Volatile compounds profile of some Indonesian shallot varieties

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Abstract. Shallot, Allium ascalanicum L., is one of the leading horticultural commodities that are widely cultivated in Indonesia. Shallot is a commonly used seasoning for various types of dishes. This study aimed to determine the volatile compounds profile of some raw Indonesian shallot varieties. Four shallots varieties (Bima Brebes, Biru Lancor, Saptosari, and Filipin) were analyzed the volatile component profiles using Solid-Phase Microextraction (SPME)-Gas Chromatography-Mass Spectroscopy (GCMS). The GCMS analysis detected 104 types of volatile compounds in which the major volatile compounds were disulfides, sulfur-containing, thiophenes, and diverse functional groups. The most abundant volatile compound groups in the Bima Brebes variety were sulfur-containing compounds (40.61%), followed by diverse functional groups (28.43%) and disulfide (17.51%). In the Biru Lancor variety, the major volatile compounds were disulfide (44.68%), followed by sulfur-containing (30.90%) and thiophenes (8.80%). The most abundant volatile groups in the Saptosari variety were sulfur-containing (57.06%), followed by disulfide (22.68%) and thiophenes (9.19%). In the Filipin variety, the major volatile compound groups were disulfide (53.80%), followed by thiophenes (15.70%), and sulfur-containing (10.55%). The most abundant volatile compounds in all shallots volatiles were dipropyl disulfide, 1-methylethyl propyl disulfide, (E)-1-(prop-1-en-1-yl)-2-propyl disulfane, and propyl mercaptan.

1. Introduction
Shallot is one of the vegetable commodities which widely planted, from lowland areas (< 1 m above sea level) to highland areas (> 1000 m above sea level). The plant originates from Tajikistan, Afghanistan, and Iran and is widely cultivated in tropical regions of Asia [1]. Some types of shallots are widely cultivated such as garlic (Allium sativum L.), shallot (A. cepa L. var. Aggregatum), leeks (A. ampeloprasum L. var. Porrum), and green onion (A. fistulosum L) [2]. The total value of Indonesian seasonal vegetable exports (17 types of vegetables included shallot) in 2018 reached USD 11.82 million. Shallots was the largest commodity contributor to the foreign exchange exported with a net weight of 5.22 thousand tons with an export value of 6.29 million USD [3].

Onion is known to be used as spices, food, and medicine throughout the world. Besides being eaten directly in raw form, it is also used as a spice in cooking and pickles. Shallots can be used as a medicinal ingredient as they contain functional bioactive components such as saponins, sapogenins, sulfuric compounds (thiosulfimates), and flavonoids, including quercetin and kaempferol [4]. It was
also reported that shallot has medicinal effects such as antioxidants [5,6], regulating the immune system [7], anticancer [8], anti-blood clotting [9], antifungal [10], and maintaining and improving liver function [11,12].

In Indonesia, some shallots varieties, i.e. local, improved, and introduced, are widely cultivated. Indonesian Agency for Research and Development released some improved shallot varieties such as Bima, Lancer Biru, Trisula, Katumi, and Sembrani [1,13]. These varieties are thought to have physical or chemical/physicochemical properties, such as tuber size and shape, color, resistance to pests and diseases, harvest age, and tuber aroma. There is very limited literature on Indonesian shallot postharvest, especially on the volatile compound profiles. Galingging et al. [14] studied the profile of flavor compounds of fifteen shallot varieties grown in Indonesian tidal swampland using solvent (methanol extraction). Some researchers studied the shallot physicochemical properties [13], storage [15,16], drying [17], antioxidant activity [18-20], and fried shallot properties [21-22]. This study aimed to study the volatile component’s profile of some raw shallot varieties using Solid-Phase Microextraction (SPME)- Gas Chromatography-Mass Spectroscopy (GCMS).

2. Materials and Methods

2.1. Shallots Sample Preparation
The research was conducted from April to September 2016. Four shallot varieties were taken from several regions in Indonesia, namely Bima Brebes from Brebes (Central Java), Biru Lancer from Probolinggo (East Java), Saptosari from Gunung Kidul (Yogyakarta Special Region), and Filipin. Both Bima Brebes and Biru Lancer are improved shallot varieties. Saptosari is a local shallot, whereas Filipin is an introduced variety from the Philippines. The shallot varieties were grown on an inceptisol soil at 200 meters above sea level of Yogyakarta Assessment Institute for Agricultural Technology, Sleman, Yogyakarta Special Region. The harvested tubers were analyzed the volatile component’s profiles using Solid-Phase Microextraction (SPME) Gas Chromatography-Mass Spectroscopy (GCMS).

2.2. Volatile compounds analysis
Analysis of volatile components was carried out at Flavor Analysis Laboratory of Indonesian Center for Rice Research, Subang, West Java. The volatile compounds of shallot samples were analyzed using SPME-GCMS. Five grams of finely sliced raw shallot sample were put in a 20 ml SPME vial, then the extraction was carried out at 35 °C for 30 minutes with a 50/30 um divinylbenzene/ carboxen/polydimethylsiloxane (85 µm, Supelco Inc., PA, USA) SPME fiber. The SPME fiber was then desorbed at 250 °C for 20 minutes to the Agilent GCMS 7890A-5975C injection port. In The GC, the DB FFAP column (30 m x 250 µm x 0.25 µm) was used for the separation of volatile compounds. A spitless injection was used for sample introduction. The oven’s initial temperature is 50 °C, held for 3 minutes then programmed to 210 °C at a rate of 5 °C/minute, and held at 210 °C for 0 seconds. The helium carrier gas rate was set at 1.8 mL/ min. The MS was operated in electron impact mode at an ionization voltage of 70 eV and a source temperature of 230 °C. MS performed a scan at m/z 29-40.

The volatile components were tentatively identified by matching the mass spectra with the spectra of reference compounds in the NIST/ EPA/NIH mass spectral library 2014 (NIST14). Sparkman et al. [23] pointed out that the Wiley Registry of Mass Spectral Data and the NIST/EPA/NIH Mass Spectral Database is the most widely used mass spectra database for the interpretation of the mass spectrum in GC-MS. The content of volatile compounds in each shallot was presented as relative peak area (%) [14,24-26]. The method of compounds quantification was rough, only intended to provide a comparative picture of the amounts in each shallot variety.

3. Result and Discussion
The GC-MS analysis tentatively identified 104 volatile compounds from the shallot extracts (Table 1). Of the compounds, Bima Brebes, Biru Lancer Saptosari, and Filipin variety contained 54, 63, 48, and
61 volatile compounds, respectively. Galingging et al. [14] identified 64 volatiles in the methanol extract of fifteen cultivars of Indonesian shallots. Fasihzadeh et al. [4] detected 49 volatile compounds of the essential oil constituents of raw Persian shallot (Allium stipitatum Regel).

Genetic (variety), environmental, cultivation, and postharvest factors influence the volatile compounds of shallot. Lekshmi et al. [27] reported that geographical factors, climate, soil fertility, and cultivation methods influenced the volatile compounds of shallot. Besides, cooking processes such as baking and frying influenced the volatile compounds of shallot [28,29].

**Table 1. Volatile compounds identified in all raw shallot samples.**

| No. | RT (min) | Compound                          | Chemical Abstract Service (CAS) | Relative peak area (%) |
|-----|----------|-----------------------------------|---------------------------------|------------------------|
|     |          |                                   |                                 |                        |
|     |          |                                   | Bima B                         | Biru L.        | Saptosari | Filipin |
|     |          |                                   |                                 | nd                      | nd         |          |
| Monosulfides |                            |                                    |                                |                        |
| 1   | 2.98     | Propyl sulfide                    | 111-47-7                       | 0.0359                 | 0.0764     | nd       | nd |
| 2   | 3.80     | Allyl isopropyl sulfide           | 50996-72-0                     | nd                      | nd         | 0.3203   |   |
| 3   | 24.04    | Allyl n-propyl sulfide            | 1000342-31-5                   | 2.9264                 | nd         | nd       | nd |
| 4   | 28.31    | 1-propenyl 1-propynyl sulfide     | 89533-93-7                     | 0.0166                 | 0.2105     |          |   |
| Disulfides |                            |                                    |                                |                        |
| 5   | 2.85     | dimethyl disulfide                | 624-92-0                       | nd                      | 0.0369     | 0.0670   | 0.2543 |
| 6   | 3.36     | 1-[(1-methylethyl) thio]-propane  | 5008-73-1                      | nd                      | nd         | nd       | 0.0507 |
| 7   | 3.55     | 3-(methythio)-propanal            | 3268-49-3                      | nd                      | nd         | nd       | 0.0006 |
| 8   | 6.04     | methyl propyl disulfide           | 2179-60-4                      | 0.6056                 | 2.6387     | 0.2547   | 2.4610 |
| 9   | 7.21     | methyl 2-propenyl disulfide       | 2179-58-0                      | nd                      | 0.0140     | 0.0165   | 0.0188 |
| 10  | 7.38     | methyl 1-propenyl disulfide       | 5905-47-5                      | 0.0350                 | 0.0028     | 0.2311   | 0.1778 |
| 11  | 9.81     | dipropyl disulfide                | 629-19-6                       | 2.8474                 | 29.6895    | 21.8970  | 43.4824 |
| 12  | 9.92     | 1-methylethyl propyl disulfide    | 33672-51-4                     | 13.6315                | 12.0382    | nd       | 7.3502 |
| 13  | 10.15    | Methyl pentyl disulfide           | 72437-68-4                     | 0.2575                 | nd         | nd       | nd   |
| 14  | 10.24    | Isopropyl disulfide               | 4253-89-8                      | 0.0687                 | nd         | nd       | nd   |
| 15  | 12.76    | Diallyl disulfide                 | 2179-57-9                      | 0.0704                 | nd         | nd       | nd   |
| Trisulfides |                            |                                    |                                |                        |
| 16  | 2.24     | Dimethyl trisulfide               | 3658-80-8                      | nd                      | 0.0006     | nd       | nd   |
| 17  | 16.67    | dipropyl trisulfide               | 6028-61-1                      | 2.9910                 | 0.1428     | 0.2860   | nd    |
| 18  | 18.52    | di-2-propenyl trisulfide          | 2050-87-5                      | 0.0039                 | 0.0033     | 0.0047   | nd    |
| 19  | 23.81    | methyl 2-propenyl trisulfide      | 34135-85-8                     | 0.0024                 | 0.0960     | nd       | nd   |
| Sulfur-containing |                           |                                    |                                |                        |
| 20  | 1.13     | Propyl mercaptan                  | 107-03-9                       | 13.0993                | 0.7753     | 1.9930   | 0.7223 |
| 21  | 1.53     | Methyl thirane                    | 1072-43-1                      | 0.0581                 | 0.2445     | 0.4142   | 0.3315 |
| 22  | 3.02     | 1-[(1-methylethyl)thio]-propane   | 5008-73-1                      | 0.0281                 | 0.0142     | 0.0473   | nd    |
| 23  | 3.33     | 2-(ethethylthio)-propane          | 5145-99-3                      | 0.0003                 | nd         | nd       | nd    |
| 24  | 3.54     | 3-(methythio)-propanal            | 3268-49-3                      | nd                     | 0.0055     | 0.0011   | nd    |
| 25  | 4.00     | 3- (propthio)-1-propene           | 27817-67-0                     | nd                     | 0.0003     | nd       | 0.0183 |
| 26  | 4.26     | 1-(1-propenylthio)propane         | 33922-70-2                     | 0.1676                 | 0.4277     | 0.3908   | 0.4270 |
| 27  | 5.92     | 1,1-thiobis-1-propene             | 33922-80-4                     | nd                     | 0.0076     | 0.0028   | 0.0091 |
| 28  | 7.40     | (Z)-1-Methyl-2-(prop-1-en-1-yl)   | 23838-18-8                     | nd                     | nd         | 0.5492   | 0.7488 |

| 3 |
| No. | RT (min) | Compound | Chemical Abstract Service (CAS) | Bima B | Biru L. | Saptosari | Filipin |
|-----|----------|----------|--------------------------------|--------|---------|-----------|---------|
| 29  | 7.41     | (E)-1-Methyl-2-(prop-1-en-1-yl)disulfane | 23838-19-9 | nd    | 2.5077  | 1.0116    | 3.2352  |
| 30  | 10.05    | 1,3-Propanedithiol | 109-80-8 | 0.1363 | 9.6472  | 1.2476    | 0.2805  |
| 31  | 10.76    | (E)-1-(Prop-1-en-1-yl)-2-propyl disulfane | 23838-21-3 | 8.5286 | 22.3120 | 41.0881   | 0.2871  |
| 32  | 11.22    | (Z)-1-(Prop-1-en-1-yl)-2-propyl disulfane | 23838-20-2 | 4.7183 | 3.4440  | 0.1765    | nd      |
| 33  | 11.37    | 1,2-Dithiolane | 557-22-2 | nd    | 0.0479  | nd        | nd      |
| 34  | 12.07    | 2-methyl-1-butanethiol | 1878-18-8 | 0.2348 | nd      | nd        | nd      |
| 35  | 13.23    | Methanethiol | 74-93-1 | nd    | nd      | nd        | 3.5069  |
| 36  | 13.25    | 1,2-Ethanethiol | 540-63-6 | 1.1680 | nd      | 6.2713    | nd      |
| 37  | 18.65    | 3,5-diethyl-1,2,4-trithiolane, | 54644-28-9 | 0.0218 | 0.1340  | 0.6922    | 0.1754  |
| 38  | 18.68    | trans-3,5-Diethyl-1,2,4-trithiolane | 38348-26-4 | 3.6651 | 0.1659  | 0.5845    | nd      |
| 39  | 19.15    | Allyl mercaptan | 870-23-5 | 4.7238 | nd      | nd        | 0.1896  |
| 40  | 19.32    | 1,1'-thiobis-1-propene | 33922-80-4 | 0.0041 | nd      | nd        | nd      |
| 41  | 23.63    | Monopropyl carbonotrichoate | 68060-07-1 | 1.4945 | nd      | 2.0397    | 2.5600  |
| 42  | 23.95    | 2,4-Dimethyl-2-thiazoline | 6114-40-5 | 1.1554 | nd      | nd        | nd      |
| 43  | 26.58    | cis-3,5-Diethyl-1,2,4-trithiolane | 38348-25-3 | 1.2621 | 0.0023  | nd        | nd      |
| 44  | 29.46    | 1,3,4-trimethyl-2-pyrazoline | 14044-41-8 | nd    | nd      | nd        | 0.0224  |

**Aldehydes**

| No. | RT (min) | Compound | Chemical Abstract Service (CAS) | Bima B | Biru L. | Saptosari | Filipin |
|-----|----------|----------|--------------------------------|--------|---------|-----------|---------|
| 45  | 1.02     | Propanal | 123-38-6 | nd    | nd      | nd        | 0.4257  |
| 46  | 1.69     | Acetaldehyde | 75-07-0 | nd    | nd      | nd        | 0.1103  |
| 47  | 2.95     | Hexanal | 66-25-1 | nd    | nd      | 0.0021    | nd      |
| 48  | 4.39     | (E)-2-Octenal | 2548-87-0 | nd    | 0.0020  | nd        | nd      |
| 49  | 4.43     | 2-methyl-2-pentenal | 623-36-9 | 0.8643 | 1.8339  | 1.0653    | 2.7180  |
| 50  | 4.50     | (E)-2-Hexenal | 6728-26-3 | nd    | nd      | 0.0781    | nd      |
| 51  | 7.90     | (E)-2-Butenal | 123-73-9 | nd    | 0.0524  | nd        | nd      |
| 52  | 9.36     | 2-methylpentanal | 123-15-9 | 0.0007 | 0.0009  | nd        | 0.0010  |
| 53  | 10.39    | Nonanal | 124-19-6 | 0.2015 | 0.1301  | 0.1720    | 0.6478  |
| 54  | 11.50    | (E,E)-2,4-Heptadienal | 004313-03-5 | nd    | 0.0163  | nd        | 0.0312  |
| 55  | 11.85    | Isobutonal | 78-85-3 | nd    | nd      | 0.3374    | nd      |
| 56  | 11.92    | 2-methylbutanal | 96-17-3 | nd    | 0.0050  | nd        | 0.0038  |
| 57  | 13.55    | E-2-Undecenal | 53448-07-0 | 0.1265 | 0.0072  | 0.0183    | 0.0394  |
| 58  | 14.43    | (E)-2-Decenal | 3913-81-3 | nd    | 0.0189  | nd        | 0.0113  |
| 59  | 16.07    | (E)-2-Hexenal | 6728-26-3 | nd    | 0.0045  | nd        | 0.0028  |
| 60  | 16.82    | (E)-2-Octenal | 2548-87-0 | 0.0297 | nd      | 0.0041    | nd      |

**Thiophenes**

| No. | RT (min) | Compound | Chemical Abstract Service (CAS) | Bima B | Biru L. | Saptosari | Filipin |
|-----|----------|----------|--------------------------------|--------|---------|-----------|---------|
| 61  | 6.56     | 2,4-dimethyl-thiophene | 638-00-6 | 1.7459 | 5.5507  | 3.3898    | 5.1796  |
| 62  | 6.57     | 3,4-dimethyl-thiophene | 632-15-5 | 1.7139 | nd      | 0.1598    | 5.1581  |
| 63  | 6.60     | 2,5-dimethyl-thiophene | 638-02-8 | 0.0789 | 0.0318  | 0.1624    | nd      |
| 64  | 15.71    | 2,3-dimethyl- | 632-16-6 | 0.5649 | 2.2912  | 3.8216    | 5.2011  |
| No. | RT (min) | Compound | Chemical Abstract Service (CAS) | Bima B | Biru L | Saptosari | Filipin |
|-----|----------|----------|---------------------------------|--------|--------|-----------|--------|
| 65  | 17.35    | 2-ethyl-thiophene | 872-55-9 | nd | 0.7674 | 1.5017 | 0.0772 |
| 66  | 20.31    | 3-ethyl-thiophene | 1795-01-3 | nd | 0.1139 | 0.1357 | 0.0755 |
| 67  | 28.03    | 1,3,4-trimethyl-2-pyrazoline | 14044-41-8 | nd | nd | 0.1286 | nd |
| 68  | 32.18    | 1,5-dimethyl-1H-Tetrazole | 005144-11-6 | 0.9874 | nd | 0.0126 | 0.0341 |
| 69  | 12.34    | 2-Methylene cyclohexanol | 4065-80-9 | nd | nd | nd | 1.0026 |
| 70  | 14.44    | 1-Heptanol | 111-70-6 | 0.0466 | 0.0067 | 0.0614 | 0.0678 |
| 71  | 16.71    | 1-Pentanol | 71-41-0 | nd | 0.0054 | 0.0758 | nd |
| 72  | 17.47    | 1-Octen-3-ol | 3391-86-4 | 0.0078 | 0.0118 | 0.0126 | 0.0341 |
| 73  | 7.41     | 5-ethyl-2-imino-thiazolidin-4-one | 1762-69-2 | 0.0282 | 1.9334 | nd | nd |
| 74  | 7.90     | Bis(3-methylbutyl) fluorene-2,7-disulfonate | 253664-95-8 | nd | nd | nd | 0.0532 |
| 75  | 11.09    | (2-propenylthio)-acetic acid | 20600-63-9 | 7.9218 | nd | nd | 1.6939 |
| 76  | 11.35    | n, n’-Dihydroxyacetamide | 38762-37-7 | 1.2825 | nd | nd | nd |
| 77  | 13.63    | 2-Mercaptothiazole | 82358-09-6 | nd | 0.0601 | nd | 0.1141 |
| 78  | 14.79    | 2-Mercapto-3,4-dimethyl-2,3-dihydrothiophene | 100031-97-0 | 0.0109 | 0.0056 | 0.0192 | 0.0046 |
| 79  | 14.99    | 2-Methoxyethyl sulfanylacetate | 19788-48-8 | nd | nd | nd | 0.1009 |
| 80  | 15.47    | 2-Thio-2,4-oxazolidinedione | 2346-24-9 | nd | 0.1955 | nd | 0.3694 |
| 81  | 15.50    | 2,2-dimethyl-1,3-oxathiane | 5809-68-7 | 1.0556 | nd | nd | nd |
| 82  | 17.10    | 2-Thiophenecarboxaldehyde | 98-03-3 | nd | 0.0466 | nd | 0.0442 |
| 83  | 17.27    | 3-Thiophenecarboxaldehyde | 498-62-4 | nd | 0.0809 | nd | 0.0113 |
| 84  | 17.36    | 4-methyl-5-thiazoleacetaldehyde | 18764-34-6 | nd | nd | nd | 2.1190 |
| 85  | 18.12    | 5-ethyl-2-imino-thiazolidin-4-one | 1762-69-2 | 0.0212 | 0.0059 | 0.2326 | 0.0118 |
| 86  | 20.39    | Thiodiacetonitrile | 5848-75-9 | nd | 0.0569 | nd | nd |
| 87  | 20.79    | propyl ester-2-furanacarbodiimide acid ester | 27249-80-5 | nd | 0.1242 | nd | 0.1572 |
| 88  | 22.54    | Acetic acid, mercapto-ethyl ester | 623-51-8 | 14.9046 | 1.1004 | nd | nd |
| 89  | 23.52    | 2-hexyl-5-methyl-3(2H)-Furanone | 33922-66-6 | 0.6722 | 0.1106 | 1.4199 | 0.2413 |
| 90  | 25.28    | propyl ester formic acid | 110-74-7 | 0.3928 | nd | nd | nd |
| 91  | 25.36    | 3-Thiophenecarboxaldehyde | 498-62-4 | nd | 0.0223 | nd | nd |
| 92  | 25.36    | 2-Thiophenecarboxaldehyde | 98-03-3 | nd | nd | nd | 0.0114 |
| 93  | 27.34    | Thiophene-3-carboxyhydrazide | 39001-23-5 | nd | 0.0086 | nd | nd |
| 94  | 27.57    | Pyrazol-5-ol, 1-acetyl-3,4-dimethyl-, acetate | 5203-75-8 | nd | 0.2798 | 0.5490 | 0.0004 |
| 95  | 27.59    | 5-methyl-2-octyl-3(2H)-furanone | 57877-72-2 | 0.1753 | nd | nd | nd |
| 96  | 27.74    | p-Dithiane-2,5-diol | 40018-26-6 | 0.6592 | nd | 0.7479 | 5.9040 |
| 97  | 28.22    | mercapto-acetic acid | 68-11-1 | 1.2110 | nd | 0.2745 | nd |

**Diverse functional groups**

**Relative area (%)**

**Miscellaneous**
The most abundant volatile compounds in the shallots can be categorized into ten groups of volatile compounds (Table 2). Among them, the most abundant volatile compounds were disulfides, sulfur-containing, thiophenes, and diverse functional groups. The major volatile compound groups in the Bima Brebes variety were sulfur-containing (40.61%), followed by diverse functional groups (28.43%) and disulfide (17.51%). In the Biru Lancor variety, the most abundant volatile compounds were disulfide (44.68%), followed by sulfur-containing (30.90%) and thiophenes (8.80%). The volatile groups in the Saptosari variety were sulfur-containing (57.06%), followed by disulfide (22.68%) and thiophenes (9.19%). In the Filipin variety, the most abundant volatile compound groups were disulfide (53.80%), followed by thiophenes (15.70%), and sulfur-containing (10.55%).

**Table 2.** Categories of volatile compound groups in all shallot samples.

| No. | Volatile Compound Groups | Percentage of volatile compound groups (%) |
|-----|--------------------------|------------------------------------------|
|     |                         | Bima Brebes | Biru Lancor | Saptosari | Filipin |
| 1.  | Monosulfides             | 2.97        | 0.09        | nd        | 0.53    |
| 2.  | Disulfides               | 17.51       | 44.68       | 22.68     | 53.80   |
| 3.  | Trisulfides              | 3.00        | 0.24        | 0.29      | nd      |
| 4.  | Sulfur-containing        | 40.61       | 39.90       | 57.06     | 12.51   |
| 5.  | Aldehydes                | 1.23        | 2.08        | 1.69      | 3.99    |
| 6.  | Thiophenes               | 4.13        | 8.80        | 9.28      | 15.70   |
| 7.  | Nitrogen-containing      | 0.99        | nd          | 0.13      | nd      |
| 8.  | Alcohols                 | 0.05        | 0.02        | 0.15      | 1.10    |
| 9.  | Diverse functional group | 28.43       | 4.04        | 3.26      | 10.83   |
| 10. | Miscellaneous            | 1.08        | 0.14        | 5.46      | 1.54    |
|     | Total                    | 100.00      | 100.00      | 100.00    | 100.00  |

nd = not detected

The most abundant volatile compounds in the shallots volatiles were dipropyl disulfide, 1-methylethyl propyl disulfide, (E)-1-(prop-1-en-1-yl)-2-propyl disulfane, and propyl mercaptan (Table 1). These results were slightly different with Galingging et al. [14] report as differences in the volatile extraction; this study used the SPME (headspace extraction), whereas they used methanol extraction (solvent extraction). Furthermore, they reported that 64 volatiles were identified in fifteen Indonesian shallot varieties. Among the volatiles, cyclonaotanol was the major compound. Based on the multivariate data analysis, (23S)-ethylcholest-5-en-3β-ol, obtusifoliol, pentacosane, furfural, cholesterol, 23 S/R-methylcholesterol, 9, 17-octadecadienol, 1-nonadecene, 14-methylergost8-en-3-ol, ergost-5-en-3-ol, 14α-methyl-δ8-ergostenol, docosane, and octacosane could be used to distinguish the shallot varieties.
Thiosulfimates (Ti) and Zwiebelanes (Zw) are constituents of fresh aroma in garlic (onions) and shallots [30]. Moreover, constituents of the Ti group were dimethyl thiosulfinate, methyl propyl thiosulfinate, methyl 1-propenyl thiosulfinate, propyl methyl thiosulfinate, 1-propenyl methyl thiosulfinate, propyl 1-propenyl thiosulfinate, 1-popenyl propyl thiosulfinate, while the Zw group was cis-Zwiebelane, trans-Zwiebelane, and Zwiebelane isomer [31]. Zhang et al. [32] reported that the aroma volatiles categories of raw of Allium species (included shallot) were alkenes, alkanes, alcohols, aldehydes, ketones, sulfides, and miscellaneous compounds. Moreover, scallion and onion possessed the highest fractions of [E]-2-hexenal and 2,5-dimethyl-thiophene, respectively, whereas chive and shallot possessed the highest fraction of propanal.

Wu et al. [28] categorized the shallot oil compounds into thiols, mono-sulfides, disulfides, trisulfides, thiophenes, and oxygen compounds. Moreover, the main constituents of raw shallot oils were methyl propyl trisulfide, dimethyl trisulfide, propyl propenyl disulfide, and 1-methylthiopropylethyl disulfide.

4. Conclusion
The GCMS analysis tentatively identified 104 types of volatile compounds in all shallot varieties. Among the volatile compounds, the major volatile groups were disulfides, sulfur-containing, thiophenes, and diverse functional groups. Volatile groups of sulfur-containing were the most abundant component in Bima Brebes and Saptosari varieties, while disulfides were the most abundant component in Biru Lancor and Filipin varieties. The most abundant volatile compounds in the shallots volatiles were dipropyl disulfide, 1-methylethyl propyl disulfide, (E)-1-(prop-1-en-1-yl)-2-propyldisulfane, and propyl mercaptan.

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