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Volatile Flavor Components in *Bogyojosaeng* and *Suhong* Cultivars of Strawberry (*Fragaria ananassa* Duch.)

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Abstract

Volatile flavor components of two strawberry (*Fragaria ananassa* Duch.) varieties, *Bogyojosaeng* and *Suhong*, were extracted by SDE (Simultaneous steam distillation and extraction) using a mixture of n-pentane and diethylether (1:1, v/v) as an extract solvent. Analysis of the concentrate by capillary gas chromatography and gas chromatography-mass spectrometry led to the identification of 146 and 153 components in *Bogyojosaeng* and *Suhong* respectively. There were 49 esters, 25 alcohols, 20 ketones, 24 aldehydes, 6 acids, 9 terpenes and terpene derivatives, 2 ethers, 11 unknowns and miscellaneous in *Bogyojosaeng* and 67 esters, 21 alcohols, 24 ketones, 17 aldehydes, 4 acids, 12 terpenes and terpene derivatives, 2 ethers, 9 unknowns and miscellaneous in *Suhong*. Among these, (*E*)-2-hexenyl acetae (4.56%) in *Bogyojosaeng* and (*E*)-nerolidol (12.38%) in *Suhong* were major compounds and acetic acid, (*E*)-2-hexenal, hexyl acetate, ethyl acetate, ethyl butanoate, methyl butanoate, ethyl hexanoate and γ-dodecalactone were the main components in each sample, though there were several differences in composition and threshold of volatile compounds. Total contents of volatile components isolated and identified in *Bogyojosaeng* and *Suhong* were 9.010 and 12.527 mg/kg, respectively.

Key words: strawberry, *Bogyojosaeng*, *Suhong*, flavor, threshold

INTRODUCTION

Cultivated varieties of the strawberry, *Fragaria ananassa* Duch. were caused by breeding the genotypes of *Fragaria virginiana* and *Fragaria chiloensis*. Strawberries are cultivated in nearly all countries of the world and are one of the most popular fruits that are consumed fresh, conserved and in manufactured products. Fresh strawberries have a very short shelf life because they easily bruise and quickly succumb to fungal attack. Therefore, the strawberry is a typical example of a sought-after quality fruit that is, unfortunately, also highly perishable. To supply high quality strawberries to consumers, care must be paid to their distribution, storage and final display in the shops.

Volatile compounds impart the aroma components of flavor to foods, including those derived from plants. Numerous investigations have shown that several plant-emitted volatile compounds, including aldehydes, ketones, alcohols and other classes of natural products, exhibit antimicrobial properties against pathogenic fungi such as *Aspergillus, Fusarium, Penicillium* and *Botrytis*, and bacteria (1-3).

Because of its typical aroma, the strawberry has always been an object in aroma analysis. And its aroma has received increasing attention from both producers and consumers. Among many volatile compounds produced by whole and macerated strawberry fruit, only a small number are important for characteristic odors and, of these, several are odor-active at an extremely low concentration. Recently many investigators used a GC/FID technique for separation and detection, and olfactory threshold analysis for determining the important compounds in fresh ripened strawberry aroma: methyl butanoate, ethyl butanoate, methyl hexanoate, hexyl acetate and ethyl hexanoate (4-6). Ulrich et al. (7) distinguished two types of cultivated strawberries by the differences in their ester contents.

The aim of this study is to examine the difference in flavor constituents of two strawberry cultivar (*Bogyojosaeng* and *Suhong*) as measured by the incidence and concentration of various volatile compounds. Then, it is expected that this study will provide useful basic data for manufacturing strawberry containing goods and developing natural flavors using flavor precursors.

MATERIALS AND METHODS

Materials

The varieties of strawberry used for this study were "*Bogyojosaeng*" and "*Suhong*" obtained from the southern region of Korea, in 2000. The strawberries were obtained from normal retail outlets and were in prime condition. They were washed and detached from their stalks.

Chemicals

Reagents were purchased from Sigma Co. (USA) and Fisher Scientific (USA). Organic solvents used for extraction and chromatography were redistilled with a wire spiral packed double distilling apparatus (Normschliff, Wertheim, Germany)

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and Milli-Q water generated with a water purification system (Millpore Corporation, Bedford, USA).

Extraction of volatile components from strawberry by SDE

300 g of each sample was homogenized in a blender (MR 350CA, Braun, Spain) for 1 min and mixed with 1 L distilled water. The resulting slurry was transferred to a 2 liter-round bottom flask and adjusted to pH 6.5 with 0.1 N NaOH solution. 1 μl n-butylbenzene was added as an internal standard for quantitative analysis.

Volatiles were extracted for 2 h with 200 ml of a mixture of redistilled n-pentane/diethylether (1:1, v/v) using a SDE (Likens & Nikerson type simultaneous steam distillation and extraction) apparatus (8) as modified by Schultz et al. (9) under atmospheric pressure.

The extract was dried over sodium sulfate anhydrous, concentrated to approximately 2 ml by using a Vigreux column and then to a final volume of 0.5 ml under a current of nitrogen after transferring into a GC vial, used for GC-FID and GC/MS analysis.

Conditions of GC-FID and GC/MS analysis

The GC analyses were carried out on a HP 5890 Plus II gas chromatograph equipped with a flame ionization detector. DB-Wax capillary column (60 m×0.25 mm i.d., 0.25 μm film thickness, J&W, USA) were used. Oven temperature was programmed as follows : from 40°C (isothermal for 3 min) to 150°C at 2°C/min and to 200°C at 4°C/min and isothermal period at 200°C for 15min. The temperature of injector port and detector were, respectively, 250°C and 300°C. Helium was used as carrier gas at a flow rate of 1.0 ml/min and injector volume was 1 μl with a split ratio of 1:20.

GC/MS spectra were recorded by a Shimadzu GC/MS QP 5000 equipped with the same column and operating conditions described above. In the electron impact mode (EI), the mass spectrometer was scanned from m/z 31 to 450, the ionization voltage was 70 eV and the ion source and interface temperature kept at 230°C.

Identification of volatile compounds

Mass spectra were identified with aid of the mass spectral data of our own and the mass spectrum library (NIST 12, NIST 62 and WILEY 139) and mass spectral data book (10,11). Also, the compounds were identified by comparison of retention indices with reference data (12,13) and laboratory data of authentic compounds (C_7~C_{30}) in our laboratory.

Quantitative determination

The quantity of the X compound in the strawberry samples was calculated using the following formula :

Cx (mg/kg of strawberry) = $SG \times Sx \times 1000$ g / $S_E \times 300$ g

SG = specific gravity of internal standard (0.860 (20/20°C))

Sx = peak area (%) of X compound in the organic extract of strawberry

S_E = peak area (%) of internal standard in the organic extract of strawberry

RESULTS AND DISCUSSION

Volatile compounds from *Bogyojosaeng* strawberry fruit

A total of 146 compounds were collected and concentrated sufficiently by SDE from *Bogyojosaeng* whole strawberry fruit, detected and identified by GC and GC/MS. They are presented in Table 1 and Fig. 1.

Aroma patterns, 49 esters, 25 alcohols, 20 ketones, 24 aldehydes, 6 acids, 9 terpenes and terpene derivatives, 2 ethers, 11 unknowns and miscellaneous were identified and quantified (Table 2). Among these compounds, (*E*)-2-hexenyl acetate (4.56%), acetic acid (4.02%) and (*E*)-nerolidol (3.67%) were

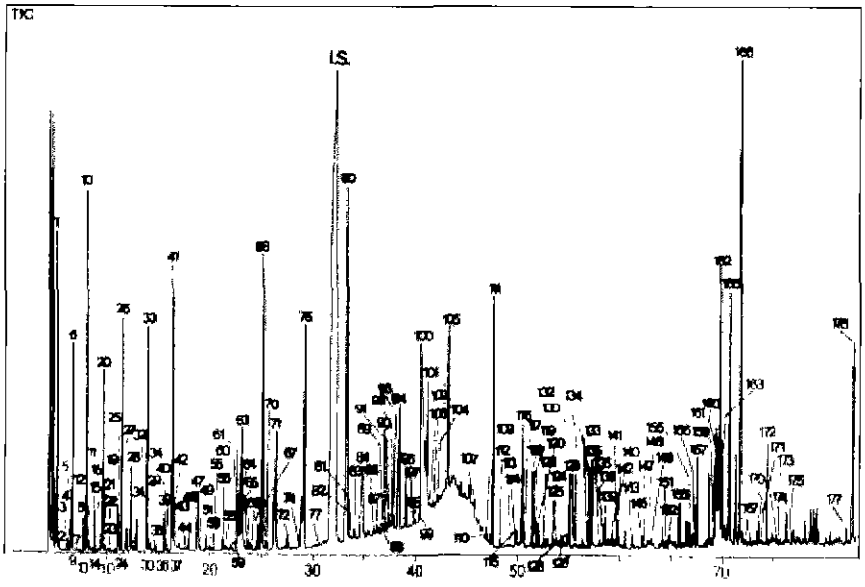

Fig. 1. GC chromatogram of volatile flavor components from *Bogyojosaeng*.

Table 1. Volatile flavor components in *Bogyojosaeng* and *Suhong* strawberry fruit

Peak No.	RT	RI	Compound	MF	MW	*Bogyojosaeng*		*Suhong*	
						Area%	mg/kg	Area%	mg/kg
1	5.100	708	Acetaldehyde	C_2H_4O	44	1.81	0.275	1.53	0.278
2	5.403	739	sec-Butyl ethyl ether	$C_5H_{12}O$	88	0.01	0.002	0.02	0.004
3	6.065	800	Propanal	C_3H_6O	58	0.04	0.006	0.02	0.004
4	6.161	806	Octane	C_8H_{18}	114	0.06	0.009	0.04	0.007
5	6.482	823	2-Propanone	C_3H_6O	58	0.25	0.037	0.22	0.039
6	6.616	830	Ethyl formate	$C_3H_6O_2$	74	0.93	0.140	0.77	0.140
7	7.028	850	2-Propenal	C_3H_4O	56	0.02	0.003	-	-
8	7.696	880	Butanal	C_4H_8O	72	0.15	0.023	0.04	0.007
9	7.826	886	2-Methyl-2-propenal	C_4H_6O	70	0.01	0.001	0.01	0.002
10	8.005	893	Ethyl acetate	$C_4H_8O_2$	88	2.02	0.306	2.97	0.538
11	8.127	898	Diethylacetal	$C_6H_{14}O_2$	118	0.05	0.007	0.08	0.014
12	8.284	904	Isopropyl acetate	$C_5H_{10}O_2$	102	0.07	0.010	0.15	0.027
13	8.350	906	2-Butanone	C_4H_8O	72	0.03	0.004	0.01	0.002
14	8.533	911	Methyl propanoate	$C_4H_8O_2$	88	0.02	0.002	0.05	0.009
15	8.714	916	2-Methylbutanal	$C_5H_{10}O$	86	0.02	0.003	0.01	0.002
16	8.851	920	3-Methylbutanal	$C_5H_{10}O$	86	0.16	0.025	0.07	0.013
17	8.933	922	Methyl 2-methylpropanoate	$C_5H_{10}O_2$	102	-	-	0.01	0.002
18	9.175	929	3-Methyl-2-butanone	$C_5H_{10}O$	86	-	-	0.02	0.003
19	9.375	934	2-Propanol	C_3H_8O	60	0.05	0.007	0.03	0.006
20	9.628	941	Ethanol	C_2H_6O	46	1.08	0.164	1.24	0.225
21	9.854	946	3-Buten-2-one	C_4H_6O	70	0.03	0.004	0.03	0.005
22	10.285	957	Ethyl propanoate	$C_5H_{10}O_2$	102	0.01	0.002	0.16	0.029
23	10.625	965	Ethyl 2-methylpropanoate	$C_6H_{12}O_2$	116	0.01	0.001	0.05	0.010
24	10.967	973	Propyl acetate	$C_5H_{10}O_2$	102	0.02	0.002	0.01	0.002
25	11.049	975	2-Pentanone	$C_5H_{10}O$	86	0.37	0.057	0.30	0.055
26	11.431	983	Methyl butanoate	$C_5H_{10}O_2$	102	1.03	0.156	3.73	0.677
27	11.967	994	Decane	$C_{10}H_{12}$	142	0.01	0.002	0.01	0.002
28	12.344	1002	4-Methyl-2-pentanone	$C_6H_{10}O$	100	0.40	0.061	0.18	0.033
29	12.487	1005	Methyl 2-methylbutanoate	$C_6H_{12}O_2$	116	0.02	0.004	0.18	0.033
30	12.658	1009	2-Methylpropyl acetate	$C_6H_{12}O_2$	116	0.01	0.001	0.02	0.004
31	12.789	1012	3-Methyl-2-pentanone	$C_6H_{10}O$	100	0.04	0.007	0.09	0.017
32	12.934	1015	Methyl 3-methylbutanoate	$C_6H_{12}O_2$	116	0.15	0.023	0.34	0.062
33	13.874	1034	Ethyl butanoate	$C_6H_{12}O_2$	116	1.18	0.178	4.64	0.843
34	14.065	1037	1-Methylethyl butanoate	$C_7H_{14}O_2$	130	0.06	0.010	0.15	0.028
35	14.108	1038	4-Penten-2-one	C_5H_8O	84	-	-	0.02	0.003
36	14.392	1043	S-Methyl thioacetate	C_3H_6OS	90	0.01	0.001	0.03	0.006
37	14.600	1047	3-Hexanone	$C_6H_{12}O$	100	0.01	0.001	0.01	0.002
38	14.696	1049	Ethyl 2-methylbutanoate	$C_7H_{14}O_2$	130	0.05	0.007	0.53	0.095
39	15.557	1064	Ethyl 3-methylbutanoate	$C_7H_{14}O_2$	130	0.23	0.035	0.45	0.082
40	15.769	1068	Butyl acetate	$C_6H_{12}O_2$	116	0.07	0.010	0.13	0.023
41	16.334	1078	Hexanal	$C_6H_{12}O$	100	2.11	0.318	0.34	0.061
42	16.583	1082	Methyl pentanoate	$C_6H_{12}O_2$	116	0.06	0.010	0.02	0.004
43	16.992	1088	2-Methylpropanol	$C_4H_{10}O$	74	0.02	0.003	0.04	0.007
44	17.692	1099	Methyl *(E)*-2-butenoate	$C_5H_8O_2$	100	0.03	0.004	0.05	0.009
45	17.880	1102	Propyl isopropyl ether	$C_6H_{14}O$	102	-	-	0.39	0.071
46	17.953	1104	2-Hydroxy-2-methyl-1-propanal	$C_4H_8O_2$	88	0.10	0.015	-	-
47	18.792	1118	3-Methylbutyl acetate	$C_7H_{14}O_2$	130	0.55	0.083	-	-
48	18.904	1120	3-Penten-2-one	C_5H_8O	84	-	-	3.22	0.584
49	19.055	1123	*(E)*-2-Pentenal	C_5H_8O	84	0.03	0.005	0.01	0.002
50	19.555	1131	Ethyl pentanoate	$C_7H_{14}O_2$	130	-	-	0.03	0.006
51	19.633	1132	*(E)*-Allyl propenyl ether	$C_6H_{10}O$	98	0.08	0.013	-	-
52	19.870	1136	5-Methyl-2-hexanone	$C_7H_{14}O$	114	-	-	0.04	0.007
53	19.956	1137	2-Methyl-4-pentenal	$C_6H_{10}O$	98	0.02	0.003	-	-
54	20.061	1139	Methyl 4-methylpentanoate	$C_7H_{14}O_2$	130	-	-	0.03	0.005
55	20.319	1143	Butanol	$C_4H_{10}O$	74	0.02	0.003	0.03	0.005
56	21.255	1157	1-Penten-3-ol	$C_5H_{10}O$	86	0.07	0.011	0.01	0.002
57	21.290	1158	Ethyl 2-butenoate	$C_6H_{10}O_2$	114	-	-	0.10	0.018
58	21.529	1161	2-Ethylbutanal	$C_6H_{12}O$	100	0.04	0.007	0.01	0.002
59	22.061	1169	Pentyl acetate	$C_7H_{14}O_2$	130	0.05	0.007	0.03	0.005
60	22.605	1177	2-Heptanone	$C_7H_{14}O$	114	0.28	0.042	0.63	0.115
61	22.722	1179	Heptanal	$C_7H_{14}O$	114	0.21	0.032	-	-
62	22.774	1179	Pyridine	C_5H_5N	79	-	-	0.25	0.044
63	22.994	1182	Methyl hexanoate	$C_7H_{14}O_2$	130	1.46	0.220	2.03	0.368

Peak No.	RT	RI	Compound	MF	MW	*Bogyojosaeng*		*Suhong*	
						Area%	mg/kg	Area%	mg/kg
64	23.634	1191	Methanethiol	CH_4S	48	0.06	0.010	-	-
65	23.848	1194	*(Z)*-3-Hexenal	$C_6H_{10}O$	98	0.06	0.010	-	-
66	24.028	1196	Docosane	$C_{12}H_{26}$	170	0.03	0.005	-	-
67	24.601	1205	3-Methylbutanol	$C_5H_{12}O$	88	0.16	0.025	0.23	0.041
68	25.127	1213	*(E)*-2-Hexenal	$C_6H_{10}O$	98	3.16	0.477	1.08	0.195
69	25.142	1213	Butyl butanoate	$C_8H_{16}O_2$	144	-	-	0.03	0.005
70	25.468	1219	2-Methyl-3-buten-2-ol	$C_5H_{10}O$	86	0.11	0.017	-	-
71	26.195	1230	Ethyl hexanoate	$C_8H_{16}O_2$	144	1.32	0.200	3.44	0.624
72	27.524	1250	Pentanol	$C_5H_{12}O$	88	0.13	0.019	0.12	0.021
73	28.318	1261	2-Butyl acetate	$C_6H_{12}O_2$	116	-	-	0.04	0.008
74	28.658	1266	Isopentyl butanoate	$C_9H_{18}O_2$	158	0.02	0.002	0.05	0.010
75	29.158	1273	Hexyl acetate	$C_8H_{16}O_2$	144	2.58	0.390	0.97	0.177
76	30.092	1285	Methyl-2-hexenoate	$C_7H_{12}O_2$	128	-	-	0.01	0.002
77	30.591	1292	1-Hydroxy-2-propanone	$C_3H_6O_2$	74	0.02	0.003	-	-
78	30.799	1294	2-Octen-4-one	$C_8H_{14}O$	126	-	-	0.05	0.009
I.S.	32.255	1316	Butylbenzene	$C_{10}H_{14}$	134	18.96	2.867	-	-
79	32.571	1321	*(E)*-2-Heptenal	$C_7H_{12}O$	112	0.03	0.004	0.12	0.023
80	33.356	1333	*(E)*-2-Hexenyl acetate	$C_8H_{14}O_2$	142	4.56	0.689	1.98	0.360
81	33.540	1336	6-Methyl-5-hepten-2-one	$C_8H_{14}O$	126	0.04	0.006	-	-
82	33.725	1338	Hexyl propanoate	$C_9H_{18}O_2$	158	0.03	0.005	0.01	0.002
83	34.036	1343	Ethyl 2-hexenoate	$C_8H_{14}O_2$	142	0.10	0.014	0.03	0.005
84	34.863	1355	Hexanol	$C_6H_{14}O$	102	1.16	0.176	0.57	0.104
85	35.317	1361	*(Z)*-3-Hexen-1-ol	$C_6H_{12}O$	100	-	-	0.01	0.002
86	35.976	1371	Ethylidene diacetate	$C_6H_{10}O_4$	146	0.07	0.011	0.09	0.017
87	36.244	1374	Methyl 2-hydroxybutanoate	$C_5H_{10}O_3$	118	0.07	0.011	0.08	0.014
88	36.470	1377	5-Methylindan	$C_{10}H_{12}$	132	0.06	0.009	0.04	0.006
89	36.887	1383	*(E)*-3-Hexen-1-ol	$C_6H_{12}O$	100	0.15	0.022	0.02	0.004
90	37.171	1387	Methyl octanoate	$C_9H_{18}O_2$	158	0.04	0.007	0.12	0.021
91	37.389	1390	Nonanal	$C_9H_{18}O$	142	0.19	0.029	-	-
92	37.675	1394	Methyl 2-hydroxy-3-methylbutanoate	$C_6H_{12}O_3$	132	0.08	0.012	0.10	0.018
93	37.831	1396	Pentyl butanoate	$C_9H_{18}O_2$	158	0.10	0.015	0.02	0.004
94	38.454	1405	*(E)*-2-Hexenol	$C_6H_{12}O$	100	1.61	0 243	0.75	0.136
95	38.683	1409	Butyl hexanoate	$C_{10}H_{20}O_2$	172	-	-	0.01	0.002
96	39.097	1416	Hexyl butanoate	$C_{10}H_{20}O_2$	172	0.37	0.057	0.21	0.038
97	39.817	1428	*(E)*-2-Octenal	$C_8H_{14}O$	126	0.02	0.003	-	-
98	39.929	1430	Hexyl 2-methylbutanoate	$C_{11}H_{22}O_2$	186	0.03	0.005	0.06	0.010
99	40.383	1437	Ethyl octanoate	$C_{10}H_{20}O_2$	172	0.04	0.006	0.17	0.030
100	40.484	1439	Acetic acid	$C_2H_4O_2$	60	4.02	0.607	2.45	0.445
101	41.137	1449	*(Z)*-Linalool oxide	$C_{10}H_{18}O_2$	170	1.16	0.176	1.90	0.344
102	41.400	1454	7-Octen-4-ol	$C_8H_{16}O$	128	0.11	0.016	0.29	0.053
103	41.715	1459	Furfural	$C_5H_4O_2$	96	0.07	0.011	-	-
104	42.160	1466	Pentyl hexanoate	$C_{11}H_{22}O_2$	186	0.08	0.012	0.16	0.029
105	43.171	1481	*(E)*-Linalool oxide	$C_{10}H_{18}O_2$	170	1.45	0.220	0.96	0.175
106	43.680	1489	Butandiol diacetate	$C_8H_{14}O_4$	174	-	-	0.08	0.014
107	45.766	1521	Benzaldehyde	C_7H_6O	106	0.09	0.013	-	-
108	46.725	1535	2,3-Epoxyhexanol	$C_6H_{12}O_2$	116	-	-	0.02	0.003
109	46.958	1539	Propanoic acid	$C_3H_6O_2$	74	0 05	0.007	0.12	0.021
110	47.312	1544	*(E)*-2-Nonenal	$C_9H_{16}O$	140	0.02	0.003	0.09	0.016
111	47.602	1549	Linalool	$C_{10}H_{18}O$	154	1.73	0.261	2.93	0.532
112	48.288	1559	Octanol	$C_8H_{18}O$	130	0.06	0.008	0.05	0.009
113	49.350	1574	Nonanyl acetate	$C_{11}H_{22}O_2$	186	0.01	0.002	0.06	0.010
114	49.810	1580	Dimethyl sulfoxide	C_2H_6OS	78	0.06	0.009	0.05	0.009
115	49.942	1582	*(E,Z)*-2,6-Nonadienal	$C_9H_{14}O$	138	0.04	0.006	0.06	0.011
116	50.499	1590	1,2-Propanediol	$C_3H_8O_2$	76	1.22	0.184	0.44	0.079
117	50.683	1593	2-Undecanone	$C_{11}H_{22}O$	170	0.03	0.005	0 05	0.009
118	51.463	1604	Hexyl hexanoate	$C_{12}H_{24}O_2$	200	0.46	0.069	0.23	0.042
119	51.859	1611	Octyl butanoate	$C_{12}H_{24}O_2$	200	0.07	0.010	0.10	0.018
120	52.057	1614	Butan-3-one-2-yl butanoate	$C_8H_{14}O_3$	158	0.14	0.022	0.77	0.140
121	52.502	1622	Pentyl 3-methylbutanoate	$C_{10}H_{20}O_2$	172	-	-	0.06	0.011
122	52.595	1623	1,2-Ethanediol	$C_2H_6O_2$	62	0.10	0.015	-	-
123	53.118	1632	Ethyl decanoate	$C_{12}H_{24}O_2$	200	-	-	0.08	0.014
124	53.440	1638	*(E)*-2-Decenal	$C_{10}H_{18}O$	154	0.03	0.005	-	-
125	53.776	1643	Methyl 3-hydroxyhexanoate	$C_7H_{14}O_3$	146	0.06	0.009	0.08	0.014
126	54.592	1656	Nonanol	$C_9H_{20}O$	144	0.02	0.003	-	-

Peak No.	RT	RI	Compound	MF	MW	*Bogyojosaeng*		*Suhong*	
						Area%	mg/kg	Area%	mg/kg
127	54.689	1658	(*Z*)-β-Farnesene	$C_{15}H_{24}$	204	-	-	0.05	0.008
128	54.880	1661	Ethyl benzoate	$C_9H_{10}O_2$	150	0.06	0.010	0.07	0.013
129	55.077	1664	(*E*)-2-Hexenyl hexanoate	$C_{12}H_{22}O_2$	198	0.47	0.071	0.26	0.048
130	55.500	1671	3-Methylbutanoic acid	$C_5H_{10}O_2$	102	0.06	0 009	-	-
131	55.651	1673	Decyl acetate	$C_{12}H_{24}O_2$	200	-	-	0.04	0.007
132	55.787	1676	Ethyl 3-hydroxyhexanoate	$C_8H_{16}O_3$	160	0.02	0.003	0.06	0.011
133	56.848	1692	α-Terpineol	$C_{10}H_{18}O$	154	0.02	0.003	0.04	0.008
134	57.042	1695	γ-Hexalactone	$C_6H_{10}O_2$	114	0.02	0.003	-	-
135	57.284	1699	Unknown	-	-	0.54	0.082	0.67	0.122
136	58.035	1713	Octyl butanoate	$C_{12}H_{24}O_2$	200	0.04	0.006	0.04	0.008
137	58.242	1717	(*Z,E*)-α-Farnesene	$C_{15}H_{24}$	204	-	-	0.02	0.004
138	58.414	1721	α-Muurolene	$C_{15}H_{24}$	204	0.06	0.009	0.11	0.020
139	58.590	1724	Benzyl acetate	$C_9H_{10}O_2$	150	0.20	0.030	0.17	0.031
140	59.262	1737	Epoxylinalool	$C_{10}H_{18}O_2$	170	0.12	0.019	0.05	0.008
141	59.708	1745	4,8-Dimethyl-nonanol	$C_{15}H_{32}O$	228	0.03	0.004	-	-
142	59.837	1748	Butyl butyrolactate	$C_{11}H_{20}O_4$	216	0.17	0.025	0.17	0.031
143	61.203	1773	4-Methyl-5-nonanone	$C_{10}H_{20}O$	156	0.10	0.016	0.15	0.027
144	61.314	1775	2-Heptyl hexanoate	$C_{13}H_{26}O_2$	214	-	-	0.04	0.007
145	61.966	1787	2-Nonyl butanoate	$C_{13}H_{26}O_2$	214	-	-	0.07	0.012
146	62.163	1791	1-Phenyl-1-butanone	$C_{10}H_{12}O$	148	0.10	0.015	0.05	0.009
147	62.351	1794	Methyl dodecanoate	$C_{13}H_{26}O_2$	214	0.02	0.003	0.03	0.006
148	62.521	1797	6,7-Dodecanedione	$C_{12}H_{22}O_2$	198	0.02	0.004	0.08	0.015
149	63.091	1810	β-Phenethyl acetate	$C_{12}H_{12}O_2$	164	0.07	0.010	0.15	0.027
150	64.250	1837	Ethyl dodecanoate	$C_{14}H_{28}O_2$	228	-	-	0.07	0.012
151	64.492	1843	Undecanol	$C_{11}H_{22}O$	170	0.05	0.008	0.06	0.011
152	64.844	1851	Hexanoic acid	$C_6H_{12}O_2$	116	0.17	0.026	0.04	0.007
153	65.806	1874	Benzyl alcohol	C_7H_8O	108	0.39	0.059	0.20	0.036
154	66.049	1879	Dodecyl acetate	$C_{14}H_{28}O_2$	228	-	-	0.01	0.003
155	66 759	1896	Dimethyl sulfone	$C_2H_6O_2S$	94	0.23	0.034	0.06	0.011
156	67.277	1909	2-Phenethyl alcohol	$C_8H_{10}O$	122	0.12	0.019	-	-
157	67.548	1917	Dodecanol	$C_{12}H_{24}O$	184	0.55	0.083	0.15	0.027
158	67.937	1928	6,7-Tridecandione	$C_{13}H_{24}O_2$	212	-	-	0.03	0.005
159	69.172	1963	Heptanoic acid	$C_7H_{14}O_2$	130	0 14	0.022	0.03	0.006
160	69.292	1967	2-Hexenoic acid	$C_6H_{10}O_2$	114	0.67	0.101	-	-
161	69.410	1970	1-Phenyl-1-butanol	$C_{10}H_{14}O$	150	0.49	0.075	0.07	0.013
162	69.757	1980	Unknown	-	-	2.55	0.386	1.41	0.256
163	69.943	1985	Nerolidol oxide	$C_{15}H_{26}O_3$	254	0.54	0.082	0.21	0.038
164	70.270	1994	(*Z*)-Nerolidol	$C_{15}H_{26}O$	222	-	-	0.15	0.027
165	70.668	2005	Unknown	-	-	1.98	0.300	1.52	0.276
166	71.738	2033	(*E*)-Nerolidol	$C_{15}H_{26}O$	222	3.67	0.555	12.38	2.248
167	72.340	2049	(*E,E*)-Farnesol	$C_{15}H_{26}O$	222	0.06	0.009	0.09	0.016
168	72.533	2054	3-Methylbutyl dodecanoate	$C_{17}H_{34}O_2$	270	-	-	0.02	0.004
169	73.134	2070	Methyl cinnamate	$C_{10}H_{10}O_2$	162	-	-	0.04	0.007
170	73.528	2080	Acetoveratrone	$C_{10}H_{12}O_3$	180	0.10	0.015	0.19	0.034
171	73.848	2088	7-Tridecanol	$C_{13}H_{28}O$	200	0.02	0.003	-	-
172	74.350	2101	Hexahydrofarnesyl acetone	$C_{18}H_{36}O$	268	0.49	0.075	0.17	0.031
173	75.262	2141	γ-Decalactone	$C_{10}H_{18}O_2$	170	0.07	0.011	0.10	0.019
174	75.671	2159	Tetradecanol	$C_{14}H_{30}O$	214	0.05	0.008	0.05	0.010
175	76.875	2208	δ-Undecalacton	$C_{11}H_{20}O_2$	184	0.05	0 008	0.09	0.016
176	77.492	2227	2-Heptadecanone	$C_{17}H_{34}O$	254	-	-	0.01	0.002
177	82.162	2354	Hexadecanol	$C_{16}H_{34}O$	242	0.13	0.020	0.09	0.016
178	82.819	2369	γ-Dodecalacton	$C_{12}H_{22}O_2$	198	1.80	0.273	2.40	0.436
			Total			78.5	9.010	84.80	12 527

the major compounds and (*E*)-2-hexenal, hexyl acetate, hexanal, ethyl acetate and γ-dodecalactone were the main components.

Total contents of volatile components isolated and identified were 9.010 mg/kg of *Bogyojosaeng* strawberry.

Volatile compounds from *Suhong* strawberry fruit

Approximately 153 volatiles were collected and identified using the above method and are presented in Table 1 and Fig. 2. 67 Esters, 21 alcohols, 24 ketones, 17 aldehydes, 4 acids, 12 terpenes and terpene derivatives, 2 ethers, 9 unknowns and miscellaneous were identified and quantified (Table 2). (*E*)-Nerolidol (12.38%) was the predominant volatile compound and ethyl butanoate (4.64%), methyl butanoate (3.73%), ethyl hexanoate (3.44%) and 3-penten-2-one (3.22%)

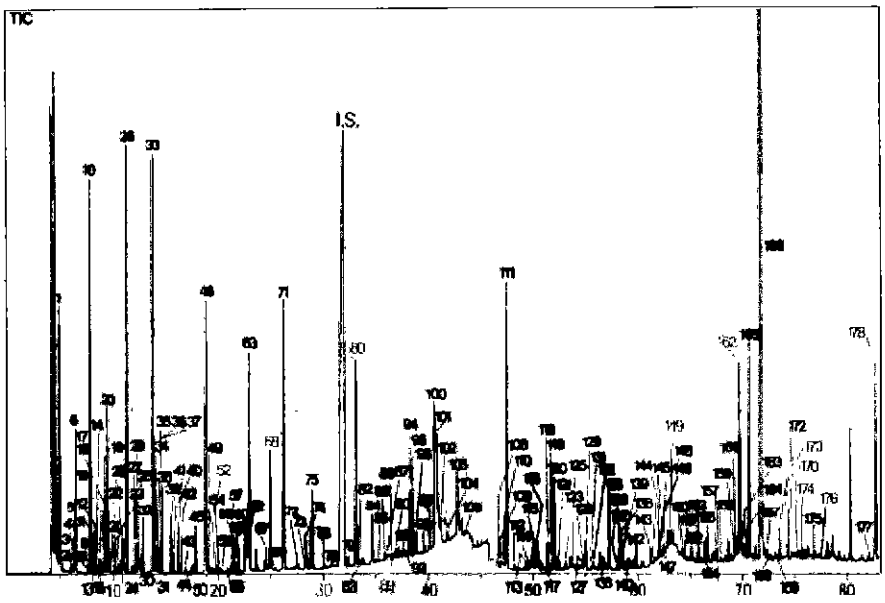

Fig. 2. GC chromatogram of volatile flavor components from *Suhong*.

Table 2. Relative content of functional groups in strawberry

Functional group	*Bogyojosaeng*		*Suhong*	
	Number	Area%	Number	Area%
Esters	49	19.31	67	26.95
Aldehydes	24	8.48	14	3.47
Alcohols	25	7.90	21	4.47
Ketones	20	4.25	24	8.14
Terpenes and derivatives	9	8.81	12	18.89
Acids	6	5.11	4	2.64
Ethers	2	0.09	2	0.41
Miscellaneous	11	5.59	9	3.83
Total	135	53.95	144	64.97

were relatively more abundant than other compounds.

Total contents of volatile components isolated and identified were 12.527 mg/kg of Bokyochosaeng strawberry.

Volatile flavor compounds from strawberry fruit

The major component of the volatiles was (*E*)-nerolidol (12.38% in *Suhong*, especially) with other carbonyl compounds present in small amounts. Apart from (*E*)-nerolidol, the other principal components were esters, which would contribute significantly to the flavor of strawberry. In addition to common esters, methyl, ethyl, 3-methylbutyl (isoamyl) and 2-methylpropyl (isobutyl), pentyl and hexyl were detected in volatiles. They would probably be responsible for the fruity ester aroma of the strawberry.

In general, unsaturated esters in fruit volatiles have a double bond in the acidic moiety in pear (14) and pineapple (15). Among such esters, (*E*)-2-hexenyl esters that were identified in this study are available and well-known in the flavor and fragrance industry as those with an unsaturated alcoholic moiety (16).

Aroma does not necessarily depend on the quantitative concentration of any volatile compound. Compounds that are highly significant as regards their concentration may have no significance as regards the aroma and, conversely, some compounds that are only present in trace amounts could be very important to the aroma (17). For strawberries, similar analyses were performed to determine that methyl butanoate, ethyl butanoate, methyl hexanoate, hexyl acetate and ethyl hexanoate play an important role in aroma (4-6) as indicated by the results of this study. It does not mean that the above compounds are necessarily present in large quantities, but their contribution to the characteristic flavor was high because the thresholds were very low despite the small quantity.

The contribution of these compounds to the total aroma impression is the aroma value, which is defined as the quotient of concentration and odour thresholds. For example, by comparing ethyl hexanoate to ethyl acetate, these have thresholds of 1 and 13,500 μL/10^3 L (18,19) and relative peak areas of 1.32% and 2.02% in *Bogyojosaeng*, respectively. While the concentration of ethyl hexanoate in the strawberry extract is lower, it contributes to the strawberry aroma more (13,200-fold) than ethyl acetate, because aroma values ware 1.32 and 0.0001.

Sanz et al. and Hirvi reported that furaneol (2,5-dimethyl-4-methoxy-3(2H)-furanone, DMF) and its methyl ether (2,5-dimethyl-4-methoxy-3(2H)-furanone, DHF), which can be present at low levels relative to other volatile compounds (20,21), and nerolidol (3,7,11-trimethyl-1,6,10-dodecatrien-3-ol) (17,21-23) play an important role in flavor acceptability of strawberry fruit. Despite the relatively high sensitivity of FID, DMF and DHF were not detected with purge-and-trap sampling and GC/FID or GC/MS (4,16,24), also these compounds were not found in our work. The failure to detect DHF may be caused either by its low abundance in the volatiles and/or

by chemical instability (25). Another reason was discovered in the report by Ulrich et al. (26). They said that all genotypes investigated can be subdivided into methylanthranilate-containing and methylanthranilate-free types. The methylanthranilate-free group is divided into a sensorial pleasant group (ester-type) and a less pleasant group (DHF-type). *Fragaria ananassa* Duch. with a fresh and fruity aroma (used in this investigation) may be grouped into ester-type.

Green odour notes based on hexenals and hexenols have an exceptional quality. In particular, (Z)-3-hexenal, with its very low threshold value of 0.25 $\mu L/10^3$ L, contributes essentially to the fresh aroma impression and is necessary for the positive strawberry aroma (27). But, thermally processed or frozen berries lack such 'green note' components and differ significantly from fresh fruit. As precursors to green note components are multiple-unsaturated fatty acids, the formation of these substances only starts after destruction of cell tissue during homogenization (28).

Besides green notes, a series of saturated and unsaturated γ- and δ-lactones ranging from chain length C_6 to C_{12}, with concentration maxima for γ-dodecalactone, were a major class of constituents. Lactones and peroxidation products of unsaturated fatty acids (i.e. C_6 aldehydes and alcohols) were major constituents of the volatiles.

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