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RESEARCH NOTE

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Discriminant Analysis of Marketed Liquor by a Multi-channel Taste Evaluation System

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Abstract As a device for taste sensation, an 8-channel taste evaluation system was prepared and applied for discriminant analysis of marketed liquor. The biomimetic polymer membranes for the system were prepared through a casting procedure by employing polyvinyl chloride, bis (2-ethylhexyl)sebacate as plasticizer and electroactive materials such as valinomycin in the ratio of 33:66:1, and were separately attached over the sensitive area of ion-selective electrodes to construct the corresponding taste sensor array. The sensor array in conjunction with a double junction reference electrode was connected to a high-input impedance amplifier and the amplified sensor signals were interfaced to a personal computer via an A/D converter. When the signal data from the sensor array for 3 groups of marketed liquor like *Maesilju*, *Soju* and beer were analyzed by principal component analysis after normalization, it was observed that the 1st, 2nd and 3rd principal component were responsible for most of the total data variance, and the analyzed liquor samples were discriminated well in 2 dimensional principal component planes composed of the 1st-2nd and the 1st-3rd principal component.

Keywords: polymer membranes, taste sensor array, marketed liquor

Introduction

The substances which elicit basal taste, including sweet, salty, sour and bitter taste, are reportedly known to be perceived by the biological membrane of gustatory cells in taste buds present in the tongue. The information about the taste of a substance is transduced into an electric signal, which is transmitted along the nerve fiber to the brain to induce taste sensation (1, 2). Taste sensors, which are collectively known as electronic tongue, are devices which mimic the transduction mechanism of human gustatory system. Various polymeric membranes which had lipids of biological membranes (3-5), ionophores and ion-exchangers (6, 7) as the electroactive materials have been prepared and attached over the sensitive area of an electrode body which was in a solid-state or ion-sensitive form to produce a sensor array possessing non-specific or group-specific binding property to substances of taste. The signals from the taste sensor array were amplified and then interfaced to a personal computer in the internal circuit of the corresponding taste sensor system. The amplified taste sensor signals are normally used for pattern analysis, analyses on taste sensation and taste interaction between taste substances like synergistic and suppression effect, and taste evaluation of various food samples by statistical methods like principal component analysis (PCA) and artificial neural network (ANN) like the case of electronic nose (8, 9). Until now, the taste sensors having lipid materials, ionophores and ion-exchangers have been utilized for the qualitative and quantitative taste analysis of various foodstuffs like coffee, mineral water, sake and beverage via the methods described above (1, 10-13).

In our present study, an 8-channel taste evaluation system which exhibited group-specific binding properties to individual food components was prepared and utilized for the analysis of liquor taste. The signals from the sensor array for various domestically marketed liquor were evaluated by a discriminant analysis exploiting PCA for the possible grouping of the tested liquors.

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Materials and Methods

Preparation of polymer membranes Each polymer membrane for the 8-channel taste sensor array was prepared by a casting procedure by employing polyvinyl chloride as the polymer matrix of the membrane, Bis(2-ethylhexyl) sebacate as the plasticizer and an electroactive material in the volume ratio of 33:66:1 (7). The membrane thus prepared was stored in a glass bottle and a punched small part of the membrane (5 mm diameter) was installed over the sensitive area of a Phillips electrode body (model IS-561, Switzerland). Amongst the electroactive materials used, cation-selective materials were 4-tert-butylcalix[4] arene tetraacetic acid tetraethyl ester (calix[4]arene), monensin decyl ester (MDE), valinomycin, nonactin and tridodecylamine (TDDA). Whereas, anion-selective materials were tridodecylmethylammonium chloride (TDMA), tri-*n*-octylmethyl-ammonium chloride (TOMA) and *meso*-tetra-phenylporphyrin manganese(III) chloride (Mn-porphyrin).

Construction of taste evaluation system System construction was carried out by following a previously reported procedure (7). The sensor array, and a double junction Ag/AgCl reference electrode (Orion Research Inc., USA) which was filled with outer and inner filling solution (from the same company) for the reference electrode, were connected to a 16-channel high input impedance amplifier which had a buffer circuit with the input impedance and current of 1.5 TΩ and 5 pA, respectively. The high input impedance amplifier thus prepared was connected to a multi-channel A/D converter (National Instruments Co., USA) and an A/D converter control software was developed by using a basal software of the same company. The sensor signals which were acquired by a personal computer through the high input impedance amplifier and A/D converter had low current values in mV level and the noise was inevitably present. To improve signal to noise ratio (S/N ratio), an averaging method for digital filtering was used.

Sample analysis Three liquor groups comprising of *Maesilju*, *Soju* and beer were purchased from local markets at Bundang area of Songnam (Korea). One hundred milliliters of each sample were diluted to 30% solution to prepare an analytical sample. The membrane potentials of the polymer membranes constituting the sensor array were measured with the sample, and the actual response potentials of the sample were regarded as the membrane potential of the polymer membranes minus the potential obtained in the basal solution mimicking human salivary fluid comprising of 50 mM Tris buffer (pH 7.0) containing 5 mM NaCl, 0.5 mM citric acid and 0.1 mM KCl (7, 13).

Test of significance for the responses of the taste sensor array The potential responses of the individual taste sensors constituting the taste sensor array for 3 liquor groups were evaluated for their significance by analysis of variance (ANOVA) and Student-Newman-Keuls test in 95% level of significance.

Principal component analysis for the responses of the taste sensor array Because of the innate non-specificity of taste sensor responses, there was plausible occurrence of multi-colinearity in the sensor signals. Hence, an algorithm was designed to convert the sensor signals from 8 channels into principal components by using a statistical software of Mathwork Co. (USA). In PCA, the inner product value to the eigen vector having the highest eigen value is defined as the 1st PC. In our study, the 1st and 2nd PC showed similar data variance in the sensor signals amounting to 40.91 and 35.53%, respectively. The value of the 3rd PC which contributed to 15.80% of the total data variance was also calculated from the signal data gathered from the analytical samples of the above liquor.

Results and Discussion

The S/N ratios for the response signals from the taste sensor array were measured according to the number of averaging points. For example, the standard deviation for data average and the S/N ratio for the valinomycin membrane electrode were 0.81 mV and 55.47, respectively when 1000 point average was done for the consecutive 1000 Hz data measured. When the sensor signals of all channels were measured for one single membrane electrode with an electrode simulator, the standard deviation below 0.24 mV was obtained, which indicated a conspicuously high precision of the system (7, 13).

One of the promising field of application for a taste evaluation system may be discriminant analysis of liquid foods and their grouping according to specific taste property (1, 14). In our present study, for a discriminant analysis of marketed liquor, the individual taste sensors of the sensor array attached with the cation- and anion-selective polymer membranes were used for measuring the potential responses of 19 different samples from 3 liquor groups of *Maesilju*, *Soju* and beer (Fig. 1). From their brand labeling, it was found that the alcohol contents in the samples of *Maesilju*, *Soju* and beer were in the range of 13-14, 21-30 and 4.1-4.5%, respectively. In the *Soju* samples, some other constituents like amino acids were

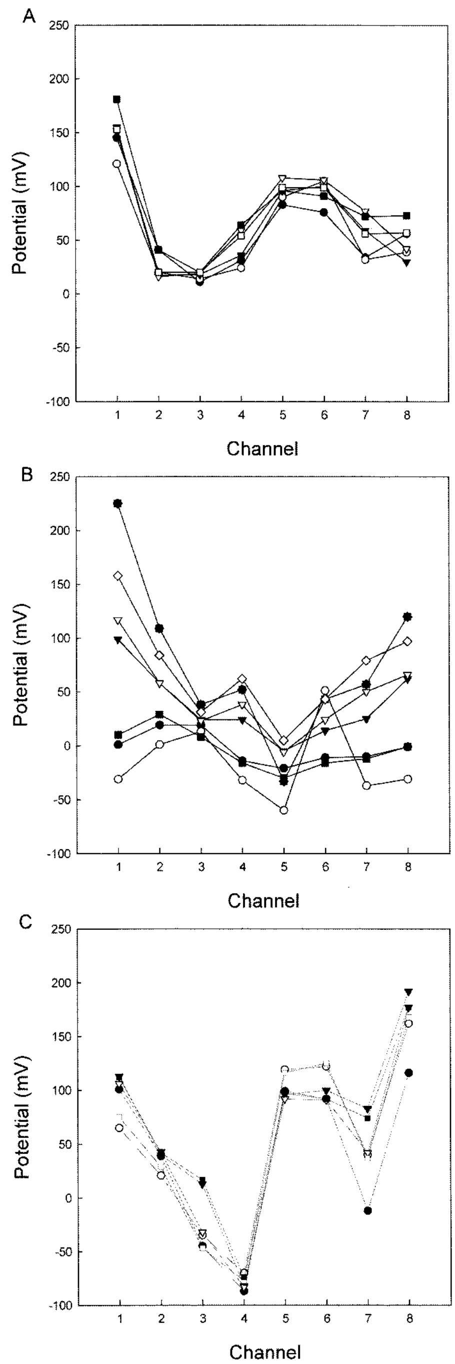

Fig. 1. Responses of the individual taste sensors in the sensor array to various groups of liquor. A; *Maesilju*, B; *Soju*, C; beer. The electroactive materials in the polymer membranes of channel 1, 2, 3, 4, 5, 6, 7 and 8 were Mn-porphyrin, TDMA, TOMA, calix [4]arene, valinomycin, nonactin, MDE and TDDA, respectively. All symbols in a specific panel represent different samples belonging to the corresponding liquor group.

Table 1. Responses of the taste sensors in the sensor array to various groups of liquor

Electroactive material	Response (mV)		
	Maesilju	*Soju*	Beer
Mn-porphyrin	151.17^{a}	82.31^{a}	95.33^{a}
TDMA	25.83^{a}	51.14^{a}	35.67^{a}
TOMA	17.00^{a}	22.29^{a}	-21.50^{b}
Calix[4]arene	44.67^{a}	16.29^{a}	-78.83^{b}
Valinomycin	95.33^{a}	-21.43^{b}	103.17^{a}
Nonactin	96.17^{a}	21.14^{b}	103.67^{a}
MDE	55.00^{a}	21.71^{a}	44.00^{a}
TDDA	49.50^{b}	44.57^{b}	165.33^{a}

^{a,b}Means within the same row with different superscripts are significantly different at $p<0.05$ by ANOVA.

included. Whereas, in the *Maesilju* samples various *Maesil* extracts, starch sugar and other constituents were also present. From our previous report (7), it is well established that the taste sensors exhibit characteristic Nerstian or non-Nernstian concentration-dependency in the range of 51.9-76.7 mV/decade for artificial taste substances. As shown in Fig. 1, the differences in potential response among the samples from *Maesilju* and beer were smaller than that from *Soju* in most of the channels of the sensor array. This phenomenon indicated the diversity in taste quality of the marketed *Soju* samples and seemed to be attributable to the fact that the *Soju* samples had a broad range of alcohol content together with the presence of other constituents like amino acids.

The significance in the potential responses of the taste sensor array for the samples from each liquor group was evaluated as 95% level of significance (Table 1). For *Maesilju*, the mean values in potential response were positive at all polymer membrane electrodes in the sensor array. Whereas, the valinomycin membrane electrode for *Soju*, and the TOMA and calix[4]arene membrane electrode for beer showed negative mean potential responses. The different directions in potential response as stated above seemed to represent an unique response characteristics of the polymer membrane electrodes against a specific liquor sample (7). On the other hand, the differences in mean membrane potential amongst the polymer membrane electrodes for the individual liquor groups were in an increasing order of 103.74, 134.07 and 244.16 mV in the case of *Soju*, *Maesilju* and beer, respectively. When the responses of the individual polymer membrane electrodes were compared for their significance, the potential responses of 5 polymer membrane electrodes containing TOMA, calix[4]arene, valinomycin, nonactin and TDDA as the electroactive materials were significantly different between *Soju* and beer. In the liquor groups of *Maesilju*-beer and *Maesilju*-*Soju*, 3 electrodes attached with TOMA, calix[4]arene and TDDA polymer membrane, and 2 electrodes containing valinomycin and nonactin as the electroactive materials showed significant differences, respectively. Compared to our previous work on the grouping of marketed beverage, the potential responses of the taste sensor array of this study showed a lesser degree of significant difference in mean potential response which seemed to be closely

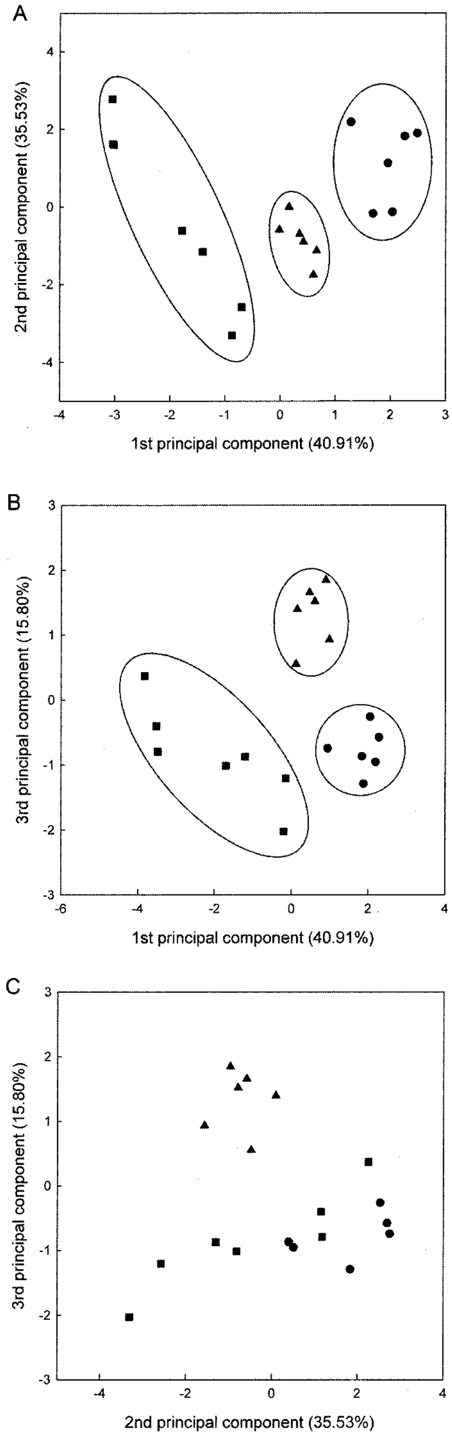

Fig. 2. Two dimensional principal component analysis for the signal data on 3 liquor groups of *Maesilju* (▲), *Soju* (■) and beer (●).

related with the grouping of marketed liquor (13). This fact also required a new development of the electroactive materials for the polymer membranes of the sensor array to discriminate liquor groups more than 3 in the nearest future (13).

For 3 liquor groups comprising of *Maesilju*, *Soju* and beer, PCA was performed in 2 dimensional planes composed of the individual pair of the 1st, 2nd and 3rd PC which contributed to most of the total data variance. As shown in Fig. 2, all liquor groups were discriminated well in the planes of the 1st and 2nd PC, and the 1st and 3rd PC. However, in the 2 dimensional plane of the 2nd and 3rd PC, no clear discrimination was possible among the above 3 liquor groups.

It was possible to classify 3 marketed liquor groups comprising *Maesilju*, *Soju* and beer in 2 dimensional planes by PCA from the potential responses of the taste sensor array of the current taste evaluation system. In the future, more liquor groups such as whiskey, brandy and wine, and other traditional Korean liquor including *Macgulri* will be classified by statistical analysis and/or ANN from the potential responses of the taste sensor array upon further development of newer electroactive materials (15).

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References

1. Toko K. Electronic tongue. Biosens. Bioelectron. 13: 701-709 (1998)
2. Iiyama S, Miyazaki Y, Hayashi K, Toko K, Yamafuji K, Ikezaki H, Sato K. Highly sensitive detection of taste substances using monolayer lipid membrane. Sens. Mater. 4: 21-27 (1992)
3. Hayashi K, Matsuki Y, Toko K, Murata T, Yamafuji KE, Yamafuji KA. Sensing of "umami" taste and synergistic effects with synthetic lipid membranes. Sens. Mater. 1: 321-334 (1989)
4. Hayashi K, Yamanaka M, Toko K, Yamafuji K. Multichannel taste sensor using lipid membranes. Sens. Actuat. B: Chemical 2: 205-213 (1990)
5. Toko K, Matsuno T, Yamafuji K, Hayashi K, Ikezaki H, Sato K, Toukubo R, Kawarai S. Multichannel taste sensor using electric potential changes in lipid membranes. Biosens. Bioelectron. 9: 359-364 (1994)
6. Kurihara K, Yoshi K, Kashiwayanagi M. Tranduction mechanism in chemoreception. Comp. Biochem. Physiol. A 85: 1-22 (1986)
7. Kim N, Park K-R, Park I-S, Cho Y-J, Bae YM. Application of a taste evaluation system to the monitoring of *Kimchi* fermentation. Biosens. Bioelectron. 20: 2283-2291 (2005)
8. Youn AR, Noh BS. Prediction of the freshness for soybean curd by the electronic nose in the fluctuating temperature condition. Food Sci. Biotechnol. 14: 437-439 (2005)
9. Park EY, Noh, BS, Ko SH. Prediction of shelf life for soybean curd by the electronic nose and artificial neural network system. Food Sci. Biotechnol. 11: 245-251 (2002)
10. Arikawa Y, Toko K, Ikezaki H, Shinha Y, Ito T, Oguri I, Baba S. Analysis of sake taste using multielectrode taste sensor. Sens. Mater. 7: 261-270 (1995)
11. Fukunaga T, Toko K, Mori S, Nakabayashi Y, Kanda M. Quantification of taste of coffee using sensor with global selectivity. Sens. Mater. 8: 47-56 (1996)
12. Iiyama S, Yahiro M, Toko K. Quantitative sensing of mineral water with multichannel taste sensor. Sens. Mater. 7: 191-201 (1995)
13. Park K-R, Bae YM, Park I-S, Cho Y-J, Kim N. Discriminant analysis of marketed beverages using multi-channel taste evaluation system. J. Korean Soc. Appl. Biol. Chem. 47: 300-306 (2004)
14. Imamura T, Toko K, Yanagisawa S, Kume T. Monitoring of fermentation process of *miso* (soybean paste) using multi-channel taste sensor. Sens. Actuat. B: Chemical 37: 179-185 (1996)
15. Cho Y-J, Park I-S, Kim N. Taste response of electrodes coated with polymeric lipid membrane. J. Kor. Soc. Agric. Machin. 27: 249-258 (2002)