

Isolation and Identification of Volatile Flavor Compounds in Nonfermented Coarse-Cut Sausage. Flavor as a Quality Factor of Nonfermented Sausage. 1

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The volatile flavor compounds of nonfermented sausage have been investigated. A homogenate of commercially processed coarse-cut sausage and water containing 2-heptanol as an internal standard was steam distilled under reduced pressure and the distillate passed through a column packed with porous polymer beads (Porapak Q). The adsorbed volatiles were then eluted with diethyl ether, and the concentrate was analyzed by gas chromatography and gas chromatography-mass spectrometry. Of a total of 108 peaks, 99 peaks were definitely or tentatively identified by mass spectrometry and modified Kovats indices. With respect to the species, liquid smoke, and meat itself, the origins of isolated volatiles were clarified and the change in the composition during processing was revealed.

INTRODUCTION

To date, over 700 volatile compounds from cooked meat have been reported, and the chemistry of meat flavor formation has been extensively investigated and reviewed by many authors (Watanabe and Sato, 1974; van den Ouweland et al., 1978; MacLeod and Seyyedain-Ardebili, 1981; MacLeod, 1986; Shahidi, 1989).

Sausage, one of the most popular meat products, is available in a wide variety of forms such as salami, fresh sausage, frankfurter, wiener, liver sausage, and blood sausage (Belitz and Grosch, 1987). Among them, nonfermented coarse-cut sausage is most widely consumed in Japan due to its mild flavor without fermentation note. The sausage is flavored with spices and smokes, and the flavoring significantly affects its acceptability. There have been many studies on the volatile flavor compounds of various spices such as pepper, coriander, cumin, mace, and cardamon (Varo and Heine, 1970; Redshaw et al., 1971; Richard and Jennings, 1971; Forrest and Heacock, 1972; Debrauwere and Verzele, 1976; Bretschneider and Werkhoff, 1988; Kim et al., 1989). Extensive literature (Lustre and Issenberg, 1969; Fiddler et al., 1970; Hruza et al., 1974; Baltes et al., 1981) exists on the comparison of sawdust smoke and liquid smoke (natural) flavors. Lustre and Issenberg (1970) studied the uptake of phenols from wood smoke in smoked pork bellies. Baltes and Söchtig (1979) reported having identified 14 phenols in a smoke flavor condensate as an admixture to sausages.

Much research has been carried out on the flavor of ham (Ockerman et al., 1964; Lillard and Ayres, 1969; Shen et al., 1988; Berdagué et al., 1991) and fermented sausages (Halvarson, 1973; Berger et al., 1990). However, there has been limited research with respect to volatile flavor constituents of nonfermented sausage. This paper deals with the identification and quantification of volatile flavor compounds in nonfermented coarse-cut sausage in comparison with their composition in a mixed spice and liquid smoke added to the sausage.

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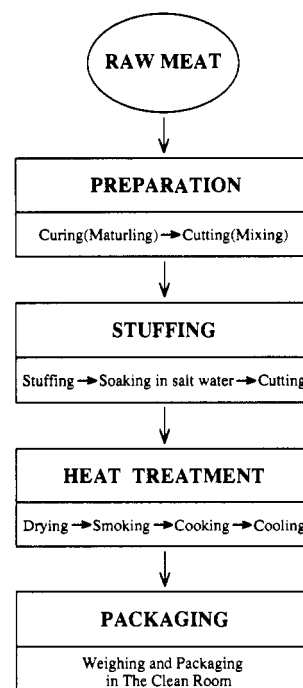


Figure 1. Processing of the nonfermented coarse-cut sausage.

Table I. Formulation of the Nonfermented Coarse-Cut Sausage

ingredient	composition, %	ingredient	composition, %
pork	60.00	salt	1.00
beef	5.00	sodium nitrite	0.02
pork fat	15.00	sodium ascorbate	0.04
water	12.00	other ingredients	6.94

MATERIALS AND METHODS

Materials. The commercially processed sausage was obtained from Marudai Food Co., Ltd. (Osaka, Japan) as a nonfermented coarse-cut sausage with the declared ingredients as shown in Table I, which as manufactured through a series of processes shown in Figure 1. The mixed spice and liquid smoke used in the processing were also from Marudai Food. Diethyl ether and anhydrous sodium sulfate were from Nakarai Tesque, Inc. (Kyoto, Japan). 2-Heptanol was from Tokyo Kasei Kogyo Co., Ltd. (Tokyo, Japan), and methanol was purchased from Wako Pure

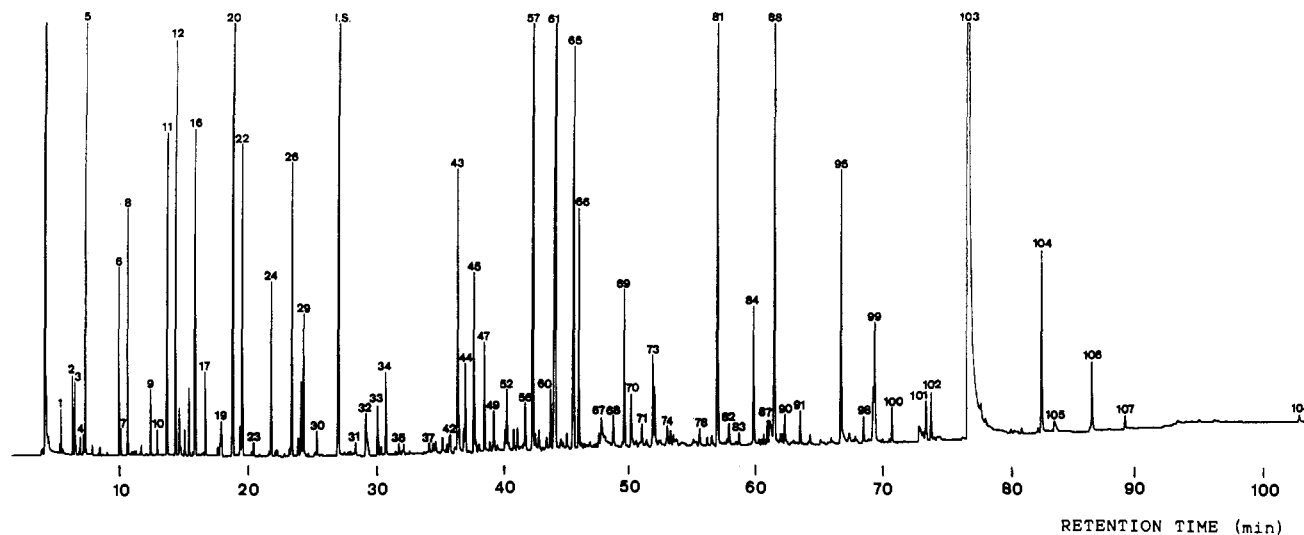


Figure 2. Gas chromatogram of flavor concentrate from coarse-cut sausage. I.S. corresponds to 2-heptanol (internal standard). For more information, see Tables II-IV and Materials and Methods.

Table II. Identification and Composition of Volatile Compounds Derived from Mixed Spice

peak ^a	compound	Kovats index ^b	reliability of ID ^c	content, ^d ppb	relative area, ^e %	
					sausage	mixed spice
3	3-methylbutanal	914	A	55.6	0.6	0.3
4	methyl isobutanoate	924	A	17.9	0.2	tr ^f
5	ethanol	930	A	655.9	6.8	tr
6	α -pinene	1019	A	165.8	1.7	4.0
7	unknown	1022		25.4	0.3	0.5
11	β -pinene	1108	A	376.9	3.9	6.2
12	α -thujene	1120	A	467.0	4.8	4.1
16	Δ^3 -carene	1146	A	379.4	3.9	10.8
17	myrcene	1160	A	93.8	1.0	3.7
18	α -terpinene	1179	A	15.8	0.2	0.5
20	<i>d</i> -limonene	1198	A	1197.3	12.4	10.8
21	β -terpinene	1206	A	46.2	0.5	0.8
22	1,8-cineole	1209	A	400.2	4.1	0.4
24	γ -terpinene	1243	A	214.3	2.2	0.9
25	1,2,3-trimethylbenzene	1257	A	16.7	0.2	0.1
26	<i>p</i> -cymene	1268	A	373.0	3.8	1.1
27	<i>trans</i> -ocimene	1276	A	23.5	0.2	0.2
29	terpinolene	1282	A	175.6	1.8	0.8
44	δ -elemene	1465	A	166.9	1.7	3.3
47	α -copaene	1487	A	165.4	1.7	0.5
57	linalool	1546	A	1141.4	11.8	2.6
58	linalyl acetate	1553	A	49.0	0.5	0.1
59	sesquiterpene hydrocarbon	1562	D	50.2	0.5	0.1
65	β -caryophyllene	1587	A	761.9	7.9	30.2
67	butanoic acid	1630	A	195.1	2.0	0.2
69	2-furanmethanol	1659	A	232.2	2.9	0.1
70	α -caryophyllene	1667	A	115.2	1.2	2.0
73	α -terpineol	1697	A	260.9	2.7	1.6
75	methylphosphonic acid dimethyl ester	1718	C	39.6	0.4	0.4
80	2-butenic acid	1773	A	41.7	0.4	0.2
81	4-(1-methylethyl)benzaldehyde	1781	B	797.3	8.2	3.5
83	sabinol	1810	A	32.4	0.3	0.2
86	unknown	1845		20.6	0.2	0.3
87	hexanoic acid and <i>p</i> -cymen-8-ol	1851	A	144.8	1.5	0.2
90	5-(2-propenyl)-1,3-benzodioxole	1874	C	69.6	0.7	0.4
92	2,6-di- <i>tert</i> -butyl- <i>p</i> -cresol (BHT)	1910	A	31.7	0.3	1.0
93	unknown	1923		27.4	0.3	0.2
98	unknown	1989		49.7	0.5	1.3
102	unknown	2087		86.7	0.9	0.4
104	2,6-dimethoxyphenol	2269	A	323.7	3.3	4.6
106	1,2,3-trimethoxybenzene	2335	B	122.9	1.3	0.1
108	1,4-benzenediol	2693	B	16.1	0.2	1.2
	total			9692.7	100.0	100.0

^a Peak number in Figure 1. ^b Modified Kovats indices calculated for DB-Wax capillary column on the GC system. ^c The reliability of the identification or structural proposal is indicated by the following symbols: A, mass spectrum and retention index identical with those of an authentic sample; B, mass spectrum and Kovats index in agreement with corresponding literature data; C, mass spectrum consistent with spectra found in the literature; D, tentative identification by mass spectrum. ^d Concentration in the sausage. ^e Total amounts of these compounds represented about 38 and 96% of total volatiles in the sausage and the mixed spice, respectively. ^f tr, <0.1%.

Chemical Industries Co., Ltd. (Osaka, Japan). Methanol was purified by passing it twice through a column (50 cm \times 3 cm i.d.)

packed with activated charcoal (analytical grade). Porapak type Q (50-80 mesh) was from Millipore Corp. (Milford, MA).

Table III. Identification and Composition of Volatile Compounds Derived from Liquid Smoke

peak ^a	compound	Kovats index ^b	reliability of ID ^c	content, ^d ppb	relative area, ^e %	
					sausage	liquid smoke
2	ethyl acetate	885	A	50.7	0.7	0.1
3	3-methylbutanal	914	A	55.6	0.8	0.1
4	methyl isobutanoate	924	A	17.9	0.3	0.1
5	ethanol	930	A	655.9	9.3	0.1
8	toluene	1035	A	225.7	3.2	0.1
13	ethylbenzene and (<i>E</i>)-2-pentenal	1125	A	52.3	0.7	0.1
19	<i>o</i> -xylene	1181	A	61.6	0.9	0.1
23	1-ethyl-3-methylbenzene	1222	B	19.7	0.3	0.1
27	<i>trans</i> -ocimene	1276	A	23.5	0.3	0.2
28	α -phellandrene	1279	A	104.8	1.5	0.3
29	terpinolene	1282	A	175.6	2.5	0.1
30	tridecane	1300	A	35.1	0.5	0.8
32	1-hexanol	1353	A	110.5	1.6	1.4
33	2-methyl-2-cyclopenten-1-one	1367	B	75.6	1.1	0.7
37	2-cyclohexen-1-one	1424	B	35.3	0.5	0.1
40	1-hydroxy-2-pentanone	1439	A	46.9	0.7	0.4
41	acetic acid	1442	A	17.6	0.2	4.0
43	2-furfural	1457	A	473.4	6.7	11.4
45	diallyl disulfide	1475	C	283.6	4.0	0.2
49	1-(2-furanyl)ethanone	1497	B	84.4	1.2	0.9
51	camphor	1511	A	52.9	0.7	0.8
53	3-oxopentanoic acid methyl ester	1522	C	46.5	0.7	0.8
54	1-(acetyloxy)-2-butanone	1526	C	44.0	0.6	0.8
55	propanoic acid	1531	A	25.5	0.4	1.6
59	sesquiterpene hydrocarbon	1562	D	50.2	0.7	0.3
60	isopulegol	1567	A	101.0	1.4	2.0
67	butanoic acid	1630	A	195.1	2.8	1.3
68	3,5,5-trimethyl-2-cyclopenten-1-one	1644	C	83.8	1.2	0.5
69	2-furanmethanol	1659	A	282.2	4.0	5.2
70	α -caryophyllene	1667	A	115.2	1.6	0.2
71	3,3-dimethylbicyclo[2.2.1]heptan-2-one	1680	B	79.0	1.1	0.2
74	3-methyl-2(5 <i>H</i>)-furanone	1713	A	60.4	0.9	0.8
77	2(3 <i>H</i>)-furanone	1726	A	36.1	0.5	1.2
80	2-butenic acid	1773	A	41.7	0.6	0.7
82	2,4-dimethyl-1,3-cyclopentanedione	1796	B	70.5	1.0	0.6
83	sabinol	1810	A	32.4	0.5	0.6
84	2-hydroxy-3-methyl-2-cyclopenten-1-one	1830	A	271.1	3.8	7.2
85	3,4-dimethyl-(<i>Z</i>)-3-hexen-2-one	1838	B	20.4	0.3	0.2
86	unknown	1845		20.6	0.3	0.4
88	guaiacol	1859	A	906.9	12.8	5.6
89	2-methoxy- <i>p</i> -cresol	1868	A	49.2	0.7	0.5
90	5-(2-propenyl)-1,3-benzodioxole	1874	C	69.6	1.0	0.4
91	2,4-dihydro-2,4,5-trimethyl-3 <i>H</i> -pyrazol-3-one	1896	C	70.7	1.0	1.1
92	2,6-di- <i>tert</i> -butyl- <i>p</i> -cresol (BHT)	1910	A	31.7	0.4	3.5
95	4-methylguaiacol	1956	A	507.3	7.2	3.6
96	maltol	1968	A	25.5	0.4	1.6
97	2-acetylcyclohexanone	1977	C	19.6	0.3	0.2
98	unknown	1989		49.7	0.7	1.0
99	phenyl carbamate	2006	A	336.8	4.8	1.2
100	4-ethylguaiacol	2032	A	60.0	0.8	0.8
101	4-methylphenol	2079	A	88.0	1.2	0.4
102	unknown	2087		86.7	1.2	0.3
104	2,6-dimethoxyphenol	2269	A	323.7	4.6	14.7
105	eugenol	2290	A	41.6	0.6	1.3
106	1,2,3-trimethoxybenzene	2335	B	122.9	1.7	11.0
107	1-(2,6-dihydroxy-4-methoxyphenyl)ethanone	2413	C	30.4	0.4	3.9
108	1,4-benzenediol	2693	B	16.1	0.2	0.1
	total			7070.7	100.0	100.0

^{a-d} Same as in Table II. ^e Total amounts of these compounds represented about 56 and 76% of total volatiles in the sausage and the liquid smoke, respectively.

Isolation of Volatile Flavor Compounds. Sausage (600 g) was homogenized with 900 mL of deionized water containing 60 μ L of 1% 2-heptanol in methanol as an internal standard. This homogenate was put into a 2-L round-bottom flask and distilled at 50 °C under reduced pressure (approximately 70 Torr). As described in our previous paper (Shimoda et al., 1987), the distillate was passed through a column (10 cm \times 2 cm i.d.) packed with porous polymer beads (Porapak Q), and then the column was washed with 20 mL of deionized water to remove water-soluble constituents. After adsorbed volatiles were eluted with 80 mL of diethyl ether, the eluate was dried over anhydrous sodium sulfate and concentrated to about 200 μ L.

Volatiles of the mixed spice (2 g) were extracted with 60 mL of methanol for 3 min, using a high-speed blender. Then, the

extract was centrifuged and the supernatant was diluted with 540 mL of deionized water. Extracted volatiles were concentrated using a Porapak Q column as described above.

Liquid smoke (1 mL) was diluted with 29 mL of deionized water, and concentration of volatiles was carried out using a Porapak Q column.

Capillary Gas Chromatography (GC). Capillary GC analysis was carried out on a Hewlett-Packard Model 5890A gas chromatograph equipped with a flame ionization detector and connected to a Shimadzu Chromatopak C-R5A integrator. Separation was achieved on a 60 m \times 0.25 mm i.d. fused silica capillary column, coated with cross-linked polyethylene glycol 20M, film thickness 0.25 μ m (DB-Wax, J&W Scientific, Folsom, CA). The column temperature was held at 50 °C for 4 min and

Table IV. Volatile Compounds Not Found in Mixed Spice and Liquid Smoke

peak ^a	compound	Kovats index ^b	reliability of ID ^c	content, ppb
1	unknown	821		25.8
9	1-hexanal	1079	A	64.7
10	2-methylthiophene and 2-methyl-2-butenal	1093	A	32.5
14	<i>p</i> -xylene	1132	A	32.7
15	<i>m</i> -xylene	1138	A	72.6
31	ethyl lactate	1341	A	27.9
34	unknown	1374		128.0
35	6-ethyl-2-methyldecane	1390	A	25.4
36	unknown	1396		28.4
38	ethyl octanoate	1429	A	30.4
39	unknown	1432		28.2
42	2,4-hexadienoic acid methyl ester	1444	B	56.0
46	benzenethiol	1480	B	28.9
48	unknown	1493		21.3
50	2,4-hexadienoic acid ethyl ester	1501	B	32.3
52	benzaldehyde and 3-methyl-2-cyclopenten-1-one	1513	A	132.4
56	2,3-dimethyl-2-cyclopenten-1-one	1535	B	100.3
61	γ -caryophyllene	1573	A	1156.9
62	unknown	1577		35.7
63	3-methoxypyridine	1579	B	25.3
64	β -elemene	1583	A	42.0
66	4-terpineol	1602	A	382.7
72	neoisothujyl alcohol	1694	A	37.4
76	4,5-dimethyl-4-hexen-3-one	1722	A	33.6
78	unknown	1757		49.8
79	unknown	1767		33.6
94	4-methoxy-1,3-benzenediamine	1942	C	24.4
103	(<i>E,E</i>)-2,4-hexadienoic acid	2150	A	8766.1
	total			11455.3

^{a-c} Same as in Table II.

then programmed at 2 °C/min up to 230 °C (30-min hold). The injector and detector temperatures were 200 and 250 °C, respectively. Helium was used as a carrier gas at a column flow rate of 22 cm/s (50 °C). An injection splitter was used at a split ratio of 30:1. Retention indices were estimated in accordance with a modified Kovats method (Van den Dool and Kratz, 1963).

Capillary Gas Chromatography–Mass Spectrometry (GC–MS). Electron impact mass spectrometric data were collected on a Shimadzu GCMS-9020DF gas chromatograph–mass spectrometer system. The column and the chromatographic conditions were the same as described for GC analysis. The mass spectrometer was operated at an ionization voltage of 70 V and an ion source temperature of 200 °C. The mass spectra of the unknown compounds were compared with those in the *Wiley/NBS Registry of Mass Spectral Data* by using a Shimadzu GC-MSPAC1100 computer system and other published spectra (*Eight Peak Index of Mass Spectra*, 1983; *Wiley/NBS Registry of Mass Spectral Data*, 1989).

RESULTS AND DISCUSSION

A typical gas chromatogram of the volatile components from the sausage is shown in Figure 2. Of a total of 108 individual peaks detected, 99 peaks were definitely or tentatively identified. The area of these 99 peaks represented about 98% of the chromatogram surface (excluding solvent and 2-heptanol). The compounds identified included 29 hydrocarbons, 6 aldehydes, 15 ketones, 10 alcohols, 6 carboxylic acids, 9 esters, 5 furans, 13 phenolic compounds, 3 sulfur-containing compounds, and 3 miscellaneous compounds.

Table II lists the identification and composition in the sausage and mixed spice of the compounds derived from the mixed spice. The total amount of these compounds represented about 38 and 96% of total volatiles in the sausage and spice, respectively. Many terpenes have been reported to exist in spices, for example, in black pepper (Richard et al., 1971; Debrauwere and Verzele, 1976). In practice, most of the terpenes in the sausage were detected in the mixed spice, and the terpenes constituted a high proportion (35.2%) in the odor concentrate of sausage. Hence, the spicy flavor, one of the principal flavor

attributes of sausage, could be attributed to these terpenes. As shown in Table II, the relative areas of 21 compounds, such as 3-methylbutanal, 1,8-cineole, butanoic acid, and α -terpineol, in the sausage were much higher than that in the spice. On the other hand, 13 compounds such as α -pinene, β -pinene, and δ -elemene were lower in the sausage. These changes in the composition, which may be due to isomerization, oxidation, or hydration during the process of heating or derivatizations from liquid smoke (Table III), could have a significant effect on the flavor of sausage.

Table III lists the compounds derived from the liquid smoke in sausage. The total amount of these compounds represented about 56 and 76% of total volatiles of the sausage and the liquid smoke, respectively. The relative areas of 26 compounds, such as ethyl acetate, toluene, and guaiacol, in the sausage were much higher than that in the liquid smoke. On the other hand, 12 compounds, such as tridecane, 4,5-dimethyl-4-hexen-3-one, and 2,6-dimethoxyphenol, were lower in the liquid smoke. The majority of oxygen-containing volatile compounds, other than terpenoids, were reported to have been isolated from hard wood and soft wood smoke condensate (Maga, 1987). It is well established that a significant portion of smoke flavor has been associated with phenolic compounds. In this study, 11 phenolic compounds have been identified. Of these, guaiacol, 4-methylguaiacol (4-methyl-2-methoxyphenol), and 2,6-dimethoxyphenol were the predominant phenolic compounds and most likely contributed to the smoky flavor of sausage. Guaiacol and 4-methylguaiacol have low odor thresholds, 0.021 and 0.09 ppm in water and 0.07 and 0.4 ppm in oil, respectively. Moreover, 2,6-dimethoxyphenol also has a low odor threshold in oil (0.34 ppm), whereas it has a relatively high odor threshold in water (1.65 ppm) (Wasserman, 1966). The three phenolics, along with 1,2,3-trimethoxybenzene and phenyl carbamate, constituted 87.2% of the phenolic fraction or 8.5% of the total volatiles in the sausage. On the other hand, derivatives of 2-cyclopenten-1-one, for example, 2-hydroxy-3-methyl-2-cy-

lopenten-1-one, which are characterized by an impression of burnt sugar odor, have already been reported to exist in wood smoke vapor (Lustre and Issenberg, 1969). Moreover, furans were best represented by 2-furfural and 2-furanmethanol in the sausage, and they are mainly associated with sweet, nutty, and caramel-like odors. Because of their odor attributes and high odor strength, 2-cyclopenten-1-ones and furans could contribute to the smoky flavor of the sausage along with phenolic compounds.

The compounds derived from neither mixed spice nor liquid smoke are shown in Table IV. Among them, three terpenes, i.e., γ -caryophyllene, β -elemene, and neoisothujyl alcohol, were not detected in mixed spice or liquid smoke, and they might have been formed from other terpenes in spice or smoke by isomerization, oxidation, or hydration during the process of heating. 3-Methylbutanal might have been derived from Strecker degradation of leucine, and (*E*)-2-pentenal and 1-hexanal might be autoxidation products of unsaturated fatty acid esters (Ullrich and Grosch, 1987). Many of the short-chain aldehydes and methyl ketones have been frequently found in oxidatively degraded fats and oils; therefore, they have been used as indicators of off-flavor in meats (Reineccius, 1979). However, the degradation products of lipids were hardly detected in the sausage, and this may be due to the inhibitory effect of nitrite (MacDonald et al., 1980).

(*E,E*)-2,4-Hexadienoic acid, i.e., sorbic acid, which represented up to 95% of the free carboxylic acids in the sausage, is added to the sausage as an antimicrobial agent.

The only three nitrogenous compounds in the sausage flavor concentrate were 3-methoxy-pyridine, 2,4-dihydro-2,4,5-trimethyl-3H-pyrazol-3-one, and 4-methoxy-1,3-benzenediamine. On the other hand, thiazoles, thiophenes, pyrazines, and their mercapto derivatives, reported to possess a variety of meaty notes (Wasserman, 1979), were not detected. According to Dwivedi (1975), 30–32 pyrazines and 3–10 thiazoles were identified in cooked beef and pork. Shibamoto and Bernhard (1976) reported that although some pyrazines were formed even at -5°C (after 30 days), significant formation of pyrazines began at 70°C and increased to an optimum at 120°C . The presence of these compounds in meat products is mainly related to reactions occurring during the cooking process as shown by their wide diversity in the volatile compounds of fried bacon (Ho et al., 1983). However, it was considered that since the sausage was not roasted but steamed for a short time in the process of heating, the compounds described above were not formed in the sausage.

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Registry Numbers Supplied by Author: Ethyl acetate, 141-78-6; 3-methylbutanal, 590-86-3; methyl isobutyrate, 547-63-7; ethanol, 64-17-5; α -pinene, 7785-70-8; toluene, 108-88-3; *n*-hexanal, 66-25-1; 2-methylthiophene, 554-14-3; 2-methyl-2-butenal, 497-03-0; β -pinene, 18172-67-3; α -thujene, 3387-41-5; ethylbenzene, 100-41-4; (*E*)-2-pentenal, 1576-87-0; *p*-xylene, 106-42-3; *m*-xylene, 108-38-3; Δ^3 -carene, 13466-78-9; myrcene, 123-35-3; α -terpinene, 99-86-5; *o*-xylene, 95-47-6; *d*-limonene, 5989-27-5; β -terpinene, 99-84-3; 1,8-cineole, 470-82-6; 1-ethyl-3-methylbenzene, 620-14-4; γ -terpinene, 99-85-4; 1,2,3-trimethylbenzene, 526-73-8; *p*-cymene, 99-81-6; *trans*-ocimene, 3338-55-4; α -phellandrene, 99-83-2; terpinolene, 586-62-9; tridecane, 629-50-5; ethyl lactate, 687-47-8; *n*-hexanol, 111-27-3; 2-methyl-2-cyclopenten-1-one, 1120-73-6; 6-ethyl-2-methyldecane, 62108-21-8; 2-cyclohexen-1-one, 930-68-7; ethyl octanoate, 106-32-1; 1-hydroxy-2-pentanone, 64502-89-2; 2,4-hexadienoic acid methyl ester, 1515-80-6; acetic acid, 64-19-7; 2-furfural, 98-01-1; δ -

elemene, 20307-84-0; diallyl disulfide, 2179-57-9; benzenethiol, 108-98-5; α -copaene, 3856-25-5; 1-(2-furanyl)ethanone, 1192-62-7; 2,4-hexadienoic acid ethyl ester, 5941-48-0; camphor, 76-22-2; benzaldehyde, 100-52-7; 3-methyl-2-cyclopenten-1-one, 2758-18-1; 3-oxopentanoic acid methyl ester, 2067-33-6; 1-(acetyloxy)-2-butanone, 1575-57-1; propanoic acid, 79-09-4; 2,3-dimethyl-2-cyclopenten-1-one, 1121-05-7; linalool, 78-70-6; linalyl acetate, 115-95-7; isopulegol, 89-79-2; γ -caryophyllene, 118-65-0; 3-methoxy-pyridine, 7295-76-3; β -elemene, 515-13-9; β -caryophyllene, 13877-93-5; 4-terpineol, 562-74-3; butanoic acid, 107-92-6; 3,5,5-trimethyl-2-cyclopenten-1-one, 24156-95-4; 2-furanmethanol, 98-00-0; α -caryophyllene, 6753-98-6; 3,3-dimethylbicyclo[2.2.1]heptan-2-one, 13211-15-9; neoisothujyl alcohol, 31187-53-8; α -terpineol, 98-55-5; 3-methyl-2(5*H*)-furanone, 22122-36-7; methylphosphonic acid dimethyl ester, 756-79-6; 4,5-dimethyl-4-hexen-3-one, 17325-90-5; 2(3*H*)-furanone, 20825-71-2; 2-butenic acid, 3724-65-0; 4-(1-methylethyl)benzaldehyde, 122-03-2; 2,4-dimethyl-1,3-cyclopentanedione, 34598-80-6; sabinol, 471-16-9; 2-hydroxy-3-methyl-2-cyclopenten-1-one, 765-69-5; 3,4-dimethyl-(*Z*)-3-hexen-2-one, 20685-45-4; hexanoic acid, 142-62-1; *p*-cymen-8-ol, 99-87-6; guaiacol, 90-05-1; 2-methoxy-*p*-cresol, 93-51-6; 5-(2-propenyl)-1,3-benzodioxole, 94-59-7; 2,4-dihydro-2,4,5-trimethyl-3*H*-pyrazol-3-one, 17826-82-3; 2,6-di-*tert*-butyl-*p*-cresol (BHT), 128-37-0; 4-methoxy-1,3-benzenediamine, 615-05-4; 4-methylguaiacol, 93-51-6; maltol, 118-71-8; 2-acetylcyclohexanone, 874-23-7; phenyl carbamate, 622-46-8; 4-ethylguaiacol, 2785-89-9; 4-methylphenol, 106-44-5; (*E,E*)-2,4-hexadienoic acid, 110-44-1; 2,6-dimethoxyphenol, 91-10-1; eugenol, 97-53-0; 1,2,3-trimethoxybenzene, 634-36-3; 1-(2,6-dihydroxy-4-methoxypropyl)ethanone, 7507-89-3; 1,4-benzenediol, 123-31-9.