Multiple Regression Analysis of Aroma Components and Sensory Evaluation of Miso

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Among several sensory characteristics to evaluate the quality of miso (fermented bean paste), aroma is the most difficult one. If results of chemical analysis of miso aroma could be transformed into numerical terms, the evaluation of miso may become easier. Therefore we investigated relationship between aroma components and sensory scores of rice-miso by multiple regression analysis. Thirty-four rice-miso exhibited at the National Miso Competition were used as the samples. Each peak area of the aroma components detected by GC analysis was normalized at its ratio to the peak area of the internal standard. The normalized values were used as an independent variable and the sensory scores were used as a dependent variable. High correlations with sensory scores were obtained for maltol and HEMF. As the result of a multiple regression analysis, maltol was selected at step 1 with the coefficient of determination (R^2) of 0.509. At step 7, R^2 of 0.804 was obtained. Thus about 80% of the variability in the sensory scores could be explained by the seven components. The results suggested that the multiple regression model using aroma components may be applied to the evaluation of aroma qualities of rice-miso samples exhibited at the National Miso Competition.

Miso is one of the most important Japanese seasonings. To improve the quality of the miso products, the National Miso Competition is held every year. At the competition, miso samples are evaluated about luster, aroma, taste and overall property using the traditional sensory test. Among them, the aroma is the most difficult characteristic for evaluation. If a method could be developed to transform results of chemical analysis of miso aroma into numerical terms, the evaluation of aroma qualities for miso would become easier. Therefore we studied the preparation method of aroma concentrates of miso and reported that adsorbing aroma compounds on porous polymers and eluting them with ether was effective[1]. In aroma concentrates of miso prepared by this method, we identified for the first time, HEMF (4-hydroxy-2 (or 5)-ethyl-5 (or 2)-methyl-3 (2 H)-furanone) as one of the flavor components in miso[2], and found that HEMF was produced in the aging period of miso[3]. Furthermore, we investigated the compounds contributing to the classification of rice-miso aroma by discriminant analysis[4]. The purpose of this study was to clarify the aroma components relating to results of sensory evaluation of rice-miso aroma by using multiple regression analysis.

1. Materials and Method

The samples for this study were selected from 452 rice-miso samples exhibited at the 33rd National Miso Competition. At the competition, the samples were evaluated using the traditional sensory test as follows. Ten judges evaluated the luster, aroma, taste and overall property of the samples using a three-point scale : 1 (superior), 2 (average), and 3 (inferior)[5]. Since the focus of our study was on the aroma, the sum of the scores given by the 10 judges to the aroma was used as the sensory scores[6]. The scores of most samples were lower and the distribution skewed to the superior side. There were no samples whose total score in the evaluation of aroma was in the range from 27 to 30. Two kinds of rice-miso were selected for each number from 10 to 26, making the total of 34 samples with a wide range. The average score of 34 samples was 18.0 and the standard deviation was 5.0.

The aroma concentrates were prepared in the same way as described in the previous report[4], and analyzed by GC and GC-MS. The

analytical conditions of GC and GC-MS were described previously (aforementioned).

Statistical analysis was performed using the stepwise multiple regression analysis. Each peak area of the aroma components detected by GC analysis was normalized at its ratio to the peak area of the internal standard. The normalized values (peak ratios) were used as an independent variable and the sensory scores were used as a dependent variable. Calculation was carried out using SAS (Statistical Analysis System) at the Computer Center of Iwate University.

2. Result and Discussion

(1) Correlation coefficients between sensory scores and aroma components

Fig. 1 shows the gas chromatogram of the aroma concentrate of a high-quality miso with the sensory score of 11. The identified or tentatively identified components were similar to those given in the previous papers[1)~4)]. In most samples, 101 peaks were detected by GC analysis.

The components, whose correlation coefficients were significant at 5% level, are shown in Table 1. The compound that had the highest negative correlation was HEMF. This result suggested that HEMF highly contributed to the preferable aroma of rice-miso. This result agreed with that reported in the previous report[4)]. On the other hand, the compound that had the highest positive correlation was maltol. The increase in the peak ratio of maltol was considered to make results of sensory evaluation inferior. The previous paper[3)] showed that maltol was formed while soybeans were boiled. Maltol has a sweet caramel-like aroma, but the reason why maltol contributed to lower the sensory quality could not be explained. We would like to pursue research on the relationship between the peak ratio of maltol and sensory quality in a future study.

(2) Multiple regression analysis

For a multiple regression analysis, 34 components having a higher peak ratio were selected as independent variables. The peak numbers of these components are shown in Fig. 1. The

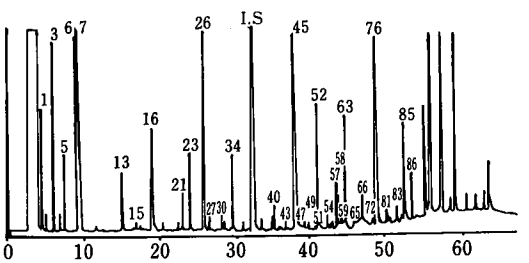

Fig. 1 Gas chromatogram of aroma concentrate of miso

Column : 0.25 mm × 30 m, fused silica capillary column, DB-WAX.

Column Temp : 40℃ held for 5 min, 40℃ to 200℃ at 3℃/min.

Table 1 The correlations coefficients (r) between sensory scores and aroma components in miso

Peak No.	r	Compound
62	−0.53**	HEMF
55	−0.45**	HDMF
82	−0.42*	unknown
75	−0.42*	unknown
34	−0.41*	5-ethoxythiazole[1)]
58	−0.40*	unknown
3	−0.40*	2-methyl-1-propanol
56	−0.40*	DMP[1)]
45	−0.39*	2-phenyl-1-ethanol
7	−0.38*	3-methyl-1-butanol
6	−0.37*	2-methyl-1-butanol
36	−0.37*	methionol
5	−0.35*	1-butanol
23	−0.35*	L-2,3-butandiol
74	−0.34*	unknown
52	0.71**	maltol
17	0.47**	acetic acid
32	0.43*	ethyl benzoate
79	0.38*	unknown
38	0.36*	ethylphenyl acetate

[1)] : tentatively identified.

** $P<0.01$; * $P<0.05$.

HEMF : 4-hydroxy-2 (or 5)-ethyl-5 (or 2)-methyl-3 (2H)-furanone.

HDMF : 4-hydroxy-2,5-dimethyl-3(2H)-furanone.

DMP : 5,6-dihydro-4-methyl-2H-pyrane-2-one.

Table 2 Multiple regression models calculated at step 7

Peak No.	Compound	Partial regression coefficient	F
15	3-hexenyl acetate	−3.890	7.30*
43	benzyl alcohol	1.989	5.08*
52	maltol	1.462	84.65**
57	ethyl tetradecanoate	−2.780	18.26**
66	2-methoxy-4-vinylphenol	0.023	1.32
76	ethyl hexadecanoate	−0.050	2.27
83	unknown	−0.729	6.47*
Intercept		17.226	

$R^2=0.804$

** $P<0.01$; * $P<0.05$.

major peaks that appeared after the peak 86 were identified as ethyl esters of higher aliphatic acids. These peaks were not selected as variables because they had significant correlation at 1% level with the peak 76 (ethyl hexadecanoate).

The partial regression coefficients of the 7 components selected by the stepwise multiple regression analysis are shown in Table 2. At step 1, maltol was selected with the coefficient of determination (R^2) of 0.509. This means that 51% of the total variation can be accounted for maltol only. Calculation was stopped when R^2 attained at 0.8, and seven components were selected. It is desirable that the correlation coefficients between independent variables are low for avoiding multicollinearity problems. Fortunately, the correlations among these 7 components were not significant at 5% level. A high R^2 of 0.804 and R of 0.897 were obtained with the seven variables. The results suggests that the multiple regression model using the peak ratios of aroma components may be applied to the evaluation of aroma for the rice-miso in the National Miso Competition.

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みその香気成分と官能評価の重回帰分析

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味噌の品質を判定する際，香気は最も評価が困難な特性の一つである．従って，香気の化学的な分析結果が数字で表現されるならば，味噌の品質評価は従来より，ずっと簡便になる．そこで，米味噌の香気成分と官能検査の関係を重回帰分析を用いて解析した．全国味噌鑑評会に出品された米味噌 34 点を試料とした．GC 分析で検出された各香気成分の内部標準物質とのピーク面積比を独立変数とし，官能検査スコアーを従属変数として用いた．官能検査スコアーと高い相関を示した成分は maltol と HEMF であった．重回帰分析の結果，ステップ 1 では maltol が選択され，決定係数は 0.508 であった．ステップ 7 で決定係数は 0.804 となり，選択された 7 成分により官能評価結果の約 80% の変動を説明することができた．この結果から，香気成分のピーク面積比を用いた重回帰式は米味噌の香気の品質評価に適用できる可能性のあることが示唆された．