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Volatile Flavor Components of Blended Tea with Fermented Tea and Herbs

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ABSTRACT: This study was conducted to characterize the volatile components of Korean fermented tea and blended tea with Korean fermented tea and several herbs. A total of 161 volatile components in 4 samples of FT (fermented tea), BT (blended tea) 1, BT2, and BT3 were analyzed in this study. A total of 61 volatile compounds were identified in the FT sample, which contained the most abundant hydrocarbons. The major compounds were 3-methyldecane (10.48%), 2,2,4,6,6-pentamethylheptane (10.00%), and 2,3,6-trimethyloctane (7.90%). A total of 75 volatile compounds were identified in the BT1 sample, which consisted of fermented tea, orange cosmos, lemon grass, chamomile, and peppermint. L-(−)-menthol (36.79%), menthone (24.92%), and isomenthone (8.70%) were the highest compounds. A total of 76 volatile compounds were identified in the BT2 sample, which was composed of fermented tea, rose hip, lemongrass, lavender, and peppermint. Alcohols were identified as the most abundant, and linalool (26.32%), linalyl acetate (18.45%), and L-(−)-menthol (11.99%) were the major components. A total of 85 volatile compounds were identified in the BT3 sample composed of fermented tea, citrus peel, chamomile, hibiscus, and beet. Sesquiterpenes were identified as the most abundant including L-limonene (74.45%), β-myrcene (3.06%), and γ-terpinene (7.47%).

Keywords: blended tea, fermented tea, herbs, volatile component, SPME

INTRODUCTION

Tea is a drink made by processing of the buds or young leaves from tea tree (*Camella sinensis*) (1). There are hundreds of tea processing methods in the world, and various kinds of tea have been produced depending on their varieties, processing methods and season of tea, and how to make it (1). In general, tea is classified depending on the degree of fermentation such as non-fermented tea, semi-fermented tea (10 to 65%), and fermented tea (85% or more) (2). Among them, fermented tea has become popular due to the increasing demand of consumers and its milder taste to drink than a green tea with a cold nature (3). Fermented tea has a unique flavor by changing catechin to compounds by the action of oxidizing enzymes depending on the degree and method of fermentation (4). Since flavor is one of the important factors that determine the inherent quality and characteristics of the tea, much research has been conducted on the volatile components of tea, and several components have been identified (5).

In Korea, many kinds of tea including fermented tea are manufactured and sold. A tea made from a single material may be good; however, it is also a good way to manufacture tea by mixing flavors and aromas with different functionalities to promote consumption of tea (6). This is called tea blending, which is the mixing of tea with different materials (7). The blending of tea has the advantages of reducing the difference in quality of other tea leaves depending on the season, producing a balanced taste, and creating higher profit by creating a new taste (8). Many kinds of materials (herbs, fruits, and spices) have been used for blending tea, but herbs are mainly used (9). Herbs are the plants used as raw materials for spices and medical herbs, and are made of roots, stems, leaves, buds, and flowers. Herbal tea is the beverage that extracts water-soluble ingredients from leaves, flowers, and stems in a raw or dried state using cold or hot water and is the easiest and safest method to consume herbs (10). Studies on the flavor analysis of single or blended teas using herbs include hibiscus tea (11), chamomile tea (12), fermented tea with rosemary (6), tea

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with roses and rose hips (13), fennel tea, and caraway tea (14).

In this study, as the use of herbal and blended teas increased due to the increase in tea consumption, three kinds of blended teas were mixed with domestic fermented tea and herbs, and their volatile flavor contents were measured.

MATERIALS AND METHODS

Materials

The blended tea used in this study was prepared by blending herbs into a fermented tea produced in Korea. The constituent materials and composition ratios for each sample are listed in Table 1. Fermented tea and beet tea (Semyungtea, Suncheon, Korea) were used and orange cosmos tea was purchased from Suncheon Society for Wildflower Research (Suncheon, Korea). Lemongrass tea, chamomile tea, rose hip tea, lavender tea, and hibiscus tea purchased from GDG Schütte GmbH & Co. KG (Breman, Germany) and peppermint tea were purchased from Nateva (Die, France). Citrus peel was purchased from Hansecofarm (Jeju, Korea).

Collection of volatile components

In this study, an experiment was conducted to select a suitable solid-phase microextraction (SPME) resin (Supelco Inc., Bellafonte, PA, USA) before analyzing the volatile flavor components of tea. The samples were analyzed using 4 SPME resins: polydimethylsiloxane (PDMS)/divinylbenzene (DVB) (65 μm), PDMS/carboxen (75 μm), PDMS (100 μm), and DVB/carboxen/PDMS (50/30 μm). PDMS/DVB (65 μm) resin, which collected the most amount of volatile components among them was selected as the analytical resin. In order to collect volatile components, 2 g of sample was placed in a 40 mL vial, frozen at −85°C, and then used as the analytical sample. The frozen sample was sealed with a stopper after replacing air in the vial with helium gas for 20 s to collect the volatile components. The sample vials were heated to 60°C using a heating mantle. When it reached 60°C, the SPME resin-needle was exposed to the headspace of the vial for 20 min for collecting the volatile components. The collected components were analyzed using a gas chromatography (GC)/mass spectrometer (MS).

GC/MS analysis method

The volatile components were injected at 240°C into the injection port of GC/MS (GCMS-QP2010, Shimadzu Co., Ltd., Kyoto, Japan) for 5 min. The volatile components

Table 1. Tea samples used in the volatile flavor compounds

Sample code[1)]	Ingredients					Total weight (g)
	Weight (g)					
FT	Fermented tea 1.20					1.20
BT1	Fermented tea 1.00	Orange cosmos tea 0.20	Lemongrass tea 0.20	Chamomile tea 0.15	Peppermint tea 0.10	1.65
BT2	Fermented tea 1.00	Rose hip tea 0.50	Lemongrass tea 0.30	Lavender tea 0.05	Peppermint tea 0.03	1.88
BT3	Fermented tea 1.00	Citrus peel 1.00	Chamomile tea 0.70	Hibiscus tea 0.50	Beet tea 0.10	3.30

[1)] FT, fermented tea; BT1, blending tea sample 1; BT2, blending tea sample 2; BT3, blending tea sample 3.

Table 2. Summary of volatile compounds in fermented tea and blended teas

Compounds	Samples			
	FT	BT1	BT2	BT3
Alcohol (33)	13 (17.24%)	16 (41.77%)	15 (47.08%)	14 (3.82%)
Aldehyde (17)	14 (13.65%)	10 (3.03%)	9 (0.77%)	12 (0.70%)
Ester (19)	1 (0.63%)	6 (2.65%)	8 (20.69%)	12 (0.52%)
Hydrocarbon (21)	15 (50.28%)	6 (0.83%)	7 (1.68%)	4 (0.12%)
Ketone (12)	4 (6.30%)	6 (40.36%)	6 (14.67%)	4 (0.48%)
Miscellaneous (9)	6 (3.50%)	4 (0.52%)	5 (1.40%)	4 (0.12%)
Monoterpene (18)	5 (6.15%)	11 (4.11%)	13 (11.17%)	9 (87.24%)
Oxide (7)	0 (0.0%)	3 (5.84%)	2 (1.45%)	3 (6.80%)
Pyrazine (4)	3 (2.25%)	1 (0.02%)	3 (0.05%)	1 (0.01%)
Sesquiterpenes (21)	0 (0.0%)	12 (0.87%)	8 (1.04%)	17 (0.19%)
Total (161)	61 (100%)	75 (100%)	76 (100%)	85 (100%)

were sampled for 1 min using a splitless mode, and then separated using a DB-5 capillary column (30 m×0.25 mm i.d.×0.25 μm, J&W Scientific, Inc., Folsom, CA, USA). Helium was used as the mobile phase gas. Analysis conditions were set to 0.8 mL/min of flow rate, 32.2 cm/min of linear velocity, and 31.9 KPa of column pressure. Oven temperature was increased to 220°C at 2.5°C/min after keeping for 5 min at 35°C, and kept for 31 min. For the MS analysis conditions, the temperatures of capillary direct interface and ion source were 220°C. The electron multiplier voltage and MS ionization voltage were 1,000 V and 70 eV. The mass range and scan rate were 40~350 m/z and 1/s, respectively. The volatile flavor component was determined by the consistency of the retention indices (RI) between the volatile components and reference material (15), or the comparison of mass spectra between volatile components and Wiley 8 (399,383 spectrum) mass spectral database (Shimadzu Co., Ltd.). RI was carried out under the same conditions as the samples using C_6~C_{24} (*n*-alkane, Aldrich, Milwaukee, MN, USA).

RESULTS AND DISCUSSION

The results of flavor components analysis of fermented

Table 3. Volatile compounds identified in fermented tea and blended teas

Compounds	RI	Samples				Identification method1)	Oder descriptions
		FT	BT1	BT2	BT3		
Alcohol (33)							
3-Methyl-1-butanol	728.5	4.1	–2)	–	2.3	MS, LRI	Malty and fruity-winey in carrageenan
2-Methylbutanol	761.5	–	–	4.5	–	MS, LRI	Malty in carrageenan; ripe onion, buttery, and dirty feet in puree
Pentanol	763.3	7.4	12.7	–	–	MS, RI	Fruity, alcoholic in Chinese liquor
2-Pentenol	767.3	4.5	–	–	–	MS, RI	Fruity in Chinese liquor
(Z)-3-hexenol	852.4	60.9	–	31.2	23.5	MS, RI	Woody, mushroom, and green
(E)-2-hexenol	864.6	16.8	–	3.4	–	MS, RI	Greenish, onion, liver, meaty, and sweaty in red pepper, fruity
Hexanol	868.3	39.5	20.2	101.1	–	MS, RI	Green leaf and green-burning in lychee
2-Butoxyethanol	904.2	11.0	–	–	–	MS, RI	
7-Octen-4-ol	979.6	–	39.6	–	–	MS, RI	
1-Octen-3-ol	979.9	–	–	139.8	–	MS, RI	Mushroom-like and fatty
6-Methyl-hept-5-en-2-ol	992.1	–	80.4	32.4	–	MS	
3-Octanol	994.8	–	126.2	146.2	–	MS, RI	Mushroom-like and buttery in mushrooms
2-Ethylhexanol	1,028.3	–	52.2	–	–	MS, LRI	
Octanol	1,073.0	–	–	–	61.2	MS, RI	Mushroom-like and buttery in mushrooms
3,3,6-Trimethyl-1,5-heptadien-4-ol	1,084.5	–	352.9	–	139.6	MS	
Linalool	1,102.6	90.7	619.3	9,957.2	2,592.8	MS, RI	Green, sweet, and mild floral
Benzeneethanol	1,109.0	203.6	–	–	–	MS, RI	Floral
(E)-Verbenol	1,118.3	–	–	–	33.2	MS, LRI	Herb
(E)-*p*-mentha-2,8-dien-1-ol	1,132.4	–	–	–	38.4	MS, LRI	
(E)-Pinocarveol	1,138.1	–	31.1	–	–	MS, LRI	Warm woody balsamic
Borneol	1,164.1	–	–	1,879.6	–	MS, RI	Sweet, menthol, and pungent
Lavandulol	1,166.8	6.2	–	–	42.5	MS, RI	Sweet, menthol, and pungent
L-(−)-menthol	1,183.0	7.5	14,715.0	4,535.2	–	MS, LRI	Fresh, green, and cool
α-Terpineol	1,190.2	3.0	177.5	551.0	209.2	MS, LRI	Woody, earthy, and musty
(E)-Carveol	1,218.3	–	–	10.5	59.4	MS, RI	Caraway-like and spicy
β-Citronellol	1,235.8	–	–	309.1	77.3	MS, LRI	Sweet and roses
Geraniol	1,252.4	9.5	339.6	–	33.0	MS, LRI	Floral, woody, and rose floral
Perillol	1,285.8	–	–	–	15.1	MS, LRI	
6-Undecanol	1,328.7	–	–	94.7	–	MS	
Dodecanol	1,473.5	–	27.4	–	–	MS, RI	Fatty, waxy, and coconut-like
Spathulenol	1,526.0	–	11.9	–	–	MS, LRI	
Ledol	1,580.5	–	44.5	–	–	MS, LRI	Sugar sweet
α-Bisabolol	1,681.9	–	55.4	18.8	27.2	MS, LRI	Sweet and waxy
Total		464.7	16,705.9	17,814.7	3,354.7		

tea and blended tea are shown in Table 2 and 3. In the 4 samples, a total of 161 volatile flavor components including 33 kinds of alcohols, 17 kinds of aldehydes, 19 kinds of esters, 21 kinds of hydrocarbons, 12 kinds of ketones, 9 kinds of miscellaneous species, 18 kinds of monoterpenes, 7 kinds of oxides, 4 kinds of pyrazine species, and 21 kinds of sesquterpenes species were identified.

A total of 61 volatile compounds were identified in the FT samples. Hydrocarbons were identified as the most abundant with 15 kinds, and then aldehydes (14 kinds), alcohols (13 kinds), and miscellaneous species (6 kinds) were identified in descending order. The hydrocarbon kinds, which were contained more in the FT sample than in the other samples, were identified as 50.28%, whereas the volatile components of esters (0.63%), oxides (0.0%), and sesquiterpenes (0.0%) were almost not identified in the FT sample. The main components of the FT samples were 3-methyldecane (10.48%), 2,2,4,6,6-pentamethylheptane (10.00%) specified as fruit and grass flavors, 2,3,6-trimethyloctane (7.90%), benzeneethanol (7.55%), and 5-ethyl-2,2,3-trimethylheptane (5.87%). These volatiles flavor components were not identified or had lower

Table 3. Continued 1

Compounds	RI	Samples				Identification method1)	Oder descriptions
		FT	BT1	BT2	BT3		
Aldehydes (17)							
2-Methyl butanal	600<	79.2	30.2	–	14.1	MS, RI	Rancid, almond-like, toasted, and chocolate
3-Methyl butanal	600<	43.6	26.8	27.6	13.6	MS, RI	Fruity, almond-like, toasted, and chocolate
Pentanal	670.3	14.8	–	–	6.4	MS, RI	Nutty, toasted, and fruity
3-Methyl-2-butenal	778.4	–	–	2.7	–	MS, LRI	Metallic, aldehydic, and herbaceous
Hexanal	796.1	49.7	42.0	24.6	2.0	MS, RI	Green and grassy
Furfural	827.8	65.4	60.0	67.0	207.5	MS, RI	Pungent and sweet
2-Hexenal	847.0	8.0	–	5.7	–	MS, RI	Green and apple-like
Heptanal	899.1	8.9	–	–	–	MS, RI	Grass and mushroom
Benzaldehyde	953.3	29.6	73.6	27.3	32.7	MS, RI	Floral, fresh, and green
5-Methyl-2-furfural	958.1	13.9	16.1	8.3	–	MS, LRI	Green and roasted
Nonanal	1,104.7	16.1	–	–	42.8	MS, RI	Floral, green, and rose floral
Lilac aldehyde	1,148.1	4.7	–	–	24.8	MS, LRI	
Citronellal	1,151.3	2.0	–	–	50.7	MS, LRI	Solvent and lemon
Decanal	1,203.0	15.4	39.3	–	142.2	MS, RI	Green and metallic
Neral	1,240.7	–	518.7	–	–	MS, RI	Lemon, citrus, and green
Geranial	1,270.2	16.7	397.4	119.1	73.0	MS, LRI	Citrus, citric fruit
Dodecanal	1,402.7	–	8.7	9.3	11.2	MS, RI	Floral and waxy
Total		368.0	1,212.8	291.6	621.0		
Esters (19)							
Amyl formate	762.7	–	–	–	3.6	MS, LRI	
Methyl 2-methylbutyrate	771.7	–	–	–	6.6	MS, LRI	Apple-like
Butyl acetate	813.0	–	–	1.9	–	MS, RI	Fruity, sweets, and apple
Ethyl 2-methylbutyrate	847.1	–	113.2	–	131.0	MS	Sweet and ester
Ethyl 3-methylbutyrate	850.2	–	77.5	–	8.9	MS	Strawberry
Propyl 2-methylbutanoate	944.9	–	61.1	–	49.8	MS	Sweet and fruity
Hexyl acetate	1,013.7	–	–	156.3	–	MS, LRI	Mulberry and banana
Butyl 2-methylbutanoate	1,040.9	–	18.9	–	–	MS, LRI	Apple and fruity
Methyl benzoate	1,091.9	–	–	–	41.5	MS, RI	Violet and floral
Octenyl acetate	1,114.0	–	–	189.0	–	MS, LRI	
Bornyl formate	1,223.5	–	–	44.6	22.2	MS, LRI	
3-Hexenyl 2-methylbutanoate	1,234.4	–	–	–	8.1	MS, LRI	
Linalyl acetate	1,260.7	–	–	6,979.2	–	MS, RI	Flowery and carnation
Menthyl acetate	1,293.1	–	759.5	182.6	–	MS, LRI	
Methyl decanoate	1,323.1	–	29.6	–	43.6	MS, RI	Green
(E)-Carvyl acetate	1,327.9	–	–	–	57.6	MS, LRI	
Citronellyl acetate	1,351.2	–	–	–	10.6	MS, LRI	Pleasant, ester, and rubber
Neryl acetate	1,358.9	17.1	–	70.6	70.7	MS, LRI	Sweet floral and orange
Geranyl acetate	1,381.6	–	–	203.8	–	MS, LRI	Rose and green odor
Total		17.10	1,059.8	7,828.0	454.2		

Table 3. Continued 2

Compounds	RI	Samples				Identification method1)	Oder descriptions
		FT	BT1	BT2	BT3		
Hydrocarbons (21)							
2,2,4-Trimethylheptane	956.9	12.9	–	–	–	MS	
2,2,6-Trimethyl-octane	978.7	24.7	–	–	–	MS	
Decane	1,000.1	85.9	19.8	38.3	–	MS, RI	
2,2,3,5-Tetramethylheptane	1,007.1	47.1	–	–	–	MS	
2,2,4,6,6-Pentamethylheptane	1,022.2	269.7	–	–	–	MS	
2,2-Dimethyl-decane	1,027.9	61.1	–	–	–	MS	
3-Methyldecane	1,030.6	282.6	–	–	–	MS	
3,7-Dimethylnonane	1,030.6	–	135.1	126.6	–	MS	
(Z)-3,7-Dimethyl-1,3,6-octatriene	1,036.1	–	–	190.3	–	MS	
5-Ethyl-2,2,3-trimethylheptane	1,050.2	158.3	–	–	–	MS	
2,3,6-Trimethyloctane	1,061.0	212.9	–	196.2	–	MS	
2,3,4-Trimethyldecane	1,072.3	–	47.7	38.5	–	MS	
2,2,3-Trimethylnonane	1,075.9	–	–	–	48.0	MS	
4-Methylundecene	1,089.9	4	–	–	–	MS, RI	
2,3,6,7-Tetramethyloctane	1,096.0	78.7	–	–	–	MS	
Dodecane	1,200.1	85.4	66.4	–	34.6	MS, RI	
Tridecane	1,300.5	7.8	–	–	4.9	MS, RI	
3-Tridecene	1,318.0	–	–	11.3	–	MS, LRI	
3-Methyltridecane	1,368.7	–	43.9	–	–	MS, RI	
Tetradecane	1,400.3	21.0	20.5	35.0	13.4	MS, RI	
Hexadecane	1,600.0	3.7	–	–	–	MS, RI	
Total		1,355.8	333.4	636.2	100.9		
Ketones (12)							
2-Methyltetrahydrofuran-3-one	804.9	2.8	–	–	–	MS, LRI	
2-Heptanone	887.9	7.9	–	–	–	MS, RI	Cured ham-like, toasted, and nutty
1-Octen-3-one	975.0	–	–	4.5	–	MS, RI	Metallic/mushroom
6-Methyl-5-hepten-2-one	986.4	146.4	850.5	962.7	105.8	MS, LRI	Plastic and mushroom
3,3,6-Trimethyl-1,5-heptadien-4-one	1,084.5	–	363.3	–	–	MS, LRI	
Camphor	114.0	–	–	1,485.4	35.5	MS, RI	Camphoraceous, medicinal, and mentholic
p-Menthan-3-one	1,153.4	–	–	2,494.9	–	MS, LRI	
Menthone	1,160.2	–	9,967.2	–	194.2	MS, LRI	Fresh and green
Isomenthone	1,166.1	–	3,477.7	–	–	MS, LRI	
Pulegone	1,237.6	–	763.1	–	–	MS, LRI	
Carvone	1,239.2	12.8	–	417.8	81.8	MS, LRI	Minty
Piperitone	1,253.3	–	720.9	185.7	–	MS, LRI	Sweet and fruity
Total		169.9	16,142.7	5,551.0	417.3		
Miscellaneous (9)						MS	
1-Ethylpyrrole	810.4	7.9	–	–	–	MS, RI	Coffee liquor-like
m-Xylene	862.4	14.3	17.1	5.3	–	MS, RI	
o-Xylene	886.0	6.2	–	–	–	MS, RI	
2-Acetylfuran	906.4	26.3	–	19.1	–	MS, RI	Sweet and caramel
γ-Butyrolactone	907.7	27.8	18.3	–	25.5	MS, LRI	Sweet, cake, caramel, and fruity
(E)-Sabinene hydrate	1,062.9	–	79.3	68.2	35.3	MS, LRI	Fresh and minty
p-Allylanisole	1,196.5	11.8	94.8	193.3	42.3	MS, LRI	
(E)-Anethole	1,283.3	–	–	240.8	–	MS, LRI	
7-epi-α-Selinene	1,516.5	–	–	–	7.1	MS, LRI	
Total		94.3	209.5	526.7	110.2		

contents in the three blended tea samples (BT1, BT2, and BT3). 3-Methyldecane, which was the highest compound in fermented tea, was reported as the volatile component contained in not only fermented tea but also in leaves of *Melia azedarach* L. (18), chickpea (19), and ham (20), and was mainly found in animal and vegetable foods (21). Choi et al. (22) reported that benzeneethanol was detected in the flavor components of fermented black tea

Table 3. Continued 3

Compounds	RI	Samples				Identification method1)	Oder descriptions
		FT	BT1	BT2	BT3		
Monoterpenes (18)							
α-Thujene	922.5	–	25.8	17.4	92.5	MS, LRI	Cooked; nutty
α-Pinene	926.6	–	20.3	24.7	390.3	MS, LRI	Soapy and fragrant; green
Camphene	940.2	–	–	36.6	–	MS, LRI	Warm and herbaceous
Verbenene	946.5	–	–	4.9	–	MS, LRI	
Sabinene	968.0	–	133.3	16.1	–	MS, LRI	Green, pungent, and green leaf
β-Pinene	968.3	21.0	–	–	533.6	MS, LRI	Woody and resinous
β-Myrcene	989.0	–	205.7	1,262.2	2,686.4	MS, LRI	Peel, unpleasant, and geranium
2-Carene	1,010.7	–	–	19.9	–	MS, LRI	Rolled oats
α-Terpinene	1,011.4	–	16.7	–	–	MS, LRI	Green-grassy and lemon-like
p-Cymene	1,019.4	11.2	154.1	127.5	–	MS, LRI	Citrus and green
1,8-Cineole	1,026.8	–	398.7	2,426.0	–	MS, LRI	Minty
L-limonene	1,027.9	61.3	376.3	–	65,318.6	MS, RI	Fresh, herbaceous, and lemon
(Z)-β-Ocimene	1,036.4	–	127.6	–	–	MS, LRI	Citrus-like
(E)-β-Ocimene	1,046.0	–	99.6	153.0	–	MS, LRI	Pleasant
o-Cymene	1,053.3	41.7	–	–	345.3	MS, RI	
γ-Terpinene	1,054.7	–	85.0	54.9	6,552.5	MS, LRI	Herbaceous, citrus, and fruity
α-Terpinolene	1,087.4	–	–	–	507.1	MS, LRI	Woody and herbaceous
δ-Elemene	1,332.2	30.6	–	52.6	109.1	MS	
Total		165.8	1,643.1	4,225.8	76,565.4		
Sesquiterpenes (21)							
α-Cubebene	1,346.2	–	–	–	115.5	MS, RI	Pleasant
α-Copaene	1,372.4	–	32.8	–	213.1	MS, RI	Cinnamon, spicy, and floral
β-Bourbonene	1,381.6	–	147.9	–	–	MS, RI	
β-Cubebene	1,381.6	–	–	–	96.1	MS, RI	Floral, terpene-like, and lemon
β-Elemene	1,389.3	–	95.6	–	1,557.6	MS, RI	Fresh and green
(E)-Caryophyllene	1,416.2	–	471.1	238.8	222.8	MS, LRI	Spicy woody and terpene note
(Z)-Thujopsene	1,425.8	–	21.0	5.7	5.3	MS, LRI	
(E)-Bergamotene	1,434.0	–	17.1	57.8	–	MS, LRI	Cucumber and sweet
α-Guaiene	1,436.0	–	–	–	15.7	MS, LRI	
α-Humulene	1,451.6	–	–	–	270.7	MS, LRI	Woody spicy
β-Farnesene	1,456.2	–	1,281.3	118.9	1,871.0	MS, LRI	Sweet and fruity
α-Amorphene	1,476.6	–	18.0	8.4	–	MS, LRI	
Germacrene D	1,480.8	–	171.0	63.3	191.1	MS, LRI	Pleasant and mild
β-Selinene	1,485.6	–	–	–	186.0	MS, LRI	Dried grass
α-Selinene	1,494.9	–	–	–	263.7	MS, LRI	Orange
Bicyclogermacrene	1,496.1	–	51.2	–	–	MS, LRI	
α-Muurolene	1,499.7	–	–	–	19.6	MS, LRI	Fruity
Germacrene A	1,504.7	–	–	–	78.1	MS, LRI	
α-Farnesene	1,511.5	–	3.3	25.7	707.9	MS, LRI	Floral oily and weak spicy
δ-Cadinene	1,512.0	–	27.2	31.0	139.3	MS, LRI	Dry-woody and spicy
Germacrene B	1,513.2	–	–	–	14.6	MS, LRI	
Total		0.0	2,337.5	549.6	5,968.1		
Pyrazine (4)							
Pyrazine	727.8	2.3	–	–	–	MS, RI	
Methylpyrazine	818.0	39.1	–	10.4	5.4	MS, RI	Hazelnut and green
2,6-Dimethylpyrazine	907.3	–	–	5.0	–	MS, LRI	
2-Ethylpyrazine	910.2	19.3	1.7	4.6	–	MS, LRI	
Total		60.7	1.7	20.0	5.4		

and was the component having the characteristic rose flavor. In the study of Choi (23), a total of 46 volatile compounds were detected in Korean black tea. Among the 11 kinds linalool, nonanal, geraniol, hexanal, (Z)-3-hexenal, hexanol, heptanal, 3-methyl butanal, 2-methyl butanal, and furfural were also identified in this study. Choi (23) reported that geraniol was common in green tea, semi-fermented tea, and Indian black tea, and the difference in the content or the presence of geraniol was affected by variety.

A total of 75 volatile compounds were identified in the BT1 sample, which consisted of fermented tea, orange

Table 3. Continued 4

Compounds	RI	Samples				Identification method[1]	Oder descriptions
		FT	BT1	BT2	BT3		
Oxide (7)							
(Z)-Linalool oxide	1,069.2	–	–	–	–	MS, LRI	Floral
(E)-Linalool oxide	1,084.9	–	–	352.7	–	MS, LRI	Floral
(Z)-Limonene oxide	1,130.1	–	–	–	8.8	MS, LRI	Fresh and citruslike
(E)-Limonene oxide	1,134.8	–	–	–	50.2	MS, LRI	
Caryophyllene oxide	1,575.5	–	51.4	41.3	–	MS, LRI	Sweet and fruity
α-Bisabolol oxide B	1,654.2	–	229.0	–	108.1	MS	
α-Bisabolol oxide A	1,743.6	–	68.0	–	–	MS, LRI	
Total		0.0	348.4	394.0	167.1		

[1] MS, RI, mass spectral data and retention indices of an authentic compound (16); MS, LRI, mass spectral data and retention indices of published literatures (17); MS, only Wiley 8 (399,383 spectrum) mass spectral data.

[2] Not detected.

cosmos, lemongrass, chamomile, and peppermint. Sixteen kinds of alcohols, 12 kinds of sesquiterpenes, 11 kinds of momoterpenes, and 10 kinds of aldehydes were identified in the BT1 sample. The major volatile flavor compounds were 41.77% of alcohols and 40.36% of ketones. Among these compounds, the high content compounds were L-(−)-menthol (36.79%), menthone (24.92%), isomenthone (8.70%), β-farnesene (3.20%), and 6-methyl-5-hepten-2-one (2.13%), in descending order. L-(−)-menthol, menthone, and isomenthone, which were the most prominent volatile components in BT1, are responsible for the taste and flavor of peppermint (24-26). The 1,8-cineole, a volatile component with a pleasant flavor similar to menthol (27), was identified only in the BT1 and BT2 samples containing peppermint. It was considered that the 1,8-cineole was identified by the peppermint contained in BT1, and BT1 can be defined as the tea sample with flavor characteristics related to peppermint. Although not shown in this study, the sensory evaluation of the BT1 sample showed a cooler sensation and a higher frequency of peppermint flavor than the other samples. Germacrene D, analyzed in the analysis study of flavor components in cosmos by Lee and Kim (28), was also identified in the BT1 sample containing the cosmos. Germacrene D played a role as the substance initiated during the sesquiterpene derivative biosynthesis process and also known as a major component in other plants containing essential oils (29). β-Pinene was not identified in this study; however, it was identified in the essential oil of cosmos reported by Lee and Kim (28). The compounds identified in the BT1 sample only were 7-octen-4-ol, 2-ethylhexanol, (E)-pinocarveol, dodecanol, spathulenol, ledol, neral, 3,3,6-trimethyl-1,5-heptadien-4-one, isomenthone, pulegone, β-bourbonene, bicyclogermacrene, and α-bisabolol oxide A. Among these compounds, 7-octen-4-ol is found not only in tea and herbs but also in oysters (30), *Sedum sarmentosum* Bunge (31), and chungkukjang (32).

A total of 76 volatile compounds were identified in the BT2 sample, which was composed of fermented tea, rose hip, lemon grass, lavender, and peppermint. Alcohols were identified as the most abundant (15 kinds), followed by monoterpenes (13 kinds), aldehydes (9 kinds), esters (8 kinds), sesquiterpenes (8 kinds), and hydrocarbons (7 kinds). Among these compounds, linalool (26.32%), linalyl acetate (18.45%), L-(−)-menthol (11.99%), *p*-menthan-3-one (6.59%), and camphor (3.93%) were the main components. Linalool with the characteristics of flower-like, fresh, and weak citrus-like flavor (33) was identified as the most abundant among the volatile compounds because this compound was contained in fermented tea (22), rose hip (31), lemon grass (34), and lavender (35) which were included in the BT2 sample. In addition, lavender contains linalool, linalyl acetate, and camphor (36), and peppermint contains L-(−)-menthol. The major compounds identified in the BT2 sample were the major components of its constituent materials.

The compounds identified only in the BT2 sample were 2-methylbutanol, 1-octen-3-ol, borneol, 6-undecanol, 3-methyl-2-butenal, butyl acetate, hexyl acetate, octenyl acetate, 7-dimethyl-1,3,6-octatriene, camphene, verbenene, 2-carene, 2,6-dimethylpyrazine, and (E)-linalool oxide. The sensory evaluation of the BT2 sample showed higher flavors of rosemary, herb, and ginger (not shown in this study). Although ginger was not contained in the BT2 sample, it was of higher frequency than in the other samples. It was considered that the flavor component of ginger was highly shown in the sensory evaluation because linalool, borneol, 1,8-cineole, and camphene, among the compounds identified in the BT2 sample, were the main flavor components (37) contained in ginger.

A total of 85 volatile compounds were identified in the BT3 sample composed of fermented tea, citrus peel, chamomile, hibiscus, and beet. The most abundant kinds of compounds were identified in the BT3 sample. Sesquiterpenes were identified the most abundant (17 kinds), followed by alcohols (14 kinds), aldehyde (12 kinds), esters (12 kinds), and monoterpenes (9 kinds). The most abundant components identified were L-limonene (74.45 %), β-myrcene (3.06%), γ-terpinene (7.47%), and β-farnesene (2.96%) in descending order. L-limonene, β-myrcene, and γ-terpinene are monoterpene compounds with 10 carbon atoms. Monoterpenes contained in plants were the main components of essential oils and used as a source of flavor (38). Among these compounds, limonene is mainly used as a food flavor as well as in soaps and cosmetics to provide the citrus flavor associated with it (39). In the analysis of hibiscus flavor components in tea, a relatively large amount of limonene was also found. Limonene is the compound found not only in hibiscus but also in the leaf of pittosporum (40), trifoliate orange (41), and the fruit and root of native *Schizandra chinensis* (42). The flavor characteristics might appear to be due to the citrus peel and hibiscus in the BT3 sample. The sensory evaluation of the BT3 sample showed high flavor characteristics of lemon, lemon grass, cherry, and fruit (not shown in this study). This result was similar to the analysis of the flavor components contained in the BT3 sample. The compounds identified in the BT3 sample only were octanol, (E)-verbenol, (E)-*p*-mentha-2,8-dien-1-ol, perillol, amyl formate, methyl 2-methylbutyrate, methyl benzoate, 3-hexenyl 2-methylbutanoate, (E)-carvyl acetate, citronellyl acetate, 2,2,3-trimethylnonane, 7-epi-α-selinene, α-terpinolene, α-cubebene, β-cubebene, α-guaiene, α-humulene, β-selinene, α-selinene, α-muurolene, germacrene A, (Z)-limonene oxide, and (E)-limonene oxide.

Based on these results, we tried to provide basic data on the quality of the product by analyzing the volatile flavor components of the blended tea with each herb. In this study, it was confirmed that characteristic components of volatile flavor compounds of each material appeared when several herbs were blended with a domestic fermented tea. The major volatile flavor components of the FT samples were 3-methyldecane, fruit flavor and 2,2,4,6,6-pentamethylheptane, specified as grass flavor. The major compounds in the BT1 sample were analyzed as L-(−)-menthol and menthone, which give the flavor and taste of peppermint, respectively. Those of the BT2 samples were analyzed as linalool, linalyl acetate, and L-(−)-menthol, which have the characteristics of floral scent, fresh scent, and weak citrus flavor, respectively. Finally, the major component of the BT3 sample was L-limonene specified as citrus flavor. In the future, it is thought that a study is necessary to identify the quality index of the product through analysis of volatile flavor components for the development of blended teas with various herbs. It is considered that blended teas are preferably commercialized by taking advantage of the flavor of the herbs to be blended with the fermented tea.

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AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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