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Statistical Analysis of Effective Components for Aroma of *Sigumjang*

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Abstract The relationship between *Sigumjang* gas chromatographic patterns precisely analyzed with capillary column and ranked order in sensory analysis was investigated by stepwise multiple regression analysis. Highly predictable multiple regression models were obtained in the analysis. Ninety percent of the *Sigumjang* aroma was explained by the regression models at step 15 in four transformation except for absolute value transformed with root square and relative value transformed with logarithm. The aroma of *Sigumjang* was most affected by 2,3-dimethylpyrazine at absolute value and absolute value transformed with logarithm and by 2-furancarboxaldehyde in other transformation. The quality of *sigumjang* was highly affected by β-phallendrenal, methylpyrazine, tetramethylpyrazine, 5-methyl-2-furancarboxaldehyde, unknown 2, octanoic acid, 4-ethylphenol, methyl 10,13-octadecanoate and ethyl linoleate.

Key words: *Sigumjang*, stepwise multiple regression analysis, aroma

Introduction

The nutritional benefit of dietary fiber from different sources has been the subject of numerous research studies (1-3). Many kinds of conventional and non-conventional sources of fiber are available as commercial ingredients such as wheat, corn and oats. Until now barley bran has not been used extensively because comparatively small quantities of barley were milled and pearled to provide by-product bran.

Lupton *et al.* (4) found out gastrointestinal transit time accelerating effect of barley bran. Lupton *et al.* (5) and Newman *et al.* (6) investigated cholesterol-lowering properties of barley bran and concluded that barley bran flour or barley oil enhances the cholesterol-lowering effect of the NCEP step 1 diet in individuals with hypercholesterolemia. Chaudhary *et al.* (7) reported that barley bran flour outperformed other fiber ingredients in producing a bread with substantially increased dietary fiber, highest loaf volume, and highest quality score of fiber-enriched bread in the result of significant differences in both composition and quality of bread by 15% using individual fiber ingredient. However, wide use as raw material in food was not accomplished yet.

Sigumjang made with barley bran flour was traditional Northeastern Asian food which was consumed as side dishes served to go with rice in winter (8). It is a common knowledge that ferment speed of *Sigumjang* was fastest among the fermented food and has gastrointestinal transit time accelerating effect, diverticulosis control effect and colonic cancer control effect (9). Despite of excellent functionality of *Sigumjang*, little study was conducted due to lack of raw material.

Concerning quality of *Sigumjang*, Choi (9) studied on brewing method. Investigating microorganisms and chemical composition of 10 commercially distributed *Sigumjangs*. Chung *et al.* (8) analyzed chemical composition of 12 commercially distributed *Sigumjang mejus* according to their size. Choi *et al.* (10) made a comparative study on volatile components between barley bran and *Sigumjang meju* come in to the market in Korea. Choi *et al.* (11) investigated changes of volatile components according to fermentation of *Sigumjang*. However, more studies have to be advanced to grasp characteristics of the peculiar fermented food, *Sigumjang*.

To standardize quality of *Sigumjang*, the preferential subject was to find out the component which contribute to taste and aroma. However, the flavor of *Sigumjang* is very complicated because it is derived from integrated effects of many compounds produced by chemical and enzymatic reactions or bacterial effects. Choi *et al.* (12) and Choi *et al.* (13) reported effective components on the taste of *Sigumjang* using multiple regression analysis and principal component analysis. However, the investigation on effective components on the aroma of *Sigumjang* was not reported.

As a part of standardization and optimization of *Sigumjang* quality, we have found the compound which give effect to aroma of *Sigumjang* using stepwise multiple regression analysis and principal component analysis of GC profiles.

Materials and Methods

Materials and sensory test The 42 different brands of commercially available fermented *Sigumjang* filled in 1 L glass bottles were used. Each *Sigumjang* was evaluated using 9-point scale test and numbered according to the preference order by 16 well-trained members of the sensory panel in Yeungnam University (12-13). The total score of each sample was used as the sensory score in this study.

Extraction and identification of aroma compounds An improved Nikerson simultaneous steam distillation and extraction apparatus was used to extract the aroma compounds of *Sigumjang* (14). Purified diethyl ether was used for extraction solvent. The process of extraction was

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as follow; put the sample and solvent in the sample port and the solvent port, respectively, and then extracted the aroma compounds for more than two hours by increasing the temperature of the sample port to boiling point after circulating the solvent. Anhydrous Na_2SO_4 at 4°C was added to whole extracted flavor to remove moisture and the fraction was concentrated to a final 100 μl by using N_2 gas to obtain the samples of GC analysis.

The mass spectrum of aroma compounds was obtained by GC-MS. The conditions of GC-MS were as follows; Instrument, GC-hewlett-packard 5892 II Gas chromatograph /Hewlett Packard, USA); column, HP-FFAP 60 m × 0.33 μm × 0.2 mm; injector temp., 230 °C; detector temp., 250°C; temp. program, 45°C for 2 min., 45-220°C (15°C/min.) and then 220°C for 11.4 min; carrier gas, He (5 ml/min.); electron voltage, 1100 eV; split ratio, 10:1.

Stepwise regression analysis N sensory scores corresponding to each of *Sigumjang* samples could be described as Y = (y_1, y_2·····y_i·····, y_n) (13). 1≤I≤n. If the gas chromatogram of each flavor concentrate shows m peaks, each gas chromatogram could be described as (x_{i1}, x_{i2},·····, x_{ij},····· x_{im}), and consequently the gas chromatograms for whole samples could be shown as the matrix described below,

$$\begin{vmatrix} X_{11}X_{12} \cdots X_{1j} \cdots X_{im} \\ \vdots \quad \vdots \quad \vdots \\ X_{i1}X_{i2} \cdots X_{ij} \cdots X_{im} \\ \vdots \quad \vdots \quad \vdots \\ X_{n1}X_{n2} \cdots X_{nj} \cdots X_{nm} \end{vmatrix}$$

Where I = 1 to 42, j = 1 to 31 in this study.
The multiple regression model is generally shown as follows

$$Y = a_1X_1 + a_2X_2 + \cdots\cdots + a_jX_j + \cdots\cdots + a_mX_m + \beta + \varepsilon \quad (1)$$

a_j = regression coefficient
β = intercept
ε = random error
Y = dependent variable
X_j = independent variable

a_j and β are computed by the linear least squares methods, and the equation is solvable for n>m. The correlation coefficient between the real Y and estimated Y obtain from the computed multiple regression model is designated as multiple correlation (R). R^2 which means the ratio of variance of Y explained by the regression model is called coefficient of multiple determination.

Smaller numbers of independent variables should be desirable for easier estimation of Y using the multiple regression model for quality tests or controls of manufacturing process. Recently, many kinds of multivariate analysis methods have been developed for this purpose, but stepwise regression analysis (SRA) is considered as the most adequate method for selecting a subset of variables. According to Draper and Smith (15), several different algorithms have been developed for selecting the variables in SRA, but the increasing and decreasing method is regarded as the most adequate way considering the efficiency of calculation and the accuracy of the analysis. Therefore, the relation between the GC-patterns and the sensory scores were analyzed by the increasing and decreasing SRA method. The SRA is performed by trial and error peak selection for obtaining the most suitable subset of the variables on the basis of F-value from the analysis of variance on each independent variable at each step, because the degree of significance of an entered variable is changed by entry of another variable. Therefore, the entry of a variable which is not yet included on the regression, and the removal of variables which are already included in the regression, are determined from the settled conditions of F-value on each variable.

The settled conditions are as follows. The variable having the highest F-value among the variables which are not included yet in the regression is selected for entry. If F-value of the variables which are already included in the regression are under 0.005, the variables are removed from the regression model. If F-value of all the variables which are not included are under 0.1, the SRA is stopped at that step. The maximum number of the step is settled as 70. The SRA was carried out using the SPSS 7.5 program. In this report, GC data was analyzed after transformation as shown in Table 2.

Contributing proportion Contributing proportion (P_i), relative importance of each PC for taste quality, was calculated using Barylko-Pikielena's method (16).

$$Pi = \frac{|s_i r_{iy} \beta_i|}{\sum |s_i r_{iy} \beta_i|} \times 100R^2 \quad (2)$$

where, s_i and r_{iy} represent standard deviation of each PC and correlation coefficient between each variable and sensory score, respectively. This analysis was performed using a SPSS 7.5 program (13).

Results and Discussion

Sensory test and GC analysis By the result of sensory evaluation, the most liked and disliked samples are 94 and 34, respectively. 4 samples were received more than 90, 8

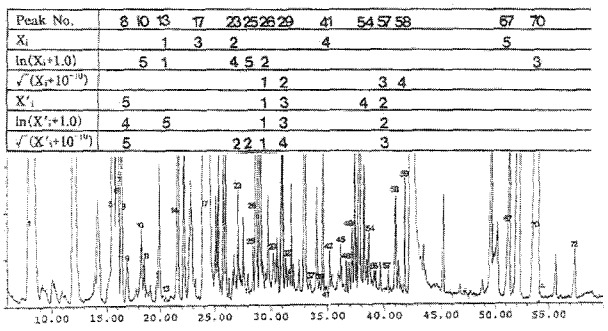

Fig. 1. Total chromatogram of aroma components in sigumjang and order of magnitude of the contributing proportions (P_i%) of each peak transformed with six variables. 8, β-phallendrenal; 10, methylpyrazine; 13, 2,3-dimethylpyrazine; 17, tetramethylpyrazine; 23, 5-methyl-2-furancarboxaldehyde; 25, pentanoic acid; 26, 2-furancarboxaldehyde; 29, 1,2-dimethoxybenzene; 41, unknown 2; 54, octanoic acid; 57, nonanoic acid; 58, 4-ethylphenol; 67, methyl-10,13-octadecanoate; 70, ethyl linoleate.

samples were 80-89, 8 samples were 70-79, 15 samples were 60-69 and 7 samples were less than 70. Mean of them was 70.9 and standard deviation was 12.7.

The gas chromatogram of the whole volatile flavor components of *Sigumjang* was shown in Fig. 1. Mean, Standard deviation, maximum and minimum value of flavor components identified by GC-MS are listed in Table 1. Among the 72 aroma components, there were twelve kinds of esters, eleven kinds of alcohols eight kinds of acids and aldehydes, seven kinds of phenols, four kinds of ketones and pyrazines, three kinds of hydrocarbones, two sulfur containing compounds, one furan and twelve others.

Table 1. Composition of aroma compounds and sensory evaluation values in *Sigumjang* [Unit : area%]

No.	Components	Mean	S.D.[1]	Max.[2]	Min.[3]
	aldehydes (8)				
X_1	3-methyl butanal	1.0	2.1	11.3	0
X_8	β-phellendrenal	1.6E-02	5.1E-02	0.2	0
X_{16}	2-furancarboxaldehyde	6.2	6.4	24.8	0
X_{21}	2-nonenal	1.9E-02	7.3E-02	0.4	0
X_{22}	benzaldehyde	0.3	1.3	8.4	0
X_{23}	5-methyl-2-furancarboxaldehyde	3.5	3.4	10.1	0
X_{27}	benzeneacetaldehyde	2.4	2.1	10.9	0
X_{49}	hexadecanal	0.1	0.5	2.8	0
	sulfur containing compounds (2)				
X_2	dimethyl disulfide	0.7	0.7	3.4	0
X_{14}	dimethyl trisulfide	0.7	0.9	3.5	0
	pyrazines (4)				
X_{10}	methyl pyrazine	0.1	0.2	1.1	0
X_{13}	2,3-dimethyl pyrazine	0.1	0.4	2.5	0
X_{15}	trimethyl pyrazine	0.4	0.9	4.7	0
X_{17}	tetramethylpyrazine	9.4	11.2	64.0	0
	ketones (4)				
X_{11}	2-octanone	8.8E-03	2.7E-02	0.1	0
X_{20}	1 (2-furanyl)-ethanone	0.2	0.3	1.3	0
X_{55}	dihydro-5-pentyl-2(3H)-furanone	6.8E-02	0.2	0.8	0
X_{60}	4-hydroxy-3-methylactophonone	0.4	1.5	7.8	0
	alcohols (11)				
X_{12}	1-hexanol	0.1	0.2	0.9	0
X_{18}	3,7-dimethyl-1,6-octadien-3-ol	0.1	0.2	0.9	0
X_{19}	1(2-furanyl)-ethanol	0.1	0.2	1.0	0
X_{26}	2-furanmethanol	1.0	1.1	4.3	0
X_{30}	3,7-dimethyl-2,6-octadien-1-ol, acetate	0.1	0.8	4.9	0
X_{31}	3,7-dimethyl-6-octen-1-ol	7.5E-02	0.3	1.3	0
X_{36}	3,7-dimethyl-2,6-octadienol	6.1E-02	0.2	0.7	0
X_{38}	mequinol	5.7E-02	0.1	0.4	0
X_{39}	benyl alcohol	0.2	0.2	1.0	0
X_{42}	phenylethyl alcohol	0.1	0.3	1.6	0
X_{44}	benzenemethanol	4.3E-02	7.8E-02	0.4	0
	hydrocarbons (3)				
X_3	1,3-dimethyl benzene	0.1	0.2	0.8	0
X_{32}	1,2,3,5,6,8-a-tetramethyl naphthalene	0.2	0.4	2.0	0
X_{33}	naphthalene	6.1E-02	8.7E-02	0.3	0
	furan (1)				
X_7	2-pentylfuran	0.6	1.1	6.8	0

Table 1. continued

No.	Components	Mean	S.D.[1]	Max.[2]	Min.[3]
	phenols (7)				
X_{37}	2-methoxyphenol	0.3	0.3	1.2	0
X_{45}	2-methoxy-4-methylphenol	1.5E-02	4.7E-02	0.2	0
X_{46}	2-methylphenol	1.4E-02	5.0E-02	0.3	0
X_{48}	phenol	7.2E-02	0.1	0.4	0
X_{52}	2-methoxy-4-methylphenol	1.0E-02	4.9E-02	0.3	0
X_{58}	4-ethylphenol	5.4	9.8	36.3	0
X_{64}	2-methoxy-4-(1-propenyl)-phenol	0.1	0.4	2.6	0
	esters (12)				
X_{34}	methyl salicylate	4.3E-02	0.1	0.6	0
X_{40}	2-ethylhexyl phthalate	3.4E-02	0.1	0.8	0
X_{47}	methyl tetradecanoate	5.1E-02	7.2E-02	0.3	0
X_{53}	ethyl tetradecanoate	0.1	0.3	1.7	0
X_{62}	ethyl hexadecanoate	6.1	11.0	41.96	0
X_{63}	dimethyl 1,2-benzendicarboxylate	5.5E-02	0.3	2.0	0
X_{65}	methyl oleate	0.2	0.3	1.4	0
X_{67}	methyl 10,13-octadecadienoate	7.0E-02	0.3	1.9	0
X_{68}	ethyl oleate	0.7	1.9	8.7	0
X_{69}	methyl linoleate	0.7	1.8	8.5	0
X_{70}	ethyl linoleate	4.7	10.1	45.7	0
X_{71}	methyl linoleate	1.5	8.0	51.8	0
	acids (8)				
X_{24}	butanoic acid	0.1	0.8	5.4	0
X_{25}	pentanoic acid	0.2	0.9	5.5	0
X_{35}	hexanoic acid	0.4	0.8	4.1	0
X_{43}	heptanoic acid	8.0E-02	0.2	1.0	0
X_{54}	octanoic acid	0.2	0.4	1.8	0
X_{57}	nonanoic acid	1.5	2.3	9.2	0
X_{61}	decanoic acid	2.7E-02	8.6E-02	0.4	0
X_{59}	hexadecanoic acid	3.2	6.5	27.0	0
	Terpenoids (3)				
X_4	β-myrcene	0.3	0.5	2.4	0
X_5	limonene	0.6	1.0	4.9	0
X_9	sabinene	5.0E-02	0.2	1.2	0
	others (9)				
X_6	unknown-1	0.6	1.6	7.0	0
X_{28}	5-(1,5-dimethyl)-1,3-cyclohexadiene	5.8E-02	0.2	1.1	0
X_{29}	1,2-dimethoxybenzene	7.7E-02	0.1	0.5	0
X_{41}	unknown-2	0.1	0.3	1.7	0
X_{50}	unknown-3	0.3	0.5	2.8	0
X_{51}	tetradecyl-oxirane	5.8E-02	0.2	0.9	0
X_{56}	unknown-4	1.5	2.3	9.2	0
X_{66}	unknown-5	0.3	0.7	2.9	0
X_{72}	unknown-6	0.1	0.4	2.0	0
Y	S.E.V.	70.9	12.7	94.0	34.0

[1]S.D.: standard deviation.; [2]Max.: maximum.; [3]Min.: minimum.; [4]S.E.V.: sensory evaluation value.
Each values are the average of 42 replication

Among the identified compounds, the content of tetramethylpyrazine (9.4±11.2%) was the most followed by 2-furancarboxaldehyde (6.2±6.4%), ethyl hexadecanoate (6.1 ±11.0%) and 4-ethyl phenol (5.4±9.8%).

Most of all *Sigumjang* samples have about 72 peaks, but the ratio of each peak was various. Among these peaks, 31 peaks of which correlation coefficient was more than 0.1 were selected as variable, as shown Fig. 1.

A) X_i

$$Y = -1.264X_{23} - 16.643X_{13} + 28.853X_8 + 0.470X_{17} + 1.326X_5$$
$$(-3.452^{**})\ (-7.127^{**})\ (1.283)\ (6.541^{**})\ (1.347)$$
$$+ 11.340X_{67} - 0.341X_{58} + 1.199X_{57} + 1.868X_6 + 7.559X_{41}$$
$$(4.391^{**})\ (-1.687)\ (1.347)\ (3.089^{**})\ (2.577^{*})$$
$$+ 43.004X_{45} + 0.164X_{70} + 63.062X_{11} - 4.380X_{39} \quad (1)$$
$$(1.873)\ (1.955)\ (1.684)\ (-1.049)$$
$$+ 2.311X_{42} + 67.044$$
$$(0.843)\ (33.106^{**})$$

$R = 0.96$, $R^2 = 0.92$, Adjusted $R^2 = 0.87$, S.E. = 4.58, $F = 19.08^{**}$
$^{*}p<0.05$, $^{**}p<0.01$.
The numbers in parentheses show the t-value for each entered variable.

B) $\ln(X_i+1.0)$

$$Y = +2.317X_1 - 22.587X_{13} - 4.416X_{23} + 23.046X_8$$
$$(1.271)\ (-4.308^{**})\ (-2.764^{*})\ (0.948)$$
$$+ 5.064X_5 + 6.783X_{17} + 24.522X_{67} + 3.191X_{70}$$
$$(2.196^{*})\ (6.614^{**})\ (4.059^{**})\ (2.852^{**})$$
$$+ 4.959X_{14} - 17.694X_{37} - 7.747X_{26} + 6.538X_6\ 8 \quad (2)$$
$$(1.898)\ (-3.003^{**})\ (-2.772^{*})\ (2.414^{*})$$
$$+ 62.865X_{45} + 12.662X_{10} + 7.248X_{41} + 60.29$$
$$(2.037)\ (1.791)\ (1.316)\ (15.079^{**})$$

$R = 0.95$, $R^2 = 0.91$, Adjusted $R^2 = 0.85$, S.E. = 4.83, $F = 17.04^{**}$

C) $\sqrt{(X_i \times 10^{-10})}$

$$Y = +4.899X_{41} - 11.051X_{13} - 1.096X_{57} + 3.638X_1$$
$$(1.022)\ (-2.633^{*})\ (-0.784)\ (2.069^{*})$$
$$+ 2.680X_{17} - 1.971X_{23} + 6.987X_{72} - 10.880X_{29} \quad (3)$$
$$(4.452^{**})\ (1.282)\ (1.580)\ (-1.549)$$
$$+ 1.265X_{70} + 14.223X_8 + 4.326X_5 - 4.252X_{25}$$
$$(1.718)\ (1.322)\ (1.984)\ (-1.634)$$
$$+ 7.683X_9 + 3.262X_{14} + 5.127X_{67} + 59.999$$
$$(1.642)\ (1.260)\ (1.019)\ (11.576^{**})$$

$R = 0.93$, $R^2 = 0.87$, Adjusted $R^2 = 0.80$, S.E. = 5.69, $F = 11.76^{**}$

D) X'_i

$$Y = -3.444X_{13} - 0.556X_{57} - 0.357X_{23} - 3.257X_8 - 0.125X_{59}$$
$$(-4.670^{**})\ (-1.715)\ (-4.000^{**})\ (-0.781)\ (-1.652)$$
$$- 0.720X_{54} + 3.852X_{67} - 1.455X_{26} + 0.378X_5$$
$$(-3.119^{**})\ (4.679^{**})\ (-3.533^{**})\ (2.137^{*})$$
$$+ 0.145X_{17} + 0.593X_6 - 0.154X_{58} - 3.532X_{29} \quad (4)$$
$$(3.618^{**})\ (2.634^{*})\ (-1.915)\ (-1.603)$$
$$- 1.432X_{37} + 0.452X_7 + 79.996$$
$$(-1.757)\ (1.286)\ (30.595^{**})$$

$R = 0.96$, $R^2 = 0.92$, Adjusted $R^2 = 0.87$, S.E. = 4.52, $F = 19.69^{**}$

E) $\ln(X'i+1.0)$

$$Y = -3.965X_{57} - 9.028X_{13} - 15.077X_{29} - 4.895X_{54}$$
$$(-1.926)\ (-2.708^{*})\ (-2.012)\ (-3.186^{**})$$
$$- 4.292X_{25} - 3.482X_{10} - 2.159X_{58} + 3.252X_{41}$$
$$(-1.516)\ (-0.661)\ (-1.368)\ (1.464)$$
$$- 2.964X_{14} + 6.064X_{72} + 4.579X_{55} + 3.282X_{42} \quad (5)$$
$$(-1.768)\ (1.645)\ (0.858)\ (0.952)$$
$$- 2.026X_{23} - 1.477X_{26} + 2.893X_{67} + 89.440$$
$$(-1.529)\ (-0.977)\ (0.965)\ (28.235^{**})$$

$R = 0.92$, $R^2 = 0.85$, Adjusted $R^2 = 0.76$, S.E. = 6.17, $F = 9.76^{**}$

F) $\sqrt{(X'_i \times 10^{-10})}$

$$Y = -3.503X_{57} - 3.508X_{13} - 8.189X_{29} - 3.648X_{54}$$
$$(-2.830^{**})\ (-2.941^{**})\ (-1.828)\ (-3.737^{**})$$
$$- 6.224X_{26} + 3.983X_{49} + 8.008X_{48} - 1.436X_{70}$$
$$(-5.717^{**})\ (1.874)\ (2.492^{*})\ (-3.134)$$
$$+ 1.572X_6 - 0.777X_{59} - 4.403X_{39} + 3.270X_{67} \quad (6)$$
$$(1.756)\ (-1.356)\ (-1.868)\ (1.578)$$
$$- 1.297X_{23} - 0.957X_{58} - 1.817X_{42} + 98.680$$
$$(-1.702)\ (-1.370)\ (-1.011)\ (30.210^{**})$$

$R = 0.95$, $R^2 = 0.900$, Adjusted $R^2 = 0.84$, S.E. = 5.09, $F = 15.17^{**}$

Correlation between sensory scores and the content of aroma compounds at six transformed values The correlation coefficients between the sensory score of each sample and the quantity of each peak are shown in Table 2. The negative correlation coefficients in each peak means the its peak gives reverse contribution with the increase of the quantity and the positive correlation coefficients that its peak gives the preferable contribution. There are many peaks which show a significant relation with the sensory score such as peaks 1 (3-methylbutanal), 8 (β-phallendrenal), 10 (methylpyrazine), 11 (2-octanone), 13 (2,3-dimethylpyrazine), 23 (5-methyl-2-furancarboxaldehyde), 25 (pentanoic acid), 26 (2-furancarboxaldehyde), 29 (1,2-dimethoxybenzene), 39 (benzyl alcohol), 41 (unknown 2), 57 (nonanoic acid), 58 (4-ethylphenol), 59 (hexadecanoic acid) and 70 (linoleic acid, ethyl ester). Further the correlation coefficient of peak 23 show more than 0.52 at absolute value and peak 1 show more than 0.54 at absolute value transformed with logarithm. Peak 8 (β-phallendrenal), 13 (2,3-dimethylpyrazine), 23 (5-methyl-2-furancarboxaldehyde), 57 (nonanoic acid) and 58 (4-ethylphenol) showed high correlation at all transformed value ($p<0.01$). In case of peak 13 (2,3-dimethylpyrazine), show especially high correlation at absolute value and relative value, and peak 23 (5-methyl-2-furancarboxaldehyde) show especially high correlation at absolute value and absolute value transformed with logarithm. Peak 57 (nonanoic acid) showed high correlation at relative value transformed with logarithm and relative value transformed with root square. Peak 58 (4-ethylphenol) showed high correlation at absolute value transformed with logarithm, relative value transformed with logarithm and relative value transformed

Table 2. Correlation coefficients between sensory scores and contents of aroma compounds

Peak No.[1)]	Correlation coefficients(r)					
	Absolute values			Relative values		
	X_i	$\ln(X_i+1.0)$	$\sqrt{(X_i+10^{-10})}$	X'_i	$\ln(X'_i+1.0)$	$\sqrt{(X'_i+10^{-10})}$
X_1	0.431**	0.542**	0.548**	0.252	0.495**	0.419**
X_5	0.226	0.239	0.187	0.184	0.240	0.206
X_6	0.214	0.151	0.094	0.214	0.124	0.128
X_7	-0.294	-0.168	-0.175	-0.235	-0.095	-0.138
X_8	0.449**	0.450**	0.457**	0.408**	0.425**	0.441**
X_9	0.186	0.214	0.261	0.234	0.274	0.285
X_{10}	-0.349*	-0.379*	-0.432**	-0.307*	-0.374*	-0.412**
X_{11}	0.395**	0.397**	0.413**	0.356*	0.367*	0.393**
X_{13}	-0.491**	-0.486**	-0.438**	-0.491**	-0.474**	-0.453**
X_{14}	0.173	0.137	0.086	0.097	0.121	0.109
X_{17}	0.280	0.080	0.157	0.348*	0.108	0.211
X_{23}	-0.521**	-0.508**	-0.499**	-0.412**	-0.469**	-0.453**
X_{25}	-0.366**	-0.319*	-0.315*	-0.366*	-0.300	-0.317*
X_{26}	-0.311*	-0.357*	-0.402**	-0.189	-0.305*	-0.304*
X_{29}	-0.343*	-0.373*	-0.511**	-0.281	-0.352*	-0.451**
X_{32}	0.178	0.147	0.011	0.202	0.156	0.084
X_{37}	-0.186	-0.220	-0.240	-0.099	-0.161	-0.169
X_{39}	-0.434**	-0.451**	-0.489**	-0.274	-0.345*	-0.395**
X_{41}	0.434**	0.480**	0.558**	0.376*	0.481**	0.505**
X_{42}	-0.225	-0.301	-0.451**	-0.175	-0.325*	-0.409**
X_{45}	-0.200	-0.197	-0.148	-0.127	-0.131	-0.109
X_{48}	-0.267	-0.273	-0.300	-0.159	-0.191	-0.238
X_{49}	0.189	0.180	0.180	0.161	0.146	0.154
X_{54}	-0.232	-0.281	-0.343*	-0.169	-0.258	-0.276
X_{55}	-0.277	-0.293	-0.339*	-0.216	-0.365*	-0.307*0
X_{57}	-0.428**	-0.461**	-0.497**	-0.449**	-0.501**	-0.523**
X_{58}	-0.393**	-0.446**	-0.436**	-0.409**	-0.469	-0.447**
X_{59}	-0.331*	-0.410**	-0.380*	-0.342	-0.363*	-0.356*
X_{67}	0.193	0.205	0.215	0.206	0.217	0.216
X_{70}	0.260	0.381*	0.336*	0.233	0.367*	0.317*
X_{72}	0.165	0.153	0.115	0.116	0.102	0.084

[1)]1, 3-methylbutanal; 5, limonene; 6, unknown 1; 7, 2-pentylfuran; 8, β-phallendrenal; 9, sabinene; 10, methylpyrazine; 11, 2-octanone; 13, 2,3-dimethylpyrazine; 14, dimethyltrisulfide; 17, tetramethylpyrazine; 23, 5-methyl-2-furancarboxaldehyde; 25, pentanoic acid; 26, 2-furancarboxaldehyde; 29, 1,2-dimethoxybenzene; 32, tetramethylnaphthalene; 37, 2-methoxyphenol; 39, benzylalcohol; 41, unknown 2; 42, phenylethylalcohol; 45, 2-methoxy-4-methylphenol; 48, phenol; 49, hexadecanal; 54, octanoic acid; 55, dihydro-5-pentyl-2(3H)-furanone; 57, nonanoic acid; 58, 4-ethylphenol; 59, hexadecanoic acid; 67, methyl-10,13-octadecanoate; 70, ethyl-linoleate; 72, unknown 3.

with root square. But, it is difficult to estimate the aroma quality of *sigumjang* on the basis of only one peak, in spite of the highly significant relationship between the quantity of the peak and the sensory score.

Stepwise multiple regression analysis In general, many factors are selected as independent variables and then reexamined. After that, some factors are removed, because of no significance for the intended analysis. In the case of *Sigumjang* aroma, 72 peaks were observed on the gas chromatograms. Concerning the purpose to find out effective components to aroma of fermented food, two important results have to be deliberated. Firstly, there exist several groups of peaks which are correlating to each other. Therefore, each of these groups should be represented by one typical peak. Secondly there exist several peaks which show approximately zero values of the contributing proportion. Therefore, these peaks should be removed from the regression analysis. Thus, the computing of the multiple regression model was carried out by using some portion out of 31 independent variables with the expectation that this would not lower the accuracy of the estimation. Among the relation between the real sensory scores and the estimated score based on multiple regression analysis with 31 variables, the results of absolute value and relative value are shown eq (1)~(6). It is known that, in this figure, assumption of sensory score was possible through multiple regression model and the content of aroma components.

According to the equality, the significance of the regression coefficients is examined on the basis of the F-value. That of these six multiple regression models was significant at the 1% level. And the significant variables were exist despite of so many variables are contained to

Table 3. Contributing proportion of each peak

Peak No.[1)]	Contributing proportion P_i(%)					
	X_i	$\ln(X_i+1.0)$	$\sqrt{(X_i+10^{-10})}$	X'_i	$\ln(X'_i+1.0)$	$\sqrt{(X'_i+10^{-10})}$
1	0.44	3.66	2.21	0.82	0.78	0.78
5	1.46	0.77	1.35	1.87	0.92	1.91
6	3.67	2.97	0.88	1.23	1.57	0.21
7	2.94	1.81	2.94	3.37	2.90	3.21
8	1.69	2.62	3.77	5.99	6.73	6.64
9	1.81	2.05	2.08	1.86	1.42	0.89
10	4.88	6.28	1.52	2.58	0.27	3.01
11	4.62	2.28	1.19	0.38	0.93	0.60
13	12.25	7.98	3.71	4.11	5.62	2.89
14	1.66	0.91	0.11	0.65	1.81	0.31
17	6.25	2.67	3.45	1.20	0.10	1.18
23	7.38	6.73	3.12	2.86	3.25	1.13
25	2.02	3.28	4.84	4.07	3.79	10.16
26	1.00	7.41	8.87	9.95	10.40	11.15
29	2.96	4.51	6.59	7.51	6.88	7.31
32	0.77	0.45	0.00	0.04	0.06	0.12
37	1.51	3.90	4.54	1.89	2.02	2.36
39	0.37	0.57	0.29	0.24	0.76	0.63
41	5.93	4.69	3.55	2.27	2.90	1.01
42	1.60	3.41	3.60	1.91	2.00	1.12
45	1.32	2.86	0.98	0.02	0.48	0.00
48	4.49	2.56	2.12	2.65	1.54	3.95
49	4.25	1.59	3.76	4.97	4.50	4.84
54	0.69	0.07	3.44	6.01	4.73	5.50
55	0.33	1.79	2.39	2.01	3.10	2.08
57	3.20	0.62	6.57	9.27	8.14	9.43
58	1.05	2.22	5.12	3.81	4.63	2.13
59	0.58	0.60	0.99	0.21	1.01	0.81
67	5.61	5.11	3.62	2.87	3.02	2.79
70	3.24	7.15	3.01	3.54	4.48	2.88
72	5.11	0.55	1.79	1.87	2.14	2.17

[1)]1, 3-methylbutanal; 5, limonene; 6, unknown 1; 7, 2-pentylfuran; 8, β-phallendrenal; 9, sabinene; 10, methylpyrazine; 11, 2-octanone; 13, 2,3-dimethylpyrazine; 14, dimethyltrisulfide; 17, tetramethylpyrazine; 23, 5-methyl-2-furancarboxaldehyde; 25, pentanoic acid; 26, 2-furancarboxaldehyde; 29, 1,2-dimethoxybenzene; 32, tetramethylnaphthalene; 37, 2-methoxyphenol; 39, benzylalcohol; 41, unknown 2; 42, phenylethylalcohol; 45, 2-methoxy-4-methylphenol; 48, phenol; 49, hexadecanal; 54, octanoic acid; 55, dihydro-5-pentyl-2(3H)-furanone; 57, nonanoic acid; 58, 4-ethylphenol; 59, hexadecanoic acid; 67, methyl-10,13-octadecanoate; 70, ethyl-linoleate; 72, unknown 3.

regression model. R^2 at four transformation except for absolute value transformed with root square and relative value transformed with logarithm of which R^2 were, respectively, 0.87 and 0.85 were more than 0.9, indicating that over 90% of the variance of the sensory score are explained by the regression model.

Contributing proportion Contributing proportion of each peak on GC to aroma of *Sigumjang* was shown in Table 3 and the order was shown in Fig. 1. Among the 31 peaks, contributing proportion of peak 13 (2,3-dimethylpyrazine) was the most at absolute value and absolute value transformed with logarithm on aroma of *Sigumjang*. The quality of *Sigumjang* aroma was most effected by peak 26 (2-furancarboxaldehyde) in absolute value transformed root square, relative value, relative value transformed logarithm and relative value transformed with root square. In case of peak 29 (1,2-dimethoxybenzene) and peak 57 (nonanoic acid), the aroma of *Sigumjang* was highly effected at absolute value transformed root square, relative value, relative value transformed logarithm and relative value transformed with root square but not effected at absolute value and absolute value transformed with logarithm much. The aroma of *Sigumjang* was highly effected by peak 8 (β-phallendrenal), 10 (methylpyrazine), 17 (tetramethylpyrazine), 23 (5-methyl-2-furancarboxaldehyde), 41 (unknown 2), 54 (octanoic acid), 58 (4-ethylphenol), 67 (methyl 10,13-octadecanoate) and 70 (ethyl linoleate) too. It was investigated, on the other hand, that the aroma of *Sigumjang* was nearly not contributed by following peaks; 1 (3-methylbutanal), 6 (unknown), 11 (2-octanone), 14 (dimethyltrisulfide), 32 (tetramethylnaphthalene), 39 (benzyl alcohol), 45 (2-methoxy-4-methylphenol) and 59 (hexadecanoic acid).

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