# Relationships Between Sensory Flavor Evaluation and Gas-Chromatographic Profiles of French Bread[1]

Y. HIRONAKA[2]

**ABSTRACT**

Cereal Chem. 63(4):369–372

The effects of the fermentation conditions (final temperature of mixing, fermentation time, punching of dough, proofing time), formulated through an experiment of orthogonal $L_8$ design, on the Japanese sensory evaluation of French bread produced by a straight-dough method, were investigated with the seven-grade, bipolar numerical scales method. The correlations between the results and the variety and amount of flavor compounds were also studied. The intensity of the fermented flavor was not affected by any of these fermentation conditions. The intensity of baked flavor and the preference flavor were increased by extending proofing time. Significant positive correlations between the preference flavor and amount of isobutylaldehyde, propylaldehyde, 2-butanone, and some unidentified compounds were found through sensory tests. Significant negative correlations were found between the preference and amount of ethyl alcohol and isobutyl alcohol.

The consumption of bread in Japan has been increasing slowly. Although French bread is consumed at a low rate compared to white bread and Japanese pastry, the consumption of French bread is gradually increasing also (Zenkoku Shokuseikatsu Kaizenkyokai 1981). The reason for this trend is thought to be partly due to Japanese curiosity for foreign foods and the fact that French bread has a bland taste like many foods in the Japanese diet, for example, rice. In Japan, French bread is usually made with the straight-dough method. Because of its lean ingredient formulation, French bread is more readily affected by fermentation conditions than white bread (Hironaka 1983, 1985b). Japanese bakers are having difficulties making French bread. Hironaka (1985c) reported that the amount of flavor compounds in the bread is highly affected by fermentation conditions. Many reports concerning bread flavor have been published (Wiseblatt 1961, Johnson et al 1966, Maga 1974, Richard-Molard et al 1979); however, few of these concern the flavor of bread produced in Japan. No reports were found regarding the correlation between the variety and amount of flavor compounds and the sensory evaluation.

The volatile fractions that are extracted from bread crumb appear to be made up of nearly 100 compounds (Richard-Molard et al 1979). Mulders (1973) formulated a synthetic mixture that resulted in a gas chromatogram identical to a bread head-space sample. However, the odor of the synthetic mixture more closely resembled that of dough than that of bread. The so-called characteristic compound (Aishima 1983) of bread flavor has not yet been discovered. The purpose of this work was to investigate the relationship between Japanese sensory evaluation of French bread and amount and variety of flavor compounds in the bread.

[1]Studies on the Processing Conditions in Bread Making. Part X.

[2]Research Laboratory, Shôgetsu-Dô Baking Co., Sawanami, Nishikiwa-ku, Ube-shi, Yamaguchi-ken, 755-01, Japan.



## MATERIALS AND METHODS

### Bread making

French bread was made from semihard wheat (Torigoe Flour Milling Co.); dry yeast (Gist-Brocades) 0.8% flour basis; salt 2%; malt flour (Nichibaku Malt Co.), 0.3%; yeast food (S. I. Lesaffré) 0.2%; and water 60.8% with the straight-dough method. The experimental fermentation conditions of breadmaking were laid out with an orthogonal $L_8$ design for four factors and two levels (Okuno and Yoshiga 1980) shown in Table I. The four factorial conditions were: final mixing temperature (27 or 29°C), fermentation time (105 or 135 min), punching ( punched or not), and final proofing time (40 or 60 min). Under the experimental design, the order of experiments should have been carried out at random; however, in order to avoid batch-to-batch variation of the final mixing temperature in bread production, two large batches designated experiment numbers 1 through 4 and 5 through 8 were mixed at the same time, because it is difficult to mix any number of batches at the same temperature. These two large batches were mixed at 27.4 and 29.5°C, respectively. Each large batch was divided into four. The dough temperatures of experiment numbers 1, 2, 3, and 4, and those of numbers 5, 6, 7, and 8 varied little. Other conditions were standardized: mixing, low speed for 3 min; salt added; mixing, high for 0.5 min; dividing weight, 160 g; bench time, 15 min; molding, "coupe" cut (L 14.5 × W 6.5 × H 4.0 cm); baking, 250°C, 20 min.

### Sensory Evaluation Test

The seven-grade, bipolar numerical scales method described by Satô (1978) and Kawakita and Yamada (1978) was used in this study. The panel consisted of eight well-trained members of the production and research section of Shôgetsudô Baking Co. In this group were two females and six males; the panelists ranged in age from 20 to 40. The properties to be evaluated were the intensity of fermented flavor and baked flavor and preference for bread flavor. A seven-point scale ranging from "intense (or like extremely)" (3) to "bland (or dislike extremely)" (−3) was selected to differentiate between eight samples on the basis of flavor. The judgments of the eight panel members were averaged.

**Measurement of Flavor Compounds**

The relative amounts of flavor compounds in the crumb and crust were measured by head-space gas chromatography (Charalambous 1979, Hironaka 1985a,c) with a Hitachi 163 gas chromatograph equipped with a flame-ionization detector. A glass column (2 m long, 3 mm i.d.) packed with PEG 6000 15%/uniport B (60–80 mesh) was held at a temperature of 80° C (crumb analysis) or 60° C (crust analysis). Nitrogen (30 ml/min) was used as the carrier gas. For gas chromatography head-space analysis, 80 g of bread crumb or crust was placed in 700-ml screw-top glass jars and held in a 30° C water bath for 150 min. Injection volumn was 1 ml (crumb analysis) or 0.5 ml (crust analysis); *n*-butyl alcohol was used as the internal standard. Tentative identification was accomplished by measuring the relative retention time of known compounds reported to be present in bread (Maga 1974) with PEG 6000, PEG 1000, EGA, XE-60, and Gaskuropack 54 (Hironaka 1985c). Each peak area was calculated by multiplying the height of the peak by its width at one-half height.

**Calculation of Correlation Coefficients**

Correlation coefficients were calculated to determine the relationship between the sensory assessment and each flavor compound measured by gas chromatography (Hironaka 1985c) using a Sharp MZ80B micro computer. Percentage points of the distribution of the sample correlation coefficient (Tôkei Sûchihyo Hensyuiinkai 1979) as a criterion for level of significance are $r$ (8, 0.05) = 0.7067 and $r$ (8, 0.01) = 0.8343.

## RESULTS AND DISCUSSION

Generally, French bread dough is difficult to handle, because the bread is more easily affected by fermentation conditions than white bread. Therefore, when dealing with mixing temperature, Japanese bakers control the temperature of French bread more carefully than that of white bread. Actually, a difference of two degrees (27–29° C) has more affect on the total titratable acidity (TTA) (Sutherland 1976) of French bread than a difference of three degrees (25–28° C) has on the TTA of white bread (Hironaka 1983, 1985b). It was confirmed that the two degrees of mixing temperature during French bread production made a difference of 0.46 in TTA. In contrast, three degrees difference during white bread production made a difference of 0.11 in TTA (Hironaka 1983, 1985b).

Many flavor compounds were detected in the crust of French bread (Hironaka 1985c). The two degrees difference intensely affected the amount of flavor compounds in French bread. The mean relative amount of acetaldehyde in the crust of bread mixed at 27° C was 34.125 and was 16.000 at 29° C. In other words, the residual amount of acetaldehyde at 27° C was more than twice that at 29° C, and results for ethylacetate were similar. Therefore, the experimental difference in mixing temperature as a fermentation condition was designed at two degrees (27 and 29° C) in this study.

The effect of fermentation conditions on the assessment of the sensory evaluations, obtained with the seven-grade, bipolar numerical scales method for French bread produced according to the orthogonal experiment design, were interpreted by the analysis variance. Percentage points of $F$ distribution (Tôkei Suchihyo Hensyuiinkai 1979) at one and three degrees of freedom were $F(1,3; 0.01) = 34.1$, $F(1,3; 0.05) = 10.1$, and $F(1,3; 0.10) = 5.54$.

As shown in Table II, the variance ratios for the four factorial effects were all smaller than $F(1,3; 0.10) = 5.54$. Consequently, the evaluation of fermented flavor was not affected by these four fermentation conditions. As shown in Table III, the variance ratio of final proofing time is 98.917; this verifies the effect of final proofing on the baked flavor at a 99 percent level of significance. The evaluation of baked flavor was increased $1.306 \pm 0.418$ when the final proofing time was lengthened from 40 to 60 min. The effect of proofing time on the total flavor was significant at the 95 percent level, as shown in Table IV. The evaluation of the preference for total flavor was increased $0.868 \pm 0.676$ when the

**TABLE I**
**Layout of Experimental Factors**

| Experiment No. | Factor: Mixing Temp (° C) | Fermentation Time (min) | Punch | Final Proof (min) |
|---|---|---|---|---|
| 1 | 27 | 105 | punch | 40 |
| 2 | 27 | 105 | ··· | 60 |
| 3 | 27 | 135 | punch | 60 |
| 4 | 27 | 135 | ··· | 40 |
| 5 | 29 | 105 | punch | 60 |
| 6 | 29 | 105 | ··· | 40 |
| 7 | 29 | 135 | punch | 40 |
| 8 | 29 | 135 | ··· | 60 |

**TABLE II**
**Analysis of Variance of Fermented Flavor[a]**

| Experiment No. | Data | Effect | Variance | Factor | Variance Ratio |
|---|---|---|---|---|---|
| 1 | −0.33 | 0.414 | | | |
| 2 | 0.33 | −0.250 | 0.125 | Punching | 1.158 |
| 3 | 0.22 | −0.086 | 0.014 | Fermentation time | 0.134 |
| 4 | 0.56 | −0.080 | 0.013 | | |
| 5 | 0.33 | −0.026 | 0.001 | Mixing temperature | 0.012 |
| 6 | 0.33 | −0.250 | 0.125 | | |
| 7 | 0.11 | −0.306 | 0.186 | | |
| 8 | 0.11 | −0.080 | 0.013 | Proofing time | 0.119 |

[a] Ve (error variance) = 0.108; LSD = 0.739.

**TABLE III**
**Analysis of Variance of Baked Flavor[a]**

| Experiment No. | Data | Effect | Variance | Factor | Variance Ratio |
|---|---|---|---|---|---|
| 1 | −0.33 | 0.750 | | | |
| 2 | 0.67 | 0.194 | 0.076 | Punching | 2.209 |
| 3 | 1.11 | −0.250 | 0.125 | Fermentation time | 3.630 |
| 4 | −0.11 | 0.194 | 0.076 | | |
| 5 | 1.22 | −0.080 | 0.013 | Mixing temperature | 0.372 |
| 6 | −0.56 | −0.084 | 0.014 | | |
| 7 | −0.11 | −0.080 | 0.013 | | |
| 8 | 1.11 | −1.306 | 3.406 | Proofing time | 98.917 |

[a] Ve (error variance) = 0.034; LSD = 0.418.

**TABLE IV**
**Analysis of Variance of Total Flavor[a]**

| Experiment No. | Data | Effect | Variance | Factor | Variance Ratio |
|---|---|---|---|---|---|
| 1 | −0.375 | 0.242 | | | |
| 2 | 0.000 | 0.352 | 0.247 | Punching | 2.722 |
| 3 | 0.780 | −0.148 | 0.044 | Fermentation time | 0.488 |
| 4 | −0.220 | 0.182 | 0.066 | | |
| 5 | 1.000 | −0.148 | 0.044 | Mixing temperature | 0.488 |
| 6 | −0.440 | −0.038 | 0.003 | | |
| 7 | −0.220 | −0.318 | 0.203 | | |
| 8 | 0.440 | −0.868 | 1.509 | Proofing time | 16.654 |

[a] Ve (error variance) = 0.091; LSD = 0.677.

**TABLE V**
**Correlation Matrix of Flavor Compounds in Crumb and Sensory Value**

| Compound | Fermented Flavor | Baked Flavor | Total Flavor |
|---|---|---|---|
| iso-Butanol+acetone | −0.238 | 0.059 | 0.213 |
| Ethanol | −0.411 | −0.766 | −0.791 |
| Propanol | −0.211 | −0.790 | −0.755 |
| iso-Butanol | −0.186 | −0.856 | −0.826 |
| Peak 5[a] | −0.011 | 0.502 | 0.537 |
| iso-Amylalcohol | −0.137 | −0.749 | −0.705 |
| Peak 7[a] | 0.000 | 0.088 | 0.049 |
| Fermented flavor | 1.000 | 0.163 | 0.180 |
| Baked flavor | 0.163 | 1.000 | 0.937 |
| Total flavor | 0.180 | 0.937 | 1.000 |

[a] Unidentified $r$ (8, 0.05) = 0.7067; $r$ (8, 0.01) = 0.8343.

**TABLE VI**
**Correlation Matrix of Flavor Compounds in Crust and Sensory Value**

| Compound | Fermented Flavor | Baked Flavor | Total Flavor |
|---|---|---|---|
| Peak 1[a] | 0.491 | 0.633 | 0.730 |
| Peak 2[a] | 0.569 | 0.705 | 0.716 |
| Peak 3[a] | 0.045 | 0.382 | 0.470 |
| Acetaldehyde | −0.150 | 0.301 | 0.294 |
| Peak 5[a] | −0.035 | 0.434 | 0.465 |
| Propanal | 0.458 | 0.698 | 0.779 |
| iso-Butanal | 0.435 | 0.726 | 0.781 |
| Acetone | −0.157 | 0.521 | 0.623 |
| Peak 9[a] | 0.267 | 0.650 | 0.804 |
| Ethylacetate | 0.153 | −0.406 | −0.412 |
| 2-Butanone | 0.220 | 0.765 | 0.909 |
| Ethanol | −0.627 | −0.714 | −0.781 |
| Diacetyl | −0.587 | −0.219 | −0.155 |
| *n*-Propanol | −0.547 | −0.304 | −0.420 |
| iso-Butanol | −0.616 | −0.734 | −0.797 |
| Fermented flavor | 1.000 | 0.163 | 0.182 |
| Baked flavor | 0.163 | 1.000 | 0.937 |
| Total flavor | 0.182 | 0.937 | 1.000 |

[a] Unidentified $r$ = (8, 0.05) = 0.7067; $r$ = (8, 0.01) = 0.8343.

proofing time was lengthened from 40 to 60 min. The effects of other factors on the baked flavor and the total flavor had no significance.

To investigate the relationship between the sensory assessments and flavor compounds measured by gas chromatography in French bread, correlation coefficients were calculated. It was assumed that flavor compounds are limited to the compounds found by gas chromatography or that the compounds produced parallel the compounds detected by chromatography.

Several positive correlations between each flavor compound in the crumb and each evaluation through the sensory test were found (Table V), but none were statistically significant. There was no significant correlation between the evaluation of fermented flavor and the amounts of flavor compounds in the crumb. There was a strong negative correlation found between baked flavor and the various alcohols, especially isobutyl alcohol. The correlation between the preference for total flavor and the evaluation of baked flavor was highly significant.

As shown in Table VI, the correlations between the evaluation of fermented flavor and flavor compounds in the crust were not significant. Significant positive correlations of baked flavor with isobutylaldehyde, 2-butanone, and an unidentified compound (peak 2) and significant negative correlations of baked flavor with ehtyl alcohol and isobutyl alcohol were found. The correlations of the preference for total flavor with isobutylaldehyde, propylaldehyde, 2-butanone, and unidentified compounds (peaks 1, 2, and 9) were negative. The correlation coefficients of the evaluation between baked flavor and the flavor compounds were similar to those between total flavor and the flavor compounds. No correlation was found between each of the sensory evaluation items and diacetyl, which had been presumed to affect fermented flavor (Inoue 1978).

Because the baked flavor has a stronger effect on the total flavor than the fermented flavor, it seems that the chemical reactions that occur during the baking process give rise to several flavor compounds that contribute to the flavor of the bread. It was found that a higher evaluation of French bread was obtained with an increase in the amount of carbonyl compounds such as 2-butanone, isobutylaldehyde, and so on, and there was a reverse effect obtained with an increase of alcoholic compounds such as ethyl alcohol and isobutyl alcohol.

Although the correlation between the preference for total flavor through sensory tests and 2-butanone were very high, it was assumed that 2-butanone was not the main compound directly affecting the French bread's flavor, because the peak area of 2-butanone reported by Hironaka (1985c) was low, and the threshold value of 2-butanone reported by Suga and Watanabe (1972) is considerably larger. Hence it was speculated that the flavor of French bread was affected by propylaldehyde, isobutylaldehyde, and unidentified (peaks 1, 2, and 9) or unknown compounds. However, as shown in Tables III and IV, the sensory assessment of French bread by Japanese was affected only by the condition of final proofing time. This is because the amount of alcoholic compounds was considerably decreased with the proofing time (Hironaka 1985c), and the effect of the decrease of alcoholic compounds on the bread flavor was larger than the effect of the increase of carbonyl compounds. Therefore, it is speculated that the main reasons for the increase of preference are the decrease of alcohols and the increase or carbonyl compounds with longer proofing time.

Although the final proofing time is a most important condition, it is also necessary to control mixing temperature in French bread production. A little difference in mixing temperature has a larger effect on the amount of carbonyl compounds (which are important flavor compounds in the bread) than the punching or final proofing time. Consequently, in order to make French bread with an excellent flavor, the bread should be made at the lower mixing temperature and with enough proofing time.

## LITERATURE CITED


AISHIMA, T. 1983. Multivariate analysis of sensory characteristics and production control of foods. J. Agric. Chem. Soc. Jpn. 57:235.

CHARALAMBOUS, G., ed. 1979. Analysis of Foods and Beverages. Academic Press: New York.

HIRONAKA, Y. 1983. Effect of fermentation conditions on the quality of white bread produced by straight dough method. J. Jpn. Soc. Food Sci. Technol. 30:516.

HIRONAKA, Y. 1985a. Effect of fermentation conditions on the flavor substances in sweet baked goods produced by the sugar containing sponge dough method. J. Jpn. Soc. Food Sci. Technol. 32:592.

HIRONAKA, Y. 1985b. Effect of fermentation conditions on the quality of french bread produced by straight dough method. J. Jpn. Soc. Food Sci. Technol. 32:664.

HIRONAKA, Y. 1985c. Effect of fermentation conditions on the flavor substances in french bread produced by the straight dough method. J. Jpn. Soc. Food Sci. Technol. 32:486.

INOUE, T. 1978. Brewing of beer and diacetyl. Chem. Biol. 16:706.

JOHNSON, J. A., ROONEY, L., and SALE, A. 1966. Chemistry of bread flavor. Page 154 in: Flavor Chemistry. Advances in Chemistry Series. Vol. 56. Am. Chem. Soc.: Washington, DC.

KAWAKITA, T., and YAMADA, M. 1978. Sensory Tests Ishiyaku Press: Tokyo.

MAGA, J. A. 1974. Bread flavor. CRC Crit. Rev. Food Technol. 5:55.

MULDERS, E. J. 1973. Qualititative determination of constituents in the vapour and their odour values. Z. Lebensm. Unters. Forsch. 151:310.

OKUNO, T., and YOSHIGA, T. 1980. Experimental design. Baihukan Co.: Tokyo.

RICHARD-MOLARD, D., NAGO, M. C., and DRAPRON, R. 1979. Influence of the breadmaking method on french bread flavor. Bakers Dig. 53(3):34.

SATŌ, S. 1978. Sensory test primer. Nikkagiren Co.: Tokyo.

SUTHERLAND, R. W. 1976. pH and TTA in baking. Bakers Dig. 50(2):47.

SUGA, K., and WATANABE, S. 1972. Aromatic chemistry. Kodansha Co.: Tokyo.
TOKEI SUCHIHYO HENSYUIINKAI. 1979. Concise statistical tables. Nippon Kikaku Kyokai: Tokyo.
WISEBLATT, L. 1961. Bread flavor research. Bakers Dig. 35(5):60.
ZENKOKU SHOKUSEIKATSU KAIZENKYOKAI. 1981. Present condition of rice and wheat products. Japanese Society of Diet Improvement: Tokyo.

[Received May 17, 1985. Revision received April 21, 1986. Accepted April 24, 1986.]