Voluntary 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 components 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 (Camellia 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
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 (Bremen, 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

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**Table 1. Tea samples used in the volatile flavor compounds**

| Sample code | Ingredients | Total weight (g) |
|-------------|-------------|-----------------|
| FT          | Fermented tea 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 0.70 | Chamomile tea 0.50 | Hibiscus tea 0.50 | Beet tea 0.10 | 3.30 |

1FT, 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       | 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 (1.66%)   | 4 (0.12%)   |
| Ketone (12)     | 4 (6.30%)   | 6 (40.36%)  | 6 (14.67%)  | 4 (0.48%)   |
| Miscellaneous (9)| 6 (3.50%)  | 4 (5.52%)   | 5 (1.40%)   | 4 (0.12%)   |
| Monoterpane (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%)   |
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Table 3. Volatile compounds identified in fermented tea and blended teas

| Compounds                        | RI      | Samples | Identification method | Oder descriptions                  |
|----------------------------------|---------|---------|-----------------------|-------------------------------------|
| Alcohol (33)                     |         | FT      | BT1   | BT2   | BT3 |               |
| 3-Methyl-1-butanol               | 728.5   | 4.1     | −     | −     | 2.3 | MS, LRI       |
| 2-Methylbutanol                  | 761.5   | −       | −     | 4.5   | −   | MS, LRI       |
| Pentanol                         | 762.3   | 7.4     | 12.7  | −     | −   | MS, RI        |
| 2-Pentanol                       | 767.3   | 4.5     | −     | −     | −   | MS, RI        |
| (Z)-3-hexenol                    | 852.4   | 60.9    | −     | 31.2  | 23.5| MS, RI        |
| (E)-2-hexenol                    | 864.6   | 16.8    | −     | 3.4   | −   | MS, RI        |
| Hexanol                          | 868.3   | 39.5    | 20.2  | 101.1 | −  | MS, RI        |
| 7-Octen-4-ol                     | 979.6   | 23.4    | −     | −     | −   | MS, RI        |
| 1-Octen-3-ol                     | 979.9   | −       | 39.6  | −     | −   | MS, RI        |
| 6-Methyl-hept-5-en-2-ol          | 992.1   | −       | 80.4  | 32.4  | −   | MS, RI        |
| 3-Octanol                        | 994.8   | −       | 126.2 | 146.2 | −   | MS, RI        |
| 2-Ethylhexanol                   | 1,028.3 | −       | −     | 52.2  | −   | MS, LRI       |
| Octanol                          | 1,073.0 | −       | −     | −     | 61.2| MS, RI        |
| 3,3,6-Trimethyl-1,5-heptadien-4-ol|1,084.5 | −       | −     | 352.9 | −   | MS, RI        |
| Linalool                         | 1,102.6 | 90.7    | 619.3 | 9,957.2| 2,592.8| MS, RI       |
| Benzeneethanol                   | 1,109.0 | 203.6   | −     | −     | −   | MS, RI        |
| (E)-Verbenol                     | 1,118.3 | −       | −     | −     | 33.2| MS, LRI       |
| (E)-p-mentha-2,8-dien-1-ol       | 1,132.4 | −       | −     | −     | 38.4| MS, LRI       |
| (E)-linalool                      | 1,138.1 | −       | 31.1  | −     | −   | MS, LRI       |
| Borneol                          | 1,164.1 | −       | −     | 1,879.6| −   | MS, RI        |
| Lavandulol                       | 1,166.8 | 6.2     | −     | −     | 42.5| MS, RI        |
| L-(−)-menthol                    | 1,183.0 | 7.5     | 14,715.0| 4,535.2| −  | MS, LRI       |
| α-Terpineol                      | 1,190.2 | 3.0     | 177.5 | 551.0  | 209.2| MS, LRI       |
| (E)-Carveol                      | 1,218.3 | −       | −     | 10.5  | 59.4| MS, RI        |
| β-Citronellol                    | 1,235.8 | −       | −     | 309.1 | 77.3| MS, LRI       |
| Geraniol                         | 1,252.4 | 9.5     | 339.6 | −     | 33.0| MS, LRI       |
| Perillol                         | 1,285.8 | −       | −     | −     | 15.1| MS, LRI       |
| 6-Undecanol                      | 1,328.7 | −       | −     | 94.7  | −   | MS, RI        |
| Dodecanol                        | 1,473.5 | −       | −     | 27.4  | −   | MS, RI        |
| Spathulenol                      | 1,526.0 | −       | −     | 11.9  | −   | MS, LRI       |
| Ledol                            | 1,580.5 | −       | −     | 44.5  | −   | MS, LRI       |
| α-Bisabolol                      | 1,681.9 | −       | 55.4  | 18.8  | 27.2| MS, LRI       |
| Total                            | 464.7   | 16,705.9| 17,814.7| 3,354.7|     |               |

Results and Discussion

The results of flavor components analysis of fermented...
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 sesquiterpenes 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-trimethylcyclooctane (7.90%), benzeneethanol (7.55%), and 5-ethyl-2,2,3-trimethylhexane (5.87%). These volatiles flavor components were not identified or had lower

| Compounds        | RI     | FT | BT1 | BT2 | BT3 | Identification method | Oder descriptions                                                                 |
|------------------|--------|----|-----|-----|-----|-----------------------|------------------------------------------------------------------------------------|
| 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                                                                            |
| Citronellial     | 1,151.3| 2.0 |    |    |    | 50.7                  | MS, LRI                                                                            |
| 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, citrus 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)

| Compounds             | RI     | FT | BT1 | BT2 | BT3 | Identification method | Oder descriptions                      |
|-----------------------|--------|----|-----|-----|-----|-----------------------|----------------------------------------|
| Amyl formate          | 762.7  |    |    |    |    | MS, LRI               | Apple-like                              |
| Methyl 2-methylbutyrate| 771.7 |    |    |    |    | MS, LRI               | Fruity, sweets, and apple               |
| 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 method<sup>1</sup> | 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-Tetramethylethane        | 1,007.1| 47.1      | −                    | −                    | −                    | MS                               |
| 2,2,4,6,6-Pentamethylethane      | 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-Tetramethylectane        | 1,096.0| 78.7      | −                    | −                    | −                    | MS, RI                           |
| Dodecane                         | 1,200.1| 85.4      | 66.4                 | −                    | 34.6                 | MS, RI                           |
| Tridecane                        | 1,300.5| 7.8       | −                    | −                    | 4.9                  | RI                               |
| 3-Tridecane                      | 1,318.0| −         | −                    | 11.3                 | −                    | MS, LRI                          |
| 3-Methyltridecane                | 1,368.7| −         | −                    | 43.9                 | −                    | MS, RI                           |
| Tetradeacne                      | 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                           |
| 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 menthol |
| p-Menth-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)                |        |           |                      |                      |                      |                                  |
| 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)-Sabinine 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.
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

| Compounds        | RI | FT  | BT1 | BT2 | BT3 | Identification method\(^1\) | Oder descriptions                    |
|------------------|----|-----|-----|-----|-----|-----------------------------|--------------------------------------|
| 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 | Warm and herbaceous                  |
| Camphene         | 940.2 | –  | –   | 36.6 | –   | MS, LRI                      |                                      |
| Verbenene        | 946.5 | –  | –   | 4.9  | –   | MS, LRI                      |                                      |
| Sabinene         | 968.0 | –  | 133.3| 16.1 | –   | MS, LRI Green, pungent, and green leaf | Woody and resinous                   |
| β-Pinene         | 968.3 | 21.0| –   | –   | 533.6| MS, LRI                      |                                      |
| 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 | Citrus and green                     |
| α-Cymene         | 1,019.4| 11.2| 154.1| 127.5| –   | MS, LRI                      |                                      |
| 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, herbageous, 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             |                                      |
| α-Cymene         | 1,053.3| 41.7| –   | –   | 345.3| MS, RI                      |                                      |
| γ-Terpine        | 1,054.7| – | 85.0 | 54.9 | 6,552.5| MS, LRI Herbageous, citrus, and fruity | Woody and herbaceous                 |
| α-Terpinolone    | 1,087.4| – | –   | –   | 507.1| MS, LRI                      |                                      |
| δ-Elemene        | 1,332.2| 30.6| –   | 52.6 | 109.1| MS, LRI                      |                                      |
| 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-Bourbonone     | 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-Murolone       | 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 oil and weak spicy | Dry-woody and spicy                 |
| δ-Cadinene       | 1,512.0| – | 27.2 | 31.0 | 139.3| MS, LRI                     |                                      |
| 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  |        |                             |                                      |
### Table 3. Continued

| Compounds          | RI       | Samples | Identification method | Odor 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 only in the BT1 sample were 7-octen-4-ol, 2-ethylhexanol, (E)-pinocarveol, dodecanol, spathulanol, 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-menth-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-undecan-3-ol, 2-methyl-2-butenal, butyl acetate, hexasyl acetate, octenyl acetate, 7-dimethyl-1,3,6-octatriene, camphene, verbene, 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 compounds 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 monoterpenes 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), trifoliolate orange (41), and the fruit and root of native Schizandra chinesis (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-menth-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-trimethylnoranone, 7-epi-α-selinene, α-terpinolene, α-cubebene, β-cubebene, α-guaiene, α-humulene, β-selinene, α-selinene, α-murolene, 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-methyldecan, 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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