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Comparison of Volatile Components in Fresh and Dried Red Peppers (*Capsicum annuum* L.)

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Abstract Fresh, and sun- and oven-dried red peppers were analyzed for volatile components. Also, their odor-active compounds were determined using gas chromatography-olfactometry (GC-O). More diverse volatile components, such as aldehydes, ketones, acids, and esters, were found in dried samples than in fresh ones. They included hexanal, ethyl acetate, α-ionone, and β-ionone. Some Strecker aldehydes, 2-methyl butanal and 3-methyl butanal, were found only in dried red peppers. More hydrocarbons of high volatility and terpene-type components, such as γ-terpinene and aromadendrene, were detected only in fresh red peppers. A considerable amount of naphthalene was formed during sun-drying, whereas 2-furancarboxaldehyde, 1-methyl-1H-pyrrole and benzeneethanol were detected only in oven-dried red peppers. Characteristic odor of fresh ones could be attributed to 3-penten-2-ol, 2-methyl-2-butenal, 2-methoxy phenol, 2-hydroxy-methyl-benzoate, and 2-phenoxy ethanol, whereas some odorants, including 2-pentyl furan, naphthalene, hexyl hexanoate, and α-ionone, could be responsible for distinctive odor property of sun-dried red peppers. 2-Furancarboxaldehyde, benzeneethanol, 4-vinyl-2-methoxy phenol, and unknown played important roles in odor property of oven-dried red peppers.

Key words: red pepper, volatile components, odor-active compounds, drying, gas chromatography-olfactometry (GC-O)

Introduction

Chili pepper belongs to *Capsicum annuum* L. species, which include chili, bell, cone, and cherry peppers, among others. 'Chili', also called 'chilly' or 'chile', means 'pepper' in South America and is named as 'red pepper' or 'hot pepper' in western countries due to its hot and spicy sensations (1, 2). Red pepper imparts intensely pungent, biting, and sharp taste attributes that are generally perceived as hot and irritating on the tongue and soft palate (3). The typical red color, hot and pungent taste, and unique aroma are important quality parameters of red peppers (4).

In Korea, red peppers are widely cultivated for use in many traditional cuisines. They are available in a wide range of forms to meet the diverse needs for food application, and the majority of products are commercially available in dry form. Although some red peppers are domestically used in fresh form, high levels of moisture content in red peppers may cause mold and microbial growth (5). In this respect, drying fresh red peppers can reduce the mold and microbial problems. However, drying and grinding can affect the quality of the final product due to the loss or degradation of the sensitive components mainly caused by lipid oxidation in the original material (3). Strecker aldehydes, such as acetaldehyde, 2-methyl-propanal, 2-methylbutanal, and 3-methylbutanal, were identified in the bell peppers processed by drying. The formation of these aldehydes indicates that the Maillard reaction occurred during the drying process (6). Drying also affects the formation and degradation of carotenoids in peppers (7-9). As such, drying step is one of the most important stages determining the final quality of red pepper powder. However, most studies on the quality changes of peppers have been focused on non-volatile pigments, carotenoids (7-9), and only one research group compared the differences in volatiles between green, ripe and dried pericarps of Japanese peppers (*Xanthoxylum piperitum* DC) (11). However, no study has been performed on the volatiles in fresh and dried red peppers.

With the enhanced use of spices, there have been continued interests in their odor-active compounds. Gas chromatography coupled with effluent sniffing, referred to as GC-O (gas chromatography-olfactometry), has been employed to determine the odor-active compounds in foods. GC-O, sometimes referred to as "GC-sniffing" is an important analytical tool which uses the human nose to evaluate individual components, complimenting instrumental analysis, in flavor research.

The objective of this study was to compare the volatile components in fresh and dried (sun- and oven-dried) red peppers. To prevent the changes in volatile components caused by thermal degradation during the extraction procedure, high vacuum sublimation was used. In addition, odor-active compounds of the original extracts were determined using GC-O.

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Materials and Methods

Materials The fresh, sun-dried, and oven-dried red peppers were purchased from Youngyang red pepper farm in Youngyang, Gyeongsangbuk-do, Korea. (The drying procedures described below refer to those used by the Youngyang red pepper farm.) The peppers harvested at the red mature stage were used. The sun-dried red peppers were manufactured by keeping the fresh peppers at 65°C in a thermostatically controlled dry house for 5-6 hr per day under the sunlight for 7-10 days. The oven-dried red peppers were manufactured by dryng the fresh peppers in a hot air-circulated (65°C) dry house without sunlight exposure for about 2 days. The moisture contents of fresh, sun-dried, and oven-dried red peppers were 77.56 (±5.66 %), 14.25 (±0.35%), and 11.75% (±1.77%), respectively. Both sun- and oven-dried red peppers were directly ground in a blender, whereas fresh red peppers were placed in a stainless steel container and frozen in liquid nitrogen prior to grinding.

Extraction of volatile components from red peppers Two hundred grams each of the ground red peppers were individually extracted by 500 mL of dichloromethane (Fisher Scientific Korea Ltd., Seoul, Korea). Each extract was divided into two portions, suspended in 250 mL dichloromethane with stirring at 200 rpm for 3 hr in a shaking incubator, and filtered through Whatman No. 41 filter paper (Whatman Ltd., Maidstone, UK) under vacuum. The residue on each filter paper was re-extracted with additional 150 mL dichloromethane and combined together. The extracts were dehydrated over anhydrous sodium sulfate (Fisher Scientific Ltd., Maidstone, UK) to remove any residual water, filtered through Whatman No. 1 filter paper, and concentrated into 75 mL volume using a Vigreux column (50 cm × 3 cm) at 45°C. Volatile components of the solvent extract were then separated from the non-volatile components using a high vacuum pumping system (Model VPC-250F, ULVAC KIKO, Inc., Yokohama, Japan) connected with custom made glasswares (Chang Young Scientific, Seoul, Korea) (12). Each solvent extract concentrated into 75 mL volume using a Vigreux column was placed in an additional funnel. The extract was then added dropwise into a 1-L round bottom flask when the operating vacuum pump level reached below 10^{-5} torr. Each sample droplet was dispersed in a round bottom flask, magnetically stirred at 400 rpm. The volatile components were collected in two cold traps immersed in liquid nitrogen. After all solvent extracts were dropped into the flask, extraction ran for additional 1.5 hr. The vacuum level ranged typically from 2×10^{-5} to 3×10^{-5} torr during extraction. After the high vacuum sublimation was completed, the cold traps in the apparatus were warmed to room temperature. The extract collected from two cold traps was reconcentrated to 5-10 mL on a Vigreux column at 45°C, then to a final volume of 0.1 mL under a gentle stream of nitrogen. The sample preparations were carried out in duplicates.

Gas Chromatography-Mass Spectrometry (GC-MS) GC-MS analysis was performed using an HP 5890A II series gas chromatograph-5972 mass selective detector (Hewlett-Packard Co., Palo Alto, CA, USA). A DB-5ms column (30 m length × 0.25 mm i.d. × 0.25 mm film thickness, J & W Scientific, Folsom, CA, USA) was used. Helium was run as a carrier gas at a constant flow rate of 1.0 mL/min. One microliter of the extract was injected in a splitless mode. The beginning part of column was cryofocused in liquid nitrogen for 2 min of the initial purge-off time. The oven program was held at 40°C for 5 min, raised to 250°C at 6°C /min and held at 250°C for 5 min. The GC-MS equipment was operated with both injector and detector temperatures of 250°C. Mass detector was performed in an electron impact mode with an ionization energy of 70 eV, the scanning range of 33-550 a.m.u., and scanning rate at 1.4 scan/sec.

Gas Chromatography-Olfactometry (GC-O) A Varian 3350 gas chromatograph (Varian Instrument Group, Walnut Creek, CA, USA) equipped with a sniffing port (Alltech Associates, Deerfield, IL, USA), a flame ionization detector (FID), and a non-polar fused silica GC capillary DB-5 column (30 m length × 0.25 mm i.d. × 0.25 mm film thickness, J & W Scientific, Folsom, CA, USA) was used for sniffing study. The injector and detector temperatures for GC-O were 230°C and 250°C, respectively. One microliter of the extract was injected in a splitless mode, and the tip of the column connected with the injector was immersed in liquid nitrogen during the 2-min of initial purge-off time. The GC oven temperature was held at 40°C for 3 min (including 2 min of initial purge-off time), increased to 180°C at 6°C/min, then to 250°C at 15 °C/min, and held at 250°C for 5 min. Helium was run as a carrier gas at a flow rate of 1.0 mL/min at 40°C. To prevent dehydration of the nasal membranes of the assessors, humidified air was added to the tip of the sniffing port. The aroma description of each compound was obtained through sniffing test.

Identification and quantification of components Tentative identification of the volatile components was based on the comparison of their mass spectral data with those of on-computer library (Wiley 275 mass spectral database, 1995) (Hewlett-Packard Co., Palo Alto, CA, USA) or by manual interpretation. In addition, retention index (RI) value of each component, determined using *n*-paraffins C_7-C_{22} as external references (13), was compared with those of the published literatures (14-18). The quantification of the volatile components identified was made based on the relative peak areas obtained from GC-MS total ion chromatogram.

Results and Discussion

Volatile components identified in fresh and dried red peppers Table 1 shows the volatile components identified in fresh and dried red peppers, including relative peak areas, RI values, and odor descriptions of each volatile components. A total of 103 volatile components were tentatively identified in the three types of red peppers. Depending on the sample types, the number and relative amount of volatile components identified varied. A total of 61, 52, and 51 components were detected in fresh, sun-dried, and oven-dried red peppers, respectively. All components identified in the three samples were grouped into 7 aldehydes, 7 alcohols, 4 acids, 4 esters, 5 ketones, 44 hydrocarbons, 15 terpenes, 8 benzenes, 4 phenols, and 5 miscellaneous according to their chemical structures. Considerable differences were observed in the overall profiles of volatile components found in the samples.

More diverse volatile components, including aldehydes, ketones and acids, which could have been mainly derived from lipid oxidation or carotenoids degradation, were found in the dried red peppers compared to the fresh one.

Table 1. Volatile components isolated from fresh, sun-dried, and oven-dried red peppers

No	RI[1)]	Possible compounds	Relative peak area[2)]			Identification[3)]
			Fresh	Sun-dried	Oven-dried	
		Aldehydes				
1	<700	3-Methyl butanal	-[4)]	2.12	1.43	GC/MS, RI , SN
2	<700	2-Methyl butanal	-	2.15	1.44	GC/MS, RI
3	740	2-Methyl-2-butenal	0.42	-	-	GC/MS, RI, SN
4	790	3-Methyl-2-butenal	0.09	0.49	-	GC/MS, RI, SN
5	805	Hexanal	-	1.50	0.45	GC/MS, RI, SN
6	833	2-Furancarboxaldehyde	-	-	0.32	GC/MS, RI, SN
7	960	Benzaldehyde	-	0.44	1.86	GC/MS, RI, SN
		Alcohols				
8	690	3-Penten-2-ol	1.17	1.08	1.12	GC/MS, RI, SN
9	769	3-Methyl-3-buten-1-ol	0.24	-	-	GC/MS, RI
10	780	3-Methyl-2-buten-1-ol	0.87	-	0.71	GC/MS, RI, SN
11	1124	Benzeneethanol	-	-	0.20	GC/MS, RI, SN
12	1219	2-Phenoxy ethanol	0.81	-	-	GC/MS, RI, SN
13	1313	2-Butyl-1-octanol	0.36	-	-	GC/MS, RI
14	1565	d-N-Nerolidol	-	1.37	1.28	GC/MS, RI, SN
		Acids				
15	1774	Tetradecanoic acid	-	0.58	0.59	GC/MS, RI
16	1958	Hexadecanoic acid	0.43	0.78	1.00	GC/MS, RI
17	2156	Octadecanoic acid	-	0.19	-	GC/MS, RI
18	>2200	3-Ritro-1,2-benzene dicarboxylic acid	-	0.08	-	GC/MS, RI
		Esters				
19	<700	Ethyl acetate	-	0.38	0.30	GC/MS, RI, SN
20	1194	2-Hydroxy-methyl-benzoate	8.34	-	-	GC/MS, RI, SN
21	1314	Hexyl hexanoate	-	1.66	-	GC/MS, RI, SN
22	1604	3-Methyl-butyl decanoate	-	0.75	0.57	GC/MS, RI
		Ketones				
23	<700	3-Methyl-3-buten-2-one	0.43	-	-	GC/MS, RI
24	1420	α-Ionone	-	0.26	-	GC/MS, RI, SN
25	1490	β-Ionone	-	2.95	1.94	GC/MS, RI, SN
26	1539	5,6,7,7-Tetrahydro-4,4,7-tri-2(4H)-benzofuranone	0.25	1.56	0.74	GC/MS, RI
27	1847	6,10,14-Trimethyl-2-pentadecanone	-	0.23	-	GC/MS, RI
		Hydrocarbons				
28	792	1-Octene	1.66	-	-	GC/MS, RI
29	800	Octane	0.92	-	-	GC/MS, RI
30	809	2-Octene	0.10	-	-	GC/MS, RI
31	814	3-Methyl-2-heptene	1.35	-	-	GC/MS, RI
32	824	2,4-Dimethyl heptane	0.10	0.85	0.54	GC/MS, RI
33	830	Propyl cyclopentane	0.22	-	-	GC/MS, RI
34	862	4-Methyl octane	-	-	0.29	GC/MS, RI
35	898	Nonane	0.35	0.20	0.20	GC/MS, RI
36	970	5-Methyl-4-nonene	1.74	-	-	GC/MS, RI
37	981	3-Methyl-4-nonene	1.30	-	-	GC/MS, RI
38	998	3,7-Dimethyl-1-octene	9.80	-	-	GC/MS, RI
39	999	(*E*)-5-Decene	0.18	-	-	GC/MS, RI
40	1003	Decane	1.97	0.86	0.52	GC/MS, RI
41	1007	3,7-Dimethyl-2-octene	0.88	-	-	GC/MS, RI
42	1014	(*E*)-2-Docene	0.47	-	-	GC/MS, RI
43	1034	3,8-Dimethyl undecane	-	-	0.77	GC/MS, RI
44	1035	Pentyl cyclopentane	0.76	-	-	GC/MS, RI
45	1058	3,4-Dimethyl decane	-	1.66	-	GC/MS, RI

Table 1. continued

No	RI[1)]	Possible compounds	Relative peak area[2)]			Identification[3)]
			Fresh	Sun-dried	Oven-dried	
46	1063	3-Methyl decane	-	1.07	-	GC/MS, RI
47	1098	Undecane	0.58	-	-	GC/MS, RI
48	1101	5-Methyl undecane	-	-	0.34	GC/MS, RI
49	1143	4-Methyl-1-undecene	0.22	-	-	GC/MS, RI
50	1203	1-Dodecene	0.61	-	-	GC/MS, RI
51	1207	Dodecane	1.57	-	-	GC/MS, RI
52	1236	Hexyl cyclohexane	-	-	0.19	GC/MS, RI
53	1297	Tridecane	0.42	1.12	0.39	GC/MS, RI
54	1359	4-Methyl tridecane	0.23	-	0.65	GC/MS, RI
55	1363	2-Methyl tridecane	-	2.46	-	GC/MS, RI
56	1379	1-Tetradecene	-	0.87	-	GC/MS, RI
57	1392	(*E*)-5-Tetradecene	5.76	-	-	GC/MS, RI
58	1411	Tetradecane	2.53	-	-	GC/MS, RI
59	1418	(*Z*)-7-Tetradecene	0.37	-	-	GC/MS, RI
60	1440	1,1-Dimethyl-2-nonyl-cyclopropane	-	1.10	2.05	GC/MS, RI
61	1450	1-Tetradecene	0.36	-	-	GC/MS, RI.
62	1460	3-Methyl tridecane	-	1.71	0.34	GC/MS, RI
63	1496	Pentadecane	0.44	1.06	1.54	GC/MS, RI
64	1590	(*Z*)-7-Hexadecene	-	-	-	GC/MS, RI
65	1605	Hexadecane	0.93	-	-	GC/MS, RI
66	1696	Heptadecane	-	0.32	0.76	GC/MS, RI
67	1786	1-Octadecene	0.30	-	-	GC/MS, RI
68	1800	Octadecane	0.32	0.13	0.08	GC/MS, RI
69	>2200	1-Nonadedecene	0.30	-	-	GC/MS, RI
70	>2200	2,6,10,14,18,22-Tetracosahexaene	0.19	0.23	-	GC/MS, RI
71	>2200	2,6,10,15,19,23-Hexamethyl tetracosane	-	1.39	0.11	GC/MS, RI
		Terpene Hydrocarbons				
72	1023	Limonene	2.67	0.22	1.53	GC/MS, RI
73	1047	(*E*)-β-Ocimene	1.01	1.44	2.28	GC/MS, RI, SN
74	1057	γ-Terpinene	0.43	-	-	GC/MS, RI, SN
75	1180	Naphthalene	0.44	16.96	1.77	GC/MS, RI, SN
76	1354	(+)-α-Longipinene	0.58	-	0.65	GC/MS, RI
77	1376	(+)-Longicyclene	-	-	0.28	GC/MS, RI
78	1380	α-Copaene	0.18	0.13	1.04	GC/MS, RI
79	1396	β-Elemene	-	3.51	2.55	GC/MS, RI
80	1448	Decahydro-1,5,5,8-tetramethyl-1,2,4-methenoazulene	-	0.54	-	GC/MS, RI
81	1453	α-Himachalene	-	0.57	0.55	GC/MS, RI
82	1457	Aromadendrene	0.14	-	-	GC/MS, RI
83	1481	Alloaromadendrene	0.16	-	-	GC/MS, RI
84	1486	γ-Himachalene	0.27	0.81	0.81	GC/MS, RI
85	1492	Aristolen	0.85	-	-	GC/MS, RI
86	1506	β-Himachalene	-	0.29	0.48	GC/MS, RI
		Benzenes				
87	765	Methyl benzene	2.65	4.43	1.97	GC/MS, RI
88	858	Ethyl benzene	0.52	0.47	0.26	GC/MS, RI
89	866	ρ-Xylene	1.35	0.52	0.82	GC/MS, RI
90	887	Stylene (Ethenyl benzene)	0.37	0.69	0.42	GC/MS, RI, SN
91	889	o-Xylene	0.47	0.31	0.21	GC/MS, RI, SN
92	958	1-Ethyl-2-methyl-benzene	0.16	-	-	GC/MS, RI
93	977	1-Ethyl-3-methyl benzene	-	-	0.14	GC/MS, RI
94	1782	(-)-Loliolide	-	0.21	-	GC/MS, RI
		Phenols				
95	1086	2-Methoxy phenol	0.24	-	-	GC/MS, RI, SN
96	1317	4-Vinyl-2-methoxy phenol	-	-	0.80	GC/MS, RI, SN

Table 1. continued

No	RI[1)]	Possible compounds	Relative peak area[2)]			Identification[3)]
			Fresh	Sun-dried	Oven-dried	
97	1507	2,4-Bis(1,1-dimethylethyl) phenol	1.22	-	-	GC/MS, RI
98	1515	2,6-Bis(1,2-dimethylethyl)-4-methyl phenol	-	1.55	-	GC/MS, RI
		Miscellaneous				
99	741	1-Methyl-1H-pyrrole	-	-	0.93	GC/MS, RI
100	784	3,4-Dihydropyran	0.31	-	-	GC/MS, RI
101	913	2-Acetyl furan	-	1.39	2.41	GC/MS, RI, SN
102	991	2-Pentyl furan	-	1.07	1.06	GC/MS, RI, SN
103	>2200	9-Octadecenamide	-	0.20	0.18	GC/MS, RI

1)Retention indices on DB-5ms column.
2)Average peak areas of two replicates (n=2), relative peak areas (%) obtained from GC-MS total ion chromatograms.
3)The compound was tentatively identified by comparing it with those of published literatures on the basis of following criteria : mass spectral data (GC/MS); retention index on DB-5ms column of GC-MS (RI); and odor property perceived at sniffing port (SN).
4)not detected

In particular, 3-methyl butanal (No. 1), 2-methyl butanal (No. 2), hexanal (No. 5), and benzaldehyde (No. 7) were found only in the dried red peppers. Some aldehydes identified in dried red peppers, such as 3-methyl butanal (No. 1) and 2-methyl butanal (No. 2), which had malty odor, were believed to be Strecker degradation products (6, 19), whereas benzaldehyde (No. 7) and its related volatile components could be the results of glucoside hydrolysis (20). In addition, benzaldehyde was formed by cyclization of 2,4-decadienal at high temperatures. Hexanal (No. 5), found only in the dried red peppers, contributes to the off-flavor because it has very low odor threshold value (4.5 μg/L in air) (21, 22). Most of the acid and ester components found mainly originated from the degradation of lipids. More acidic volatile components were found in the dried red peppers, particularly sun-dried, compared to the fresh red peppers. However, most acid components identified could not contribute significantly to the odor characteristic of red peppers mainly due to their high threshold values and low volatility. Ethyl acetate (No. 19) and 3-methyl-butyl decanoate (No. 22), probably originating from degradation of lipids, were found only in the dried samples. Most ketone-type volatiles identified in the red peppers could be produced from the degradation of lipids and/or carotenoids. More diverse ketones were found in the two dried red peppers than fresh red pepper, as observed with acids and esters.

Many studies have been conducted on the volatile components derived from the degradation of carotenoids (23-26). Among them, α- and β-ionones were believed to be responsible, in part, for the characteristic odor properties of the dried red peppers, due to their strong distinctive woody and violet-like odor notes (23, 27-29). According to investigations by Wilkins (1992) (22), β-ionone, which had extremely low threshold value of 7 pg/L in air (21), contributed to the off-flavor of spice paprika. In this study, volatile hydrocarbons and terpene hydrocarbons occupied about half of the total volatile components detected in the three samples. Noticeably, more hydrocarbon components of high volatility (RI value <1000) were detected in fresh red peppers compared to dried ones, possibly because hydrocarbons of high volatility might have been lost during the drying of red peppers. Some terpene-type components, such as γ-terpinene (No. 74), aromadendrene (No. 82), alloaromadendrene (No. 83), and aristolen (No. 85), were detected only in fresh red peppers, among which γ-terpinene (No. 74), described as citrus-like odor, was demonstrated to contribute fruit flavors in flowers (30, 31). On the other hand, some components such as β-elemene (No. 79), α-himachalene (No. 81), and β-himachalene (No. 86) were found only in the dried red peppers. In particular, β-elemene (No. 79) was a major volatile component in the dried red peppers, occupying about 2.6-3.5% of total volatile components, and also reported in another type of red peppers, paprika (Spanish type) (17). Some volatile components isolated from sun-dried red peppers could be regarded as photooxidation products formed via single oxygen. Interestingly, a considerable amount of naphthalene (No. 75), which could be responsible for the off-flavor of red peppers, was found in the volatile components of sun-dried red peppers. Kanasawud et al. (1990) reported that naphthalene could be produced during the heat treatment of β-carotene (27). Interestingly, isomer types (α-, β-, and γ-) of himachalene were detected in the three types of red peppers, and, as minor compounds, ethyl benzene (No. 88), *p*-xylene, (No. 89), *o*-xylene (No. 91), and stylene (No. 90) were also found commonly. 4-Vinyl-2-methoxy phenol (vinyl guaiacol, No. 96), which had a spicy odor, was detected in only oven-dried red pepper. This component was previously found as one of the odor-active compounds in red peppers (2). Considerable amounts of 2-acetyl furan (No. 101) and 2-pentyl furan (No. 102) were detected only in the dried red peppers, which were exposed to relatively high temperature. These components were also found in bell peppers and Kochujang (9, 32).

Odor-active compounds identified in fresh and dried red peppers GC-sniffing test was performed to determine the odor-active compounds in the red peppers. A total of 13, 17, and 21 odor-active compounds were found in the fresh, sun-dried, and oven-dried red peppers, respectively (Table 2). The major odor-active compounds identified in the three samples were described as strong almond-like (3-methyl-2-butenal), roasted and beany (2-acetyl furan), almond-like (benzaldehyde), unpleasant and mushroom-

Table 2. Odor-active components identified in fresh, sun-dried, and oven-dried red peppers by GC-O

No[1)]	RI	Possible Compounds	Odor Description[2)]	Odor Intensity[3)]		
				Fresh	Sun-dried	Oven-dried
19	<700	Ethyl acetate	Sour, Spicy		***	***
1	654	3-Methyl butanal	Malty			**
8	690	3-Penten-2-ol	Buttery	**		
3	740	2-Methyl-2-butenal	Penetrating, Ethereal	**		
10	780	3-Methyl-2-buten-1-ol	Herbaceous	**		**
4	790	3-Methyl-2-butenal	Strong almond-like	***	***	
5	805	Hexanal	Green		**	**
6	833	2-Furancarboxaldehyde	Strong caramel-like			***
90	887	Stylene (Ethenyl benzene)	Sweet	**	**	**
91	889	*o*-Xylene	Geranium	*		*
101	913	2-Acethyl furan	Roasted, Beany		***	***
A	916	Unknown	Nutty		**	
B	956	Unknown	Plastic ,Unpleasant	***		
7	960	Benzaldehyde	Almond-like		***	***
102	991	2-Pentyl furan	Metallic, Vegetable-like		**	
C	1035	Unknown	Fermented soy sauce-like		**	**
73	1047	(E)-β-ocimene	Mushroom-like	**	**	**
74	1057	γ-Terpinene	Herbaceous, Citrus	*		
95	1086	2-Methoxy phenol	Plastic, Unpleasant	**		
11	1124	Benzeneethanol	Sweet			**
D	1141	Unknown	Herbaceous, Ginseng		**	**
75	1180	Naphthalene	Strong mothball-like, Unpleasant		***	
20	1194	2-Hydroxy-methyl-benzoate	Fresh , Spicy	**		
12	1219	2-Phenoxy ethanol	Peach-like, Sweet	**		
E	1234	Unknown	Strong pungent, Spicy			***
21	1314	Hexyl hexanoate	Fresh green		**	
96	1317	4-Vinyl-2-methoxy phenol	Clove-like, Spicy			**
F	1329	Unknown	Ginseng-like, Herbaceous	**		
G	1347	Unknown	Strong spicy		***	***
H	1391	Unknown	Herb medicinal		**	**
24	1420	α-Ionone	Woody		**	
25	1490	β-Ionone	Violet-like		*	*
14	1565	d-N-Nerolidol	Floral			*
I	1669	Unknown	Weak spicy			*
J	1764	Unknown	Spicy, Fermented			**

1)Peak numbers represented in Table 1.
2)Odor descriptions at the sniffing port.
3)Odor intensity sniffied by GC-O : ***strong; **medium; *weak

like ((*E*)-β-ocimene), and strong spicy (unknown). Compared to the sun- and oven-dried red peppers, fewer odorants, including spicy odorant, were perceived in fresh red peppers. On the other hand, some odorants, such as stylene (No. 90, described as sweet) and (*E*)-β-ocimene (No. 73, mushroom-like), were detected in all of the samples. Compared to the dried red peppers, the characteristic odor of the fresh peppers could be related to 3-penten-2-ol (No. 8, buttery), 3-methyl-2-butenal (No. 4, strong almond-like), 2-methoxy phenol (No. 95, plastic and unpleasant), 2-hydroxy-methyl-benzoate (No. 20, fresh and spicy), and 2-phenoxy ethanol (No. 12, peach-like and sweet). On the other hand, ethyl acetate (No. 19, sour and fruity), hexanal (No. 5, green), 2-acetyl furan (No. 101, roasted and beany), benzaldehyde (No. 7, almond-like), β-ionone (No. 25, violet-like), and four unknowns (No. C, D, G, and H, representing fermented soy sauce-like, herbaceous and ginseng, strong spicy, and herb medicine-like, respectively) were found in only dried red peppers. Some odorants, such as unknown (No. A, nutty), 2-pentyl furan (No. 102, metallic and vegetable-like), naphthalene (No. 75, strong mothball-like and unpleasant), hexyl hexanoate (No. 21, fresh green), and α-ionone (No. 24, woody), were found only in sun-dried red peppers. On the other hand, 2-furancarboxaldehyde (No. 6, strong almond-like), benzene-ethanol (No. 11, sweet), unknown (No. E, strong pungent and spicy), and 4-vinyl-2-methoxy phenol (No. 96, clove-like, spicy) were detected in only oven-dried red peppers. These odorants, which have strong caramel-like, sweet, and spicy odor notes, were considered to be important to the odor property of oven-dried red peppers. However, naphthalene (No. 75), which possesses a strong mothball-like note, was detected only in sun-dried red peppers. Two unknowns (No. E and G), described as strong spicy, were sniffed. Although their exact structures remain uncertain, their contributions to the characteristic odor property of red peppers are unquestionable. Some other unknown compounds (A and J), although not detected by GC-MS, were found as odor-active compounds with nutty, plastic, unpleasant, herbaceous, and strong spicy notes.

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