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Influence of Butter and/or Vegetable oil on Flavors of Roux Prepared from Wheat Flour and Fat/Oil

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To examine the influence of preparation method (white or brown roux prepared by heating to 130℃ and 170℃, respectively) and fat/oil ingredients (butter fat, corn oil and salad oil), the flavors of roux prepared from wheat flour were studied by sensory analysis and chemical analyses of the aroma compounds with gas chromatography (GC) and GC-MS, followed by GC-Olfactometry.

Sensory evaluation of roux flavors in butter roux, corn oil roux and salad oil roux showed that the butter roux had a strong sweet odor and both the butter roux and the corn oil roux had generally preferable flavor. Then, the various types of roux were subjected to chemical analyses.
Through comparisons of each component for the butter roux and the corn oil roux, it was found that the difference in flavor was especially apparent in the amount of carbonyl compounds and Maillard reaction products. That is, the butter roux was composed of largely aliphatic methyl ketones (C7-C11) in both the white roux (heated to 130℃) and the brown roux (heated to 170℃), and mostly furans and somewhat cyclic ketoenols such as maltol in the brown roux, while the corn oil roux included more benzaldehyde in the white roux, and phenylacetaldehyde and (*E, E*)-2, 4-decadienal in the brown roux. Furthermore, GC-O analysis showed that butanoic acid, which confers a rancid odor, δ-decalactone, which confers a floral odor, and furfuryl alcohol and 2-nonanone with a floral odor, respectively might contribute to the flavor of the butter roux, while (*E, E*) 2, 4-decadienal with a pungent odor and benzaldehyde with an almond-like odor might affect the flavor of the corn oil roux. Therefore, the difference of flavor of the two roux may originate in the composition of the fatty acids of fat/oil.

Mixing various fat/oil in the form of butter and corn oil showed the effect of using proportions of ingredients for aroma of the cooked product, especially in the white roux.

Keywords: roux, flavor, fat/oil, sensory evaluation, aroma component

Introduction

White or brown roux prepared by heating wheat flour and butter to 130℃ or 170℃, respectively, is used as a base of various sauces and soups in cooking. A previous paper on roux and sauces found that the taste and flavor was more positively correlated with overall acceptance in sensory tests than sauce viscosity (Kato, 1995). So far, viscosity, rheological properties, and sensory evaluation of roux have been studied (Osawa and Nakahama, 1973; Shimada *et al.,* 1973). Therefore, in a previous paper, roux prepared from wheat flour and butter by heating to various temperatures were examined by chemical and sensory analyses (Kato, 2003), and it was reported that large quantitative changes in aroma components occurred with increased temperatures and were reflected in changes in the functional groups of ketones, carboxylic acids, furans, and pyrazines; sensory differences in the white and the brown roux were great for buttery and sweet attributes and odor preferences; sensory odor preferences correlated significantly with the ketone component (mainly methyl ketones) or cyclic ketoenols such as maltol, which are evaluated as having a sweet flavor. Although the flavor of the butter roux in the above study was almost clarified, little work on the flavor of roux prepared from other vegetable oils has been done. Therefore, the volatile flavor components of roux prepared from wheat flour and vegetable oil remained to be characterized.

The objective of this study is to determine flavor characteristics of the two roux (white and brown) by comparing roux made from butter fat, corn oil and salad oil, using sensory analysis, gas chromatography (GC), and GC-MS analysis, followed by GC-olfactometry. In addition, methods to create a more desirable roux flavor by mixing butter and corn oils were examined.

Materials and Methods

Materials and chemicals Materials were wheat flour (soft flour, Nisshin Flour Co., Japan), butter (Yukijirushi Dairy Co.), corn oil (Ajinomoto Co., Japan) and mixed oil of soybean and rape, termed “salad oil” (Nisshin Oil Manufacture Co.). The wheat flour, and the butter fat/oil, corn oil, and salad oil manufactured within one month were purchased from a local market. Standard chemi-

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cals to identify or confirm the compounds in aroma concentrates were obtained from commercial sources.

Although compositions of fatty acids in the fat and oil are introduced in reference (Fujimoto 1998), we confirmed the compositions of fatty acids in the butter, the corn oil, and the salad oil by GC analysis of the methyl-esterized products of fatty acids from fat/oil sources. The major fatty acids were palmitic acid ($C_{16:0}$) and oleic acid ($C_{18:1}$) in butter, while linoleic acid ($C_{18:2}$) and oleic acid in corn oil, and oleic acid and linoleic acid in salad oil. These data were supported by iodine values (I.V.) of 29.3, 134.2 and 118 for butter, corn oil and salad oil, respectively.

Sensory evaluation of the roux samples Roux samples for the sensory analysis were prepared from wheat flour and butter fat/oil, corn oil, and salad oil. After the fat/oil (30 g) was warmed to 40℃ in an aluminum pan, the wheat flour (30 g) was added and heated in air as under normal cooking conditions, until it reached 130℃ (for white roux) or 170℃ (for brown roux) with constant increase in temperature of the electric cooker (the heating time of the white roux was about 11–12 min and that of the brown roux was 18–19 min), as described in the previous paper (Kato, 2003).

In the first sensory test, intensity of the sweet odor and overall flavor, as well as degree of flavor preference for three kinds of roux samples heated to 130℃ or 170℃ were evaluated by twenty-four semi-trained female students majoring in home economics by Scheffe's paired comparison test. In the test, the paired samples were rated using seven-point scale ranging from 3 to -3. The intensity of the odor of first presented sample was compared with the second sample: 3, much stronger; 0, almost same; -3, much weaker, and the degree of flavor preference was also compared: 3, more desirable; 0, almost same; -3, much less desirable.

In the second sensory test, four kinds of roux sample were prepared from the wheat flour and four kinds of mixing fat/oil (only butter; butter and corn oil (2: 1); butter and corn oil (1: 2); only corn oil), and they were evaluated for sweet and aromatic odors and the flavor preference by twenty-one female students as panelists, using a ranking method.

The roux samples of approximately 10 g in teacups of about 150-ml capacity were presented to the panelists. The samples were covered with plastic film and aluminum foil to seal in the flavor and conceal the roux color, then warmed to a constant temperature of 50℃ in an oven to maintain constant head vapor in the teacups and to allow samples to be balanced randomly among the tasting sessions.

Instrumental and chemical analysis for roux volatiles As roux samples for chemical analysis, the butter roux and the corn oil roux were selected from the results of flavor preference by the above first sensory test. The roux sample heated to 130℃ as for sensory testing, but the roux sample was heated to 170℃ with higher electric power than for sensory sampling, as in the previous study (Kato, 2003) in order to shorten the heating time to about 7–8 min. Aroma concentrates from the two types of butter roux and the two types of corn oil roux (heated to 130℃ or to 170℃) were obtained by steam distillation under reduced pressure, followed by refined diethyl ether extraction. In the procedure, 2, 4, 6-trimethyl-pyrazine (Chung and Cadwallader, 1993) was used as the internal standard to examine the amount of each component. Thus, two replicates of each sample from each roux were prepared for GC testing to ensure accuracy. The analysis was conducted under conditions almost identical to those of GC and GC-MS in the previous paper (Kato, 2003). GC was carried out on a Shimadzu model 12 gas chromatograph with a capillary-type CBP 20M column (50 m long × 0.25 mm i.d.), as used previously. GC-MS was carried out on an HP 5890 series-II gas chromatograph coupled to an HP model 5972 mass spectrometer with a DB wax-fused silica column (60 m long × 0.25 mm i.d.).

Gas chromatography with Olfactometry (GC-O) analysis In GC-O analysis, fifteen characteristic compounds were selected based on chemical analysis of the volatiles from butter and corn oil roux. The analysis was performed using serial dilutions (Blank and Grosch, 1991) with a 10 ml solution (a total weight of 8.2 g) of an equivalent mixture (a weight of 0.4 g per compound) of 15 standard chemicals and n-hexane as a solvent, using GC on the capillary-type CBP 20M described above. The aroma perception was conducted at a sniffing port on the GC by three semi-trained panelists.

Statistical analysis The rating data of panelists by Scheffe's paired comparison test were conducted by the analysis of variance, using multi-statistics (Social Survey Research Information Co., Japan).

Results and Discussion

Sensory analysis for the flavor of the roux samples The intensity of the sweet odor and of the overall flavor, as well as the grade of flavor preference for three kinds of roux samples in the white or the brown roux, were evaluated by a panel of twenty-four female students using sensory Scheffe's paired comparison test. The roux samples were the butter roux, the corn oil roux and salad oil roux. The results of the sensory test on the white roux and the brown roux are shown in Table 1. In the white roux heated to 130℃, the butter roux was evaluated highly for the intensity of the sweet odor and the overall flavor, and the results were significant at the level of $p < 0.05$, compared with the corn oil roux or the salad oil roux, while in the brown roux heated to 170℃, the butter roux showed a significantly high evaluation for the intensity of the sweet odor ($p < 0.05$), compared to the other kinds of roux, but for the intensity of the overall flavor, there were no significant differences among these three kinds of roux.

On the other hand, the evaluations for flavor preference did not show any significant differences among three kinds of the roux, in the roux heated to 130℃ or 170℃, but there was a tendency for the butter roux and the corn oil roux to be preferable to salad oil roux. Therefore, we selected the corn oil roux for chemical comparison with the butter roux.

Table 1. Comparison of three kinds of roux samples by a sensory Scheffe's paired comparison test.

n=24

Item	White roux (heated to 130°C)				Brown roux (heated to 170°C)			
	B_w [a]	C_w	S_w	Significance [c]	B_b [a]	C_b	S_b	Significance [c]
Intensity of sweet odor	0.65 [b]	-0.31	-0.33	B_w-C_w * B_w-S_w *	0.75	-0.04	-0.71	B_b-C_b * B_b-S_b *
Intensity of overall flavor	0.58	-0.25	-0.33	B_w-C_w * B_w-S_w *	0.13	-0.21	0.08	n.s.
Flavor preference	0.06	0.08	-0.15	n.s.	0.29	0.06	-0.35	n.s.

[a] B_w, C_w and S_w represent white roux made of butter, corn oil and salad oil, respectively, and B_b, C_b and S_b represent brown roux made of the same ingredients as in white roux. [b] Values are the mean values of sensory evaluation for each sample by Scheffe's paired comparison test. In this test, the evaluation was conducted by using rating scale of seven grades from 3 to -3, and the obtained data were examined statistically by analysis of variance. [c] * $p<0.05$, n.s.: no significance.

Table 2. Yields of aroma concentrates from butter and corn oil roux, and the characteristics of flavor and color in each roux.

	Sample [a]	Yield [b] (mg/100 g)	Flavor description [c]	Color characteristics H, V / C [d]	Color
Roux heated to 130°C	Butter roux	3.05	milk-like, sweet	5Y, 9 / 6	creamy
	Corn oil roux	1.62	milk-like, pungent	7.5Y, 9 / 4	light creamy
Roux heated to 170°C	Butter roux	3.70	burnt, caramel-like	10YR, 7 / 8	brown
	Corn oil roux	1.91	burnt, fatty	2.5Y, 7/ 10	light brown

[a] Roux was prepared from wheat flour and fat/oil of butter or corn oil (weight ratio, 1:1).
[b] Yield of aroma concenrate was presented with mg/100 g of material. [c] Refer evaluation for roux flavor shown in Table 1. [d] Munsell System: H, Hue; V, Value; C, Chroma.

Yield of the aroma concentrate and flavor profile Each aroma concentrate obtained by the chemical method from each sample of the butter roux and the corn oil roux was weighed, and the yields are shown in Table 2. The yield of each aroma concentrate from two types of butter roux (heated to 130℃ and 170℃) was 3.05 and 3.70 mg/100 g of materials, respectively. The yield from each type of corn oil roux (heated to 130℃ and 170℃) was almost half the yield of the butter roux, respectively.

Compared to butter roux heated to 130℃ or 170℃ with the butter roux heated in several stages, as previously reported Kato (2003), the amount of aroma concentrate yield from the butter roux heated to 130℃ was almost identical to the roux heated to 120℃ or 140℃ in the previous paper. However, the amount of butter roux heated to 170℃ seemed to decrease a little in comparison with the roux heated to 160℃ or 180℃ in the previous paper. This suggests that the butter roux heated to 170℃ was heated more quickly than under the conditions of Kato's paper (2003).

As shown in Table 2, the characteristics released flavor of the roux heated to both 130℃ and 170℃ were a sweet odor for the butter roux but a fatty and pungent odor for the corn oil roux. Regarding color, the color of the corn oil roux was brighter than that of the butter roux.

Chemical analysis of the aroma concentrate from butter roux and corn oil roux The aroma concentrates from the two types of butter roux heated to 130℃ and 170℃ were analyzed by GC. Each peak on the chromatogram was confirmed based on results in the previous paper for the butter roux heated to 120℃-180℃ (Kato, 2003), while those from the two types of corn oil roux were analyzed by GC and GC-MS and each peak was identified and confirmed by mass spectra and Kovats index (K.I.) values of reference or authentic compounds. Four representative chromatograms are shown in Fig. 1.

The amount (μg/10 g of materials) of each aroma component in the butter roux and the corn oil roux, heated to 130℃ or 170℃, is shown in Table 3, in order of a retention time according to functional groups. The functional groups were classified into ten classes of hydrocarbons, aliphatic alcohols, aldehydes; ketones, carboxylic acids, lactones, furans, cyclic ketoenols, pyrazines, and other nitrogen-containing compounds. Then, the composition of the functional groups in the butter and the corn oil roux heated to 130℃ or 170℃ were calculated from the total amounts of components in the roux, as shown in Fig. 2.

In the white roux heated to 130℃, the carboxylic acids are the highest proportion (approximately 30%) of all functional groups in both the butter roux and the corn oil roux, but the other functional groups were present in more or less different proportions between the two kinds of roux, especially in carbonyl compounds; that is, the butter roux was quantitatively largely comprised of ketones (about 20% of all components) and the corn oil roux aldehydes had about 15%. Furthermore, the quantitative differences of each component between the two roux were surveyed from Table 3. The butter roux was

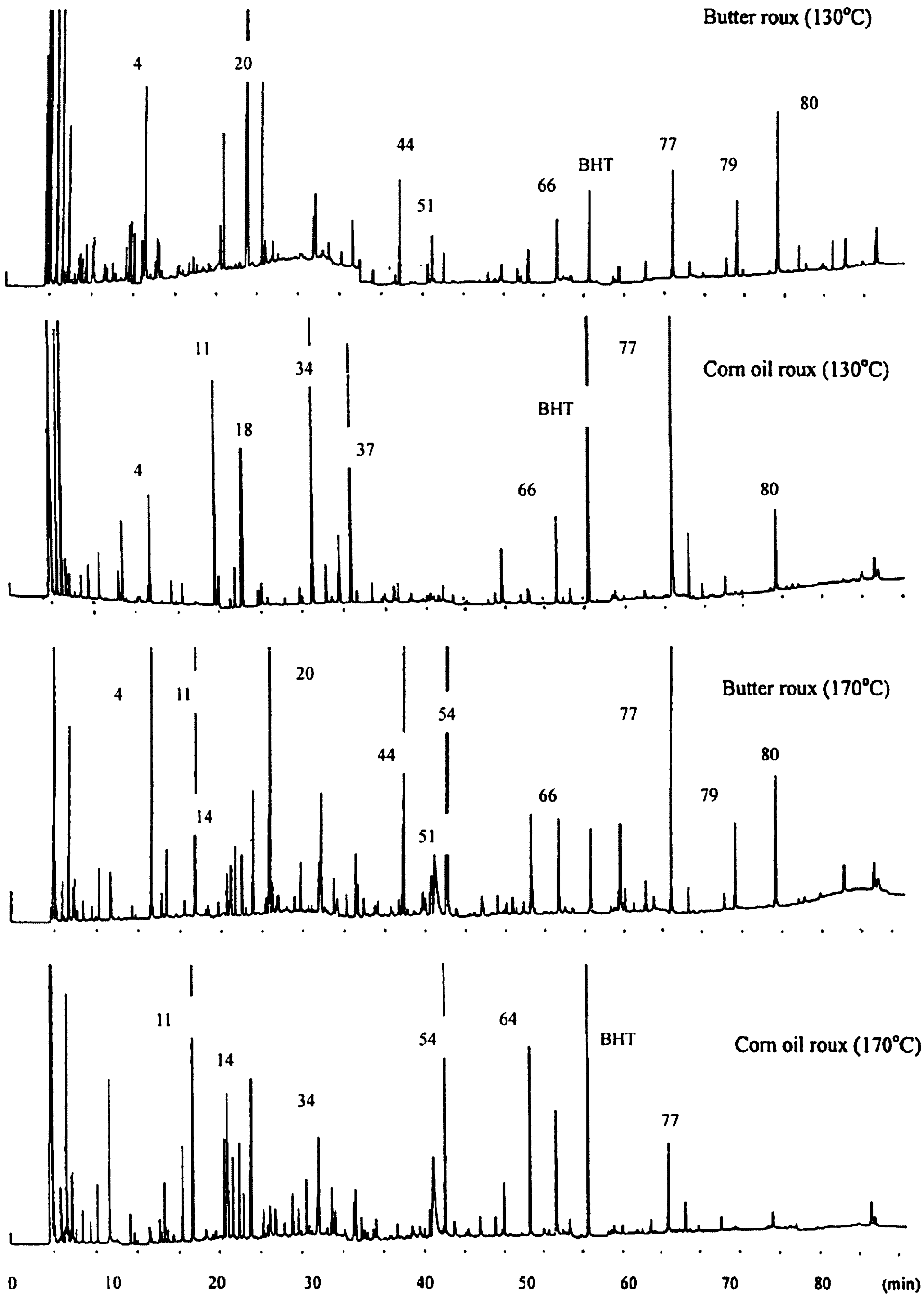

Fig. 1. Gas chromatograms of the volatiles from butter roux and corn oil roux, heated to 130℃ or 170℃.

GC analysis conditions: detector, FID; column, CBP 20 M capillary type (50 m long×0.25 mm i.d.); oven temp., 60–220℃ (2℃/min); carrier gas, herium (1.0/min). Main components in each roux are represented with peak numbers shown in Table 3: 4, 2-heptanone; 11, methylpyrazine; 14, 2, 5-dimethylpyrazine; 18, hexanol; 20, 2-nonanone; 34, furfural; 37, benzaldehyde; 44, 2-undecanone; 51, butanoic acid; 54, furfuryl alcohol; 64, (E, E)-2,4-decodienal; 66, hexanoic acid; 77, octanoic acid; 79, δ-decalactone; 80, decanoic acid. BHT: Butylated hydroxytoluene.

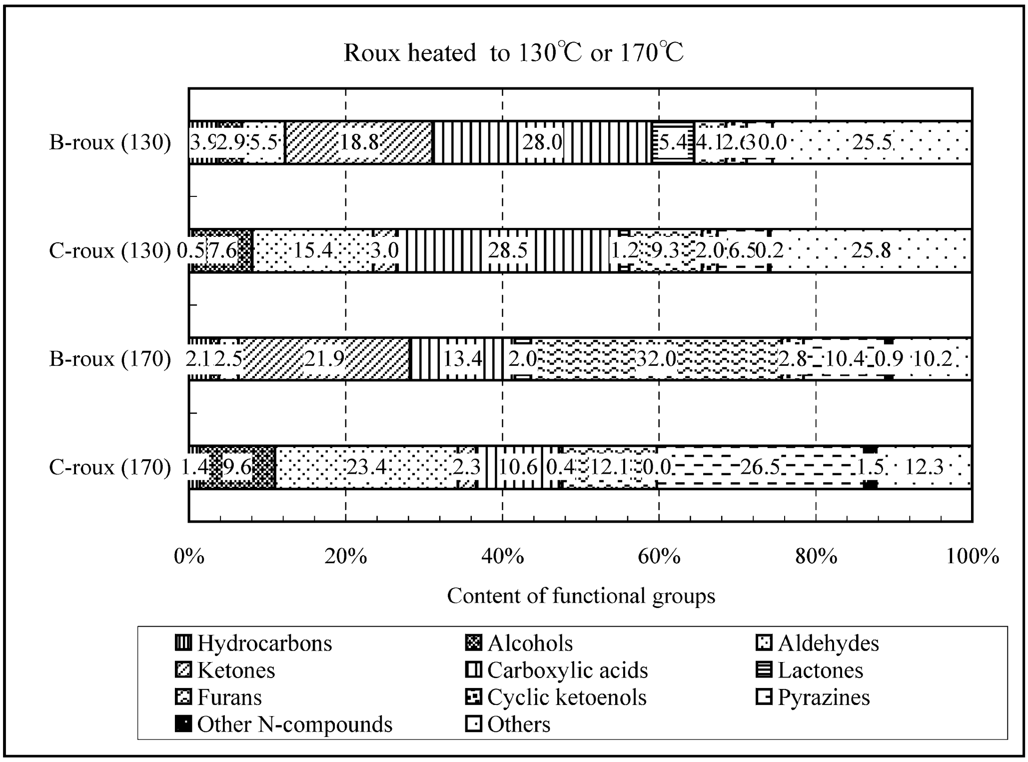

Fig. 2. Comparison of composition of functional groups in butter roux with that in corn oil roux, heated to 130℃ or 170℃.
B-roux (130) and C-roux (130) represent butter roux and corn oil roux, heated to 130℃, and B-roux (170) and C-roux (170) also show the two kinds of roux heated to 170℃, respectively.
The quantity (%) of the others described in this figure might be mainly the total quantity of minor peaks on the GC.

found to contain 2-heptanone, 2-nonanone and 2-undecanone varieties of the methyl ketones with a floral odor (Chung and Cadwallader, 1993; Bruechert *et al.,* 1988) at the high levels of 12.4, 23.2 and 14.0 μg/10 g, respectively, but in the corn oil roux, those compounds occurred in traces quantities. On the other hand, regarding aldehydes, in the corn oil roux, heptanal with a pungent odor and benzaldehyde with an almond-like aroma, which was proposed to form from 2, 4-decadienal and an aliphatic aldehyde such as hexanal at high temperatures (Shigematsu *et al.,* 1977) existed in amounts of 5.6 and 16.6μg/10 g, respectively, while in the butter roux, nonanal and benzaldehyde were present in moderate quantities.

In the brown roux heated to 170℃, the composition of the butter roux and the corn oil roux shown in Fig. 2 revealed that the proportion of carboxylic acids greatly decreased to about 10–15% in both kinds of roux, and in contrast, that of furans increased markedly only in the butter roux, reaching more than 30% of the total components. The proportions of ketones and aldehydes in the butter roux and the corn oil roux of 170℃, showed a similar tendency to compounds in the two kinds of roux heated to 130℃. In detail, the total amount of methyl ketones, such as 2-heptanone and 2-nonanone, increased considerably in the butter roux, compared with the butter roux heated to 130℃, though they were absent in the corn oil roux. However, in the corn oil roux, phenylacetaldehyde with a violet flowery odor and *(E, E)*-2, 4-decadienal with a pungent odor, were contained more quantitatively. The phenylacetaldehyde could be expected to yield only by Strecker degradation of phenylalanine, as reported by Mottram and Edwards (1983), and the dienals as *(E, E)*-2, 4-decadienal were possibly produced by hydroperoxidation and/or hydroxylation in heated trilinolein contained largely in corn oil (Warner *et al.,* 2001). However, in the butter roux, aldehydes were present in small amounts, because linoleic acid accounts for only about 1% of all fatty acids in lipids. Furans were characterized predominantly by furfuryl alcohol, which existed in the butter roux at a concentration of 105.0 μg/10 g, higher than in the corn oil roux. Pyrazines, which have a burnt or roasted odor, in the species and the amounts increased markedly in both the butter roux and the corn oil roux, compared with the roux heated to 130℃. Especially, the corn oil roux contained pyrazines in the high proportion (about 27% of all components), but the components of long-chain (carbon number of 5 or 6) substitution on the pyrazine ring could not be detected (Bruechert *et al.,* 1988; Huang *et al.,* 1987; Garlin *et al.,* 1986). That might be considered when preparing the roux under hard-heating conditions in which no water is added to the ingredients. Then, it should be noted that cyclic ketoenols such as maltol, with a sweet cooked aroma are generated via the Maillard reaction (Shigematsu *et al.,* 1977; Blank *et al.,* 1996) and were detected only in the butter roux of 170℃, but not in the corn oil roux.

Table 3. Components in butter and corn oil roux, heated to 130℃ or 170℃.

(μg/10 g)

Peak No.	K-index [a]	Component [b]	Roux heated to 130°C B-roux [d]	Roux heated to 130°C C-roux	Roux heated to 170°C B-roux	Roux heated to 170°C C-roux
Hydrocarbons						
9	1224	Dodecane	1.1	- [e]	0.2	-
13	1298	Tridecane	1.0	-	0.8	-
23	1394	Tetradecane	2.7	-	1.1	1.4
29	1481	Pentadecane	2.5	-	2.6	-
38	1526	1-Decene [c]	-	-	-	1.0
47	1616	Hexadecane	0.7	0.4	0.4	-
53	1643	Heptadecane	0.8	-	2.7	-
62	1783	Octadecane	1.3	-	1.1	-
67	1857	Nonadecane	0.8	0.4	0.6	0.3
69	1940	Icosane	-	-	0.4	-
82	2305	Tricosane	1.2	-	0.4	-
		Total	12.1	0.8	10.3	2.7
Alcohols						
3	1130	Butanol	3.5	4.0	0.6	1.2
6	1196	3-Methyl-butanol [c]	-	-	-	1.5
10	1241	Pentanol	1.1	-	0.8	4.1
18	1345	Hexanol	0.9	2.6	0.5	2.2
28	1460	1-Octen-3-ol	-	-	-	2.5
30	1481	2-Ethyl-1-hexanol [c]	-	2.3	-	2.9
40	1535	3-Methylcyclopentanol [c]	-	-	-	0.5
41	1549	Octanol	1.8	1.1	0.9	1.0
46	1615	(*E*)-2-Octen-1-ol [c]	-	0.6	-	0.7
48	1618	2-Methyl-1-octanol [c]	-	-	-	0.4
58	1732	Decanol	1.7	0.3	0.3	-
68	1870	Benzyl alcohol	-	1.4	-	1.4
70	1946	2-Phenyl ethanol	-	-	0.4	-
		Total	9.0	12.3	3.5	18.4
Aldehydes						
1	959	Pentanal	2.3	1.0	1.0	1.1
2	1070	Hexanal	2.7	0.2	2.4	7.5
5	1177	Heptanal	-	5.6	0.8	0.6
12	1282	Octanal	0.6	-	0.7	0.7
21	1386	Nonanal	4.2	0.3	2.0	2.3
25	1431	(*E*)-2-Octenal	-	-	-	1.3
37	1517	Benzaldehyde	7.0	16.6	2.0	2.8
39	1531	(*E,E*)-2,4-Octadienal	-	-	-	0.8
52	1638	Phenylacetaldehyde [c]	-	-	-	14.5
56	1694	Dodecanal	-	0.3	0.3	-
60	1755	(*E,Z*)-2,4-Decadienal	-	-	-	2.7
64	1798	(*E,E*)-2,4-Decadienal	-	0.8	-	10.3
		Total	16.8	24.8	9.2	44.6

To summarize, the difference of flavors between the butter roux and the corn oil roux was especially seen the amount of the carbonyl compounds consisting of ketones and aldehydes, and the Maillard reaction products, and differences of roux flavor are considered to originate in the composition of fatty acids of fat/oil as ingredients of roux.

GC-Olfactometry (GC-O) analysis for characteristic odorants in the roux In recent years, a system, called GC-O, have been developed to rank the 'important' or at least the most potent odorants in foods. This technique involves the formalized sensory testing of gas chromatographic effluents, and through this method, we were able to obtain a list of important odorants in food (Acree and Bloss, 1996).

In this study, fifteen characteristic compounds of three aldehydes, two ketones, three carboxylic acids, lactone, two alcohols, two furans, and two pyrazines were selected based on quantity and quality differences of each compound between the butter roux and the corn oil roux, and GC retention time of the compounds via chemical analysis of the volatiles in the two kinds of roux, as shown in Fig. 1 and Table 3. Then the flavor dilution factor of

Ketones						
4	1174	2-Heptanone	12.4	1.0	22.6	0.7
20	1381	2-Nonanone	23.2	1.6	30.1	0.7
36	1514	3-Nonen-2-one	-	-	-	2.0
44	1588	2-Undecanone	14.0	1.0	18.5	0.3
63	1795	2-Tridecanone	4.7	0.6	5.7	0.2
75	2004	2-Pentadecanone	2.9	0.7	2.0	0.3
		Total	57.2	4.9	78.8	4.2
Carboxylic acids						
27	1459	Acetic acid	6.7	0.5	3.7	0.3
42	1581	2,2-Dimethylpropionic acid [c)]	-	1.2	-	0.9
51	1638	Butanoic acid	7.7	0.4	10.2	1.7
55	1672	3-Methylbutanoic acid [c)]	-	0.6	-	1.3
59	1740	Pentanoic acid	-	-	-	1.2
66	1845	Hexanoic acid	9.7	5.7	5.8	7.2
71	1946	Heptanoic acid	-	0.7	-	0.4
77	2056	Octanoic acid	25.6	28.0	16.8	5.1
78	2160	Nonanoic acid	3.4	1.4	1.0	0.8
80	2256	Decanoic acid	24.9	5.5	8.6	1.1
81	2297	Benzoic acid	-	0.3	-	0.3
85	2403	Dodecanoic acid	7.2	1.9	2.2	-
		Total	85.3	46.2	48.3	20.3
Lactones						
49	1624	Butyrolactone [c)]	-	0.8	-	0.7
73	1965	δ-Octalactone	3.1	-	1.6	-
79	2256	δ-Decalactone	12.6	0.3	5.7	-
84	2386	δ-Dodecalactone	0.8	1.0	-	-
		Total	16.5	2.0	7.3	0.7
Furans						
31	1482	2-Phenylfuran [c)]	-	-	-	0.6
34	1505	Furfural	5.3	11.0	7.1	5.7
35	1513	2-Acetylfuran	1.2	2.5	1.3	0.5
43	1581	5-Methyl-2-furfural	1.6	0.6	0.7	0.3
54	1657	Furfuryl alcohol	4.4	0.9	105.0	16.0
86	2517	5-Hydroxymethyl-2-furfural	-	-	1.3	-
		Total	12.5	15.1	115.4	23.1
Cyclic ketoenols						
61	1755	2(5H)Furanone	2.5	3.3	0.7	-
65	1801	Cyclotene	-	-	0.5	-
72	1956	Maltol	-	-	7.2	-
83	2363	4,5-Dihydro-5-propyl-2(3H)-furanone	5.3	-	1.9	-
		Total	7.8	3.3	10.3	-

each compound with the odor description by panelists at the sniffing port on the GC for the diluted mixture solution of fifteen standard chemicals was examined (Blank and Grosch, 1991) and is shown in Table 4. The results showed that the highest FD-factor of the compounds was (*E, E*)-2, 4-decadienal, which has a pungent green deep-fried odor, the second was butanoic acid with a rancid odor, and the third was δ-decalactone with a floral and buttery odor. Nonanal with a mild milky and 2-nonanone with a floral odor had middle FD-factor values, and the other ten compounds had low values of FD-factor.

By multiplying the relative value (%) of the FD-factor of each compound for (*E, E*)-2, 4-decadienal with highest FD-factor, and the amount of each compound in Table 3, we calculated the odor potency of each compound in the butter roux and the corn oil roux heated to both 130℃ and 170℃. Table 4 shows a summary of the results (Blank and Grosch, 1991; Le Quere *et al.,* 1996). In the roux heated to 130℃, the butter roux was characterized by high odor potency of butanoic acid, δ-decalactone, and 2-nonanone, while in the corn oil roux, benzaldehyde with an almond-like odor was rated highly. On the other hand, in the roux heated to 170℃, particularly in the butter roux, a minor quantity of butanoic acid had a higher odor potency than furfuryl alcohol, which was the predominant component. In the corn oil roux, (*E, E*)-2, 4-

Pyrazines						
7	1206	Pyrazine	-	-	3.3	2.6
11	1260	Methylpyrazine	2.0	1.2	15.3	19.7
14	1313	2,5-Dimethylpyrazine	3.8	6.2	2.2	4.7
15	1318	2,6-Dimethylpyrazine	1.6	0.7	2.7	6.8
16	1320	2-Ethylpyrazine	0.6	1.8	3.5	3.7
17	1338	2,3-Dimethylpyrazine	0.6	0.5	3.2	4.7
19	1377	2-Ethyl-6-methylpyrazine	0.7	-	0.9	1.4
22	1393	2-Ethyl-3-methylpyrazine	-	-	0.9	-
24	1431	Trimetylpyrazine	0.7	-	2.7	2.2
26	1447	Ethenylpyrazine	-	-	0.3	2.6
32	1486	2-Ethenyl-6-methylpyrazine [c)]	-	-	0.3	0.4
33	1489	1-Methyl-ethenylpyrazine [c)]	-	-	-	1.7
50	1631	2-Acetylpyrazine	-	-	2.1	-
		Total	9.9	10.5	37.4	50.5
Other nitrogen-containing compounds						
45	1594	2-Acetylpyridine	-	-	0.4	-
57	1714	3-Methyl-1H-pyrrole [c)]	-	-	0.9	1.2
74	1982	2-Acetylpyrrole	-	0.3	0.5	0.6
76	2020	1H-Pyrrole-2-carboxaldehyde	-	-	1.3	1.2
		Total	-	0.30	3.1	3

[a)] Kovats index of samples. [b)] The components are listed in order of their retention times according to the functional groups. [c)] Tentatively identified. [d)] B-roux and C-roux represent butter roux and corn oil roux, respectively. [e)] -, not detected.

Table 4. Components with associated descriptions as determined by GC-Olfactometry and odor potency of each component in butter roux and corn oil roux.

No.[a)]	Component [b)]	Flavor dilution (FD)		Odor description [d)]	Odor potency [e)]			
		FD	$_{rel}$ FD [c)] (%)		Roux of 130°C		Roux of 170°C	
					B-roux [f)]	C-roux	B-roux	C-roux
3	Butanol	13	1.05	floral	△	△	△	△
11	Methylpyrazine	13	1.05	roasty	△	△	△	+
14	2,5-Dimethylpyrazine	78	6.25	roasty	+	+	△	+
20	2-Nonanone	117	9.38	floral, fruity	+++	△	++++	△
21	Nonanal	156	12.56	milky	++	△	+	+
35	2-Acetylfuran	13	1.05	sweet	△	△	△	△
37	Benzaldehyde	78	6.25	almond-like	+	+++	△	+
41	Octanol	39	3.13	floral	△	△	△	△
44	2-Undecanone	19.5	1.56	floral	+	△	+	△
51	Butanoic acid	936	75.00	fatty, rancid	+++++	+	+++++	+++
54	Furfuryl alcohol	39	3.13	floral	△	△	++++	++
64	*(E,E)* -2,4-Decadienal	1248	100.00	pungent, green, deep-fried	-	++	-	+++++
77	Octanoic acid	13	1.05	buttery	+	+	△	△
79	δ-Decalactone	624	50.00	floral, buttery	+++++	△	++++	-
80	Decanoic acid	78	6.25	buttery	+++	+	++	△

[a)] Peak numbering of components as in Table 3. [b)] The characteristic compounds selected from each functional group on basis of GC analysis of each roux are shown in Fig. 1. Sample solution containing the equivalent (weight) of 15 standard chemicals was diluted moderately with n-hexane, as shown in this Table.
[c)] $_{rel}$ FD: relative flavor dilution value (%) for FD of (*E,E*)-2, 4-decadienal. [d)] Perceived at sniffing-port on GC.
[e)] Odor potency of each component was obtained by multiplying $_{rel}$ FD-factor of a compound and the amount of the compound in Table 3 and , and it prays a role as an indicator in contributing to the flavor of each roux. Grades of odor potency: 0.1~ , △; 20~ , +; 50~ , ++; 100~ , +++; 200~ , ++++; 500~, +++++; -, not detected.
[f)] B- and C-roux represent butter roux and corn oil roux, respectively.

Table 5. Flavor improvement attempt in roux by mixing butter and corn oil as ingredients by sensory tests.

Item	Sensory test		Roux sample (heated to 130℃)				Roux sample (heated to 170℃)			
			a [b]	b	c	d	e [b]	f	g	h
Sweet odor	Test 1 [a] (n=11)	Total [c]	23	17 *	34	36	15 *	29	32	34
		Ranking	2	1	3	4	1	2	3	4
	Test 2 (n=10)	Total	20	23	26	31	16 *	18	37 *	29
		Ranking	1	2	3	4	1	2	4	3
Aromatic odor	Test 1	Total	27	17 *	32	34	26	21	32	31
		Ranking	2	1	3	4	2	1	4	3
	Test 2	Total	22	15 *	30	33	20	19	29	32
		Ranking	2	1	3	4	2	1	3	4
Flavor preference	Test 1	Total	22	19	32	37 *	18 *	27	28	37 *
		Ranking	2	1	3	4	1	2	3	4
	Test 2	Total	20	19	27	34	17	17	34 *	32
		Ranking	2	1	3	4	1	1	4	3

[a] Sensory tests 1 and 2 were performed with eleven and ten panelists, respectively.
[b] Four kinds of roux prepared from wheat flour and various mixing of fat/oil as ingredients were used as samples in roux of 130°C or 170°C: a, e, only butter; b, f, mixing oils (butter : corn oil =2: 1); c, g, mixing oils (butter : corn oil =1: 2); d, h, only corn oil. [c] Total of ranking degree from 1 (high rating) to 4 (low rating) for four samples in each item. * $p < 0.05$, by Kramer's ranking significant Table.

decadienal showed remarkably the highest odor potency among the 15 compounds. In this report, however, neither the furans of 2-acetylfuran and furfuryl alcohol, nor the pyrazines of methylpyrazine and 2, 5-dimethylpyrazine, which are Maillard reaction products generated by heating (Shibamoto, 1989), showed high odor potency. Therefore, the results of GC-O analysis might show that only the odors of one or two compounds do not contribute to the overall flavor of each roux.

Sensory improvement in the roux flavor by mixing butter and corn oil as ingredients As shown in Table 5, sensory ranking tests showed that in the white roux heated to 130℃, panelists evaluated the b-sample (in a mixture of butter and corn oils at a ratio of 2: 1, respectively) more highly than a-sample (in only butter) for sweet odor, aromatic odor, and flavor preference, but in the brown roux heated to 170℃, they highly evaluated, e-sample (only butter) for sweet odor, f-sample (in a mixture of butter and corn oils at a ratio of 2: 1, respectively) for aromatic odor, and both e-sample and f-samples for flavor preference. The effect on the flavor of roux of mixing butter and corn oil might appear when the ratio of butter and corn oil is 2: 1, especially in white roux heated to 130℃.

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