fragrance), and *sweetness* (sweet and soft). The following factors accounted for 23.8, 14.1 and 10.4% of the variance, respectively.

Figure 6 and 7 show average rotated PC scores of the four factors for each sample in the sensory space, the output data for the ANN. In these figures, the taste- and flavor-controlled samples were indicated with characters of T and F, respectively. The Standard sample, Std., was positioned almost in the center of the perceptual space as expected. The perceived tastes and flavors of the samples ranged widely in the sensory space with the central focus on the standard sample.

Food acceptance The results of MRA obtained for each 320 observations of female students, female and male office workers are shown in Table 2. The values of β are the standardized regression coefficients, showing the consumer preference. As has been explained, the pleasantness is based on the perception. It became clear that all four factors had significant influence on pleasantness in every consumer group. The results confirmed that smoothness (β = 0.696, $p < 0.001$) has a positive effect on pleasantness by female students, indicating that it is used as a quality cue by female students to infer pleasantness. It was also demonstrated that sweetness (β = 0.382, $p < 0.001$) had a positive effect on pleasantness for female students, however, it weakly affected pleasantness for male office workers (β = 0.103, $p < 0.05$). For female students, thickness (β = 0.218, $p < 0.001$) and fragrance (β = 0.182, $p <$ 0.001) were indicated as be less preferred, compared with the relative importance of thickness (β = 0.299, $p < 0.001$) and fragrance (β = 0.308, $p < 0.001$) for male office workers.

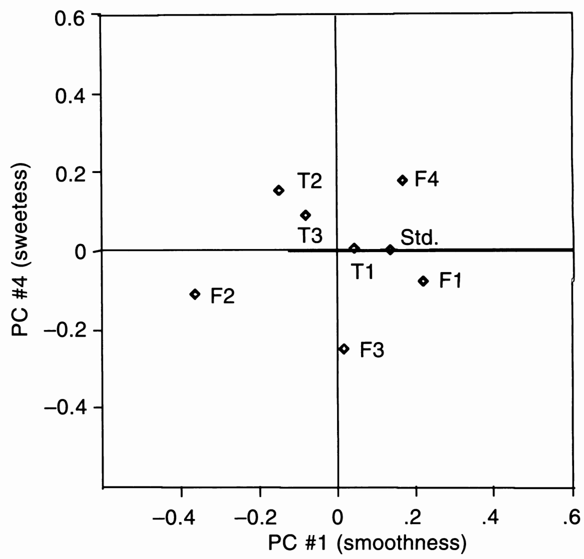

Fig. 6. PCA Plot of first and second factors in sensory space of sensory evaluation data from eight tea samples. T1 to T3, taste-controlled; F1 to F4, flavor-controlled; Std., standard sample.

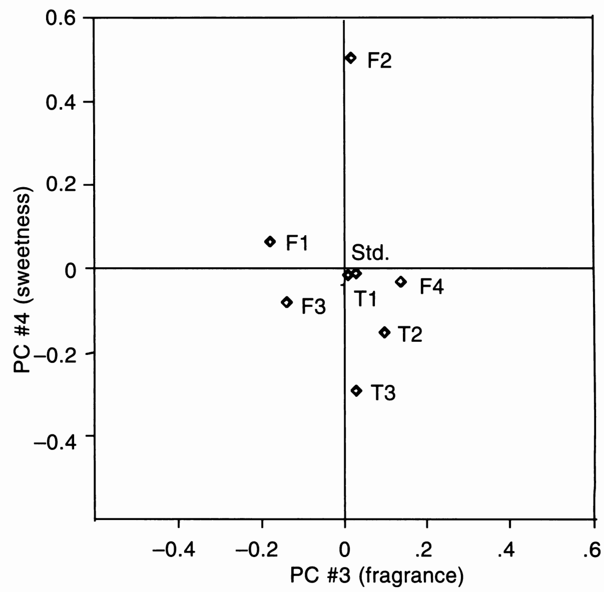

Fig. 7. PCA Plot of third and fourth factors in sensory space of sensory evaluation data from eight tea samples. T1 to T3, taste-controlled; F1 to F4, flavor-controlled; Std., standard sample.

The overall accuracy of the adjustment was quite good, and a significant part of the evaluation of pleasantness was explained by these factors. Results showed a need to maintain smoothness and sweetness levels for female students due to their positive sensory implications in the processed product. For male office workers, thickness and fragrance were recognized to be more important than sweetness. The preference of female office workers was found to exist between female students and male office workers.

Table 2. Regression of hedonic ratings on perceived quality.

Variable	Female students (n = 320)		Female office workers (n = 320)		Male office workers (n = 320)	
	β	T	β	T	β	T
(Constant)	4.726	106.03***	4.809	122.10***	4.797	119.90***
PC #1 (smoothness)	0.696	16.19***	0.686	17.49***	0.556	12.58***
PC #2 (thickness)	0.218	4.65***	0.306	8.06***	0.299	7.21***
PC #3 (fragrance)	0.182	4.05***	0.249	6.26***	0.308	7.63***
PC #4 (sweetness)	0.382	9.67***	0.239	6.06***	0.103	2.10*
Multiple R	0.715		0.777		0.731	
R Squared	0.511		0.604		0.534	
R Squared (adjusted)	0.505		0.599		0.528	
RMSE	0.794		0.699		0.712	

β = standardized regression coefficients; T = T value. $^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Instrumental analysis Table 3 and 4 document the results of the HPLC measurements per sample. Table 3 shows the concentration of caffeine and catechins. Taste-controlled samples T2 and T3 exhibited significantly higher levels of catechins. Since the concentrations of catechins were highly correlated with each other, the total catechins was set to the input of the ANN as representative of catechins. The concentration of caffeine showing small difference among samples was neglected to reduce the number of variables to correlate with the perceptual factors. Table 4 shows the concentration of amino acids, representing the taste description of umami, sweet or bitter. The taste-controlled sample T1 showed notably high levels of amino acids, especially in the concentration of glutamic acid. For

Table 3. Concentration plot of non-volatile compounds for the eight samples. T1 to T3, taste-controlled; F1 to F4, flavor-controlled; *Std.*, standard sample.

Caffeine and catechins	Means	Standard deviations	Means per samples							
			Std.	T1	T2	T3	F1	F2	F3	F4
Caffeine	150.1	5.7	155.6	155.4	155.4	155.3	144.6	145.4	144.2	144.7
Gallocatechin	133.7	6.2	137.4	136.2	142.7	140.7	127.8	128.9	127.6	128.6
Epigallocatechin	70.4	4.2	65.5	68.6	76.4	74.9	70.3	71.4	71.4	64.5
Catechin	31.8	3.0	32.1	32.3	37.3	35.2	29.2	29.2	29.0	30.4
Epicatechin	15.3	1.1	15.0	14.9	17.4	15.9	15.1	15.2	15.1	13.6
Epigallocatechin gallate	85.3	7.2	84.6	84.7	100.1	91.8	80.5	81.9	80.7	78.2
Gallocatechin gallate	97.5	9.1	98.0	97.2	115.4	106.0	90.7	92.3	90.1	90.3
Epicatechin gallate	17.1	2.4	16.5	16.2	22.2	19.1	15.8	16.2	15.9	15.0
Catechin gallate	14.9	2.6	14.7	14.6	20.0	17.4	12.9	13.0	12.7	13.6
Total catechins	466.0	33.8	463.8	464.8	531.5	501.1	442.4	448.1	442.5	434.2

Table 4. Concentration plot of non-volatile compounds for the eight samples. T1 to T3, taste-controlled; F1 to F4, flavor-controlled; Std., standard sample.

Amino acids	Taste descriptions	Means	Standard deviations	Means per samples							
				Std.	T1	T2	T3	F1	F2	F3	F4
Asp	Umami	120.7	7.4	128.4	126.9	123.7	118.7	129.4	115.0	111.5	111.9
Glu	Umami	146.3	66.4	122.0	293.9	116.7	194.6	123.1	108.7	105.9	105.7
Theanin	Sweet	298.1	18.0	319.1	310.0	303.5	290.3	321.5	287.2	279.3	274.1
Ala	Sweet	25.6	1.9	27.4	26.6	26.1	24.9	28.6	24.2	23.3	23.3
Ser	Sweet	50.8	3.6	54.4	52.5	52.4	49.5	56.1	48.1	46.6	46.8
Met	Bitter	51.5	5.6	59.4	55.6	53.6	53.8	51.2	44.3	42.8	51.2
Gly	Sweet	6.3	0.7	6.5	6.2	6.4	6.3	7.8	5.6	5.8	5.9
Thr	Sweet	14.5	1.4	15.8	15.0	14.9	14.2	16.9	13.5	12.9	13.0
Lys	Sweet	6.4	0.6	6.8	6.4	6.5	6.4	7.5	6.0	5.8	5.8
Pro	Sweet	14.3	1.3	15.6	15.3	15.0	14.4	15.8	13.1	12.4	13.0
Val	Bitter	8.2	0.8	8.9	8.5	8.3	7.9	9.5	7.6	7.3	7.5
Arg	Bitter	29.3	3.1	33.4	28.8	28.3	30.3	33.8	25.8	25.3	28.4
His	Bitter	18.6	2.2	17.7	18.2	18.2	16.5	23.1	19.3	19.6	15.9
Iie	Bitter	6.4	0.7	7.1	6.5	6.2	6.0	7.7	5.8	5.9	5.6
Phe	Bitter	7.6	0.6	8.2	7.9	7.7	7.4	8.6	7.1	7.0	6.8
Leu	Bitter	5.3	0.6	5.8	5.4	5.3	5.1	6.5	4.8	4.7	4.7
Total amino acids		809.8	89.7	836.5	983.7	792.8	846.3	847.1	736.1	716.1	719.6

ease of understanding the result, the total amount of amino acids was used for the input of ANN.

Table 5 shows the concentrations of volatile components in flavor-controlled samples measured by GC, representing the odor descriptions by GC-O. Among the 20 GC peaks, 12 were recognized by sniffing in the GC-O analysis. Total concentrations of similar odor descriptions, "flowery", "roasted", "green" and "sweet", were determined (Table 5). Flavored sample F2 indicated the highest flowery and green odors, while sample F1 showed the highest concentration of roasted and sweet odors.

Food perception As shown in Fig. 5, the ANN modeling was carried out to correlate the four factors of perception with the concentrations of total catechins, total amino acids, and the flowery, roasted, green and sweet odors. Table 6 shows the summary of estimation by ANN in terms of RMSE and the coefficients of determination or R squared for each sensory factor, which indicated sufficient accuracy in calibration considering the dependent variables evaluated by human sensory analysis; three of four sensory factors indicated R squared over 0.90.

Figures 8 and 9 show the preferable combination of components and intensities of sensory factors, respectively, estimated to maximize pleasantness by ANN modeling for three consumer groups having different social background. In Fig. 8 the preferable combinations of components were shown in the concentration ratio of components to standard sample. For female students, relatively high levels of roasted and sweet flavor components were estimated as a preferable combination, which was assumed to lead to higher smoothness and lower thickness and fragrance as shown in Fig. 9, according to the causal relationship formulated in the Food Kansei Model. Similarly, Fig. 8 shows that female and male office workers preferred the samples containing greater amount of flowery flavor and total amino acid, which offer higher thickness and fragrance through food perception. Female office workers preferred sweetness rather than thickness compared with male office workers (Fig. 9).

Conclusions

As a consumer-based approach to the improvement of quality of food products, the Food Kansei Model has been developed to formulate the causal relationships between the analyzed characteristics and perceived quality of food products. The model is applied to understand how consumers form pleasantness about green tea perception and how this issue can help us to address optimum levels of components. The combination of PCA, ANN and MRA is proposed as a technique that is particularly suited for estimating the relationships specified in the conceptual model in practical applications.

The empirical application for green tea beverages illustrates the usefulness of the model and methodology. The

Table 5. Concentration plot of volatile compounds of four flavor-controlled samples. F1 to F4, flavor-controlled samples.

Volatile compounds	Odor descriptions	Means	Standard deviations	Means per samples			
				F1	F2	F3	F4
1-Penten-3-ol		0.16	0.03	0.14	0.21	0.14	0.16
cis-2-Penten-1-ol		0.25	0.23	0.14	0.34	0.53	0.00
2,6-Dimethylpyrazine	roast	0.36	0.12	0.52	0.26	0.29	0.35
2-Ethylpyrazine		1.55	0.69	1.32	2.56	1.00	1.33
cis-3-Hexenol	green	0.54	0.12	0.61	0.65	0.38	0.53
Furfural	roast	0.70	0.32	1.14	0.49	0.44	0.72
Linalool	flowery	3.14	4.09	0.95	9.27	1.30	1.05
Hotrienol	green	0.81	0.79	0.47	1.99	0.40	0.37
a-Terpineol		0.48	0.28	0.28	0.86	0.52	0.26
3-Methylnonane-2,4-dione	green	0.03	0.02	0.02	0.05	0.04	0.01
b-Damacenone	sweety	0.02	0.01	0.02	0.04	0.02	0.02
a-Ionone	green	0.34	0.19	0.22	0.53	0.46	0.14
Guaiacol	flowery	0.26	0.07	0.33	0.27	0.26	0.17
Benzyl alcohol		0.75	0.41	1.23	0.38	0.44	0.96
Phenethyl alcohol		0.96	1.42	0.29	3.08	0.22	0.24
b-Ionone	flowery	0.36	0.24	0.24	0.72	0.26	0.21
cis-Jasmone	green	0.97	1.30	0.24	2.92	0.53	0.21
Furaneol	sweety	0.12	0.06	0.19	0.12	0.12	0.05
p-Vinylguaiacol		0.72	0.17	0.74	0.81	0.85	0.48
Total (flowery)		3.75	4.34	1.51	10.25	1.82	1.43
Total (roast)		1.05	0.44	1.66	0.75	0.73	1.07
Total (green)		2.69	2.31	1.56	6.14	1.81	1.26
Total (sweet)		0.14	0.06	0.21	0.15	0.13	0.07

Table 6. Summary of RMSE and the coefficients of determination.

	Dependent variables			
	PC #1 (smoothness)	PC #2 (thickness)	PC #3 (fragrance)	PC #4 (sweetness)
SSE	0.0080	0.0243	0.0064	0.0340
RMSE	0.0884	0.2030	0.1378	0.1501
R Squared	0.9687	0.8351	0.9241	0.9099

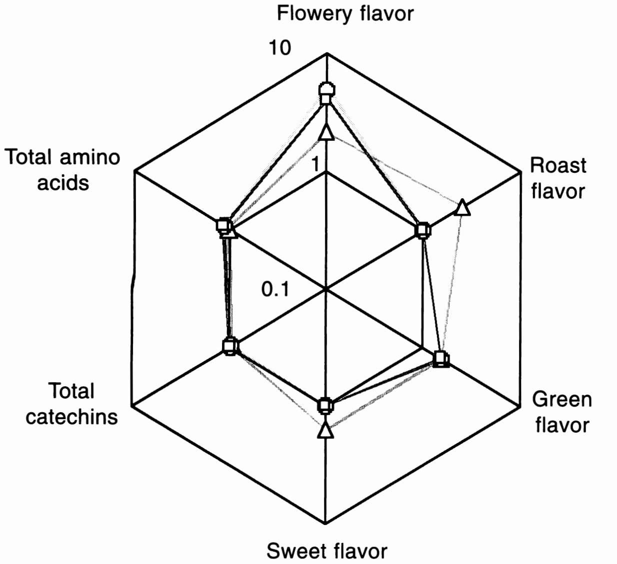

Fig. 8. Preferable concentration profiles of ingredients for female students (△), female office workers (○) and male office workers (□).

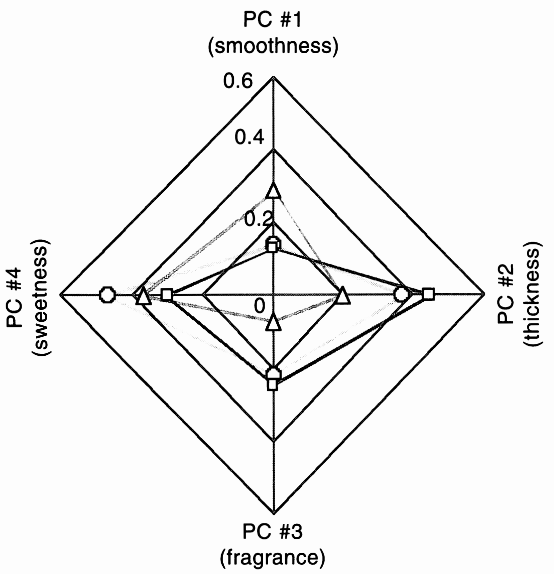

Fig. 9. Preferable sensory profiles for female students (△), female office workers (○) and male office workers (□).

results showed the preferable intensities of tastes and flavors and concentration ratio of components estimated for three consumer groups belonging to different social categories. In the present case, flowery, roasted and sweet flavor and total amino acids were identified as key components that could be modified to suit the preferences of different consumer groups by the perception of smoothness, thickness, fragrance and sweetness.

Future research might test the model on other food products. Further, the interrelations among perceptual and cognitive deserve attention. The quantitative evaluation of extrinsic attributes and cognizable images of food products would be essential to incorporate the influence of cognition into the model. The application of the Bayesian network and the other graphical modeling methods is expected to help formulation of the integrated structure of food perception and acceptance. It is likely that the application of this model is not restricted to tea or beverage in general. Finally, the Food Kansei Model may be extended to include the effects of extrinsic attributes such as advertising and brand name as well as other elements of the marketing mix.

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