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Physical, chemical and bioactive properties of onion (*Allium cepa L.*) seed and seed oil

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Summary

In this study, some physico-chemical and antioxidant properties, volatile compounds and fatty acid composition of ten different onion seeds were investigated. The fatty acid composition and volatile compounds were analyzed by gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS), respectively. Physico-chemical analysis showed that onion seeds possessed high amount of oil (21.86 %-25.86 %) and crude protein (15.7 %-26.1 %). GC results revealed that onion seed oil was rich in linoleic acid (49.42-60.66 %) which was followed by oleic and palmitic acid, respectively. There was a large number of substances such as hydrocarbons, alcohols, acids, esters and sulfur-containing compounds. It could be concluded that onion seeds can be utilized in food industry due to their physico-chemical properties and contents of oil and volatile components.

Introduction

Onion (*Allium cepa* L.) is considered to be one of the most important agricultural products all over the world. The species belongs to the family of *Liliaceae* and represents one of the world's oldest cultivated products (Tram Ngoc et al., 2005). According to the data of 2010, Turkey is number 6 at onion production in the world with annual production of 1.9 million tonnes (FAO, 2010). Onion has different nutritional composition depending on the individual parameters such as type, maturity level etc. (Mota et al., 2010).

Onion seeds are also eaten, but their commercial availability is currently limited. Perhaps if consumers were more acquainted with onion seeds' nutritional and functional properties, there would be an increase in trade of this product (Dini et al., 2005, Dini et al., 2008a).

Dini et al. (2008b) studied red onion seeds and they found 10.5 % moisture, 20.4 % oil, 24.8 % crude protein in these seeds. Onion bulbs represent a source of cysteine derivatives, which make them a functional food, but onion seeds contain only low concentration of these components. Their presence should be important for obesity treatment because they improve glycemic control, cause decrease of food intake and induce adipose tissue cell death (Lu et al., 2011; Roldan et al., 2008). Parry et al. (2006) determined the refractive index of onion seed oil as 1.4752. In terms of the composition of fatty acids of seed oils, 6.4-7.1 % palmitic acid (C16:0), 24.8-26 % oleic acid (C18:1) and 65.2-64 % linoleic acid (C18:2) was found in onion seeds by them.

In recent years, there exists an increasing interest to find new sources of edible oils such as plant seeds due to their nutritional, industrial and medicinal importance (Nehdi, 2011a). Seed oils rich in bioactive constituents which have protective effects against diseases and support to improve human health are highly demanded by consumers. On the other hand, no oil is sufficient for all purposes because of different compositions of oils obtained from various sources. In terms of the increasing demand on the nutritional and functional properties of oils and scientific awareness, quality assessment of presently unused oils attract special attention (Cerchiara et al., 2010; Silva et al., 2009; Djenontin et al., 2009; Nehdi, 2011b; Kesari et al., 2010; Hoed et al., 2011).

Numerous studies related to various onion cultivars have been described in literature but those studies specially focused on the chemical and functional properties of onion seeds are very rare. Therefore, the main purpose of this study is the presentation of the variety of physico-chemical properties of onion seeds with the determination of fatty acid composition and volatile compounds. Onion seeds used in this study were adapted varieties in Turkey. Unfortunately, no literature about these Turkish adapted varieties of onion seeds is available.

Materials and methods

Plant Material

Onion seeds of 10 different cultivars, namely cv. Guntan, cv. Polat, cv. Hasat, cv. Tan8, cv. Imrali Kirmizisi, cv. Beyaz Sogan, Ertan1, cv. Guntan Moru, cv. Akgun12, and cv. Kantartopu3 were used in this study. The seeds were obtained from commercial onion seed producers in Balikesir (in Turkey) and Ataturk Garden Cultures Central Research Institute in Yalova (in Turkey).

Sample extraction for antioxidant test

Onion seeds were powdered and 10 g defatted powder was extracted with 50 ml ethanol (1:5 w/w) for 18 hours at 25 ºC (cold extraction) in the dark. The extracts were centrifuged at 4,100 rpm for 15 minutes, then filtrated and the supernatants was collected subsequently. After filtration, the clear supernatants were evaporated under vacuum at 50 ºC. After this treatment, the dry extracts were preserved at +4 ºC.

Determination of moisture, ash, crude protein and oil content of the onion seed

The recommended methods of the Association of Official Analytical Chemists (Anon, 1990) were adopted to determine the levels of moisture, ash, crude protein and crude oil. The moisture content was determined by drying of the samples at 105 ºC to a constant weight. The ash content was detected by a laboratory furnace at 550 ºC, the temperature was increased gradually. Nitrogen content was determined by using the Dumas method (Anon, 2000) and multiplied by the factor of 6.25 to obtain the crude protein content. Crude oil was detected by the Soxhlet method. Crude oil was obtained by exhaustively extracting 10 g of each sample in a Soxhlet apparatus using petroleum ether (boiling point range 40-60 ºC) as the extractant. Each measurement was performed in triplicate and the results were averaged.

Determination of the fatty acid composition of the onion seed oil

One hundred milligram of each of the oil samples was saponified with 100 mL 2 N KOH, and 3 mL hexane was added to this mixture. The solution was strongly shaken with a Vortex mixer for 1 min, and then centrifuged at 5,000 rpm for 5 min (Nüve NM 110, Turkey).

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One milliliter of the solution was put into GC vials and the injection was started immediately. GC (Agilent 6890), equipped with an Flame Ionization Detector (FID) and a 100 m × 0.25 mm i.d. HP-88 column was used. The injection block temperature was set at 250 ºC. The oven temperature was kept at 103 ºC for 1 min, then programmed from 103 to 170 ºC at 6.5 ºC/min, from 170 to 215 ºC for 12 min at 2.7 ºC/min, and finally, at 230 ºC for 5 min. Carrier gas was helium with a flow rate of 2 mL/min; the split rate was 1/50 (ANON, 2008; YALCIN et al., 2012). Three replications were applied to determine the fatty acid composition of each oil.

Determination of refractive index of the onion seed oils

The refractive index of the onion seed oils were determined at 20 °C using an Abbe Refractometer (Reichert AR 700). The measurements were performed in triplicate and the results were averaged.

Volatile Component Analysis of the onion seed

Analysis was performed according to the procedure described by YALCIN et al. (2011) by gas chromatography mass spectrometry (Agilent 7890A gas chromatography system) using a mass selective detector (Agilent Technologies) and HP-5MS column (60 m × 0.250 mm internal diameter; film thickness, 0.25 µm). The oven temperature was held at 40 ºC for 10 minutes, heated to 95 ºC at 3 ºC/min, heated from 95 to 210 ºC at 10 ºC/min, and finally increased to 210 ºC/min and held for 10 minutes. Carrier gas was helium with a flow rate 0.5 mL/min. The voltage of electron ionization detector was 70 eV. The compounds adsorbed by the fibers were desorbed from the injection port for 15 minutes at 50 ºC in the splitless mode. The compounds were identified by comparison with spectra from the libraries Flavor 2, NIST 05a, and Wiley7Nist05 and by using internal standards (KRIST et al., 2006).

Determination of total phenolic content of the onion seed

Total phenol estimation in the extract was determined by the Folin-Ciocalteu colorimetric method (SAGDIC et al., 2011). To each tube, 2,400 µL distilled water was added and followed by 40 µL extracts and 200 µL Folin-Ciocalteu reagent. After 5 minutes, 600 µL sodium carbonate (20 %) and finally 760 µL distilled water were added. The solution was homogenized in a Vortex mixer and incubated at room temperature for 2 hours in the dark. After incubation, absorbance of the reaction mixture was measured at 765 nm. The amount of the total phenolic compounds was expressed as gallic acid equivalents (GAE) in milligrams per gram dry plant extract. The measurements were performed in triplicate and the results were averaged.

Determination of antiradical activity of the onion seed

The DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging activity was adapted by some modifications from the method used by TULUKCU et al. (2012). 100,000 ppm solution of extracts was used as stock solution. Sequences of extract concentration in methanol, that is 2,000, 1,000, 500 ppm, were prepared, and 100 µL of each concentration of extract was added to 450 µL tris-HCl and 3,500 µL 0.1 mM methanol solution of DPPH. Methanol was used as a control. Following a 30-min incubation period at room temperature in the dark, the absorbance was measured against the blank at 517 nm. The measurements were performed in triplicate and the results were averaged. Inhibition of the free radical DPPH in percent (I %) was calculated using the following equation:

Radical scavenging activity (%) = $[(A_0 - A_1) / A_0] \times 100$

A_0 = the absorbance of the control

A_1 = the absorbance of the sample.

Statistical analysis

SAS statistical software (SAS Institute, Inc., Cary, NC, USA) was used for data analysis. Data were subjected to one-way and two-way ANOVA, and the comparative analyses between means were conducted by using the Tukey multiple range test.

Results and discussion

Proximate analysis

The proximate composition was shown in Tab. 1. These values were compared to corresponding data for *Allium tuberosum* seed (HU et al., 2006). 7.8 % moisture, 2.4 % ash, 15.8 % oil, 12.3 % crude protein was determined in *Allium tuberosum* seeds. Onion seeds which are used in our study, have high levels of ash, oil and protein, but comparatively low moisture content. The high total oil content is important for evaluation of seed oil, high content of crude protein is important for quality assessment which will be obtained from the seed pulp and high content of ash is important in that it involves higher value of inorganic material. DEMIRKAYA and SIVRITEPE

Tab. 1: Chemical composition of different onion seed cultivars (%)

Cultivar	Moisture	Ash	Oil	Crude Protein
Polat	7.34±0.11 d	4.80±0.18 a	24.56±0.68 a, b, c	23.96±0.73 b, c
Hasat	9.01±0.16 b	4.38±0.37 a, b, c	21.86±1.40 c	26.16±0.33 a
Guntan Moru	8.48±0.15 c	4.28±0.60 a, b, c, d	23.72±0.14 c	24.07±0.15 b, c
Beyaz Sogan	8.53±0.06 c	4.68±0.13 a, b	24.47±0.63 a, b, c	22.59±0.09 d, e
Guntan	8.57±0.25 c	4.01±0.25 b, c, d	25.11±0.78 a, b	21.39±0.11 f, g
Tan8	9.79±0.02 a	3.58±0.02 d	25.38±1.12 a	22.23±0.86 e, f
Kantartopu3	7.17±0.06 d	3.75±0.15 d, c	25.86±0.13 a	15.70±0.16 h
Akgun12	7.06±0.09 d	3.68±0.04 d, c	24.14±1.15 a, b, c	20.57±0.04 g
Ertan1	6.49±0.05 e	3.59±0.02 d	22.29±3.65 b	23.47±0.03 c, d
Imrali Kirmizisi	7.21±0.06 d	4.06±0.06 b, c, d	21.91±0.06 c	24.74±0.03 b

Mean ± standard deviation

Different letters indicate the statistical difference in the same column ($p<0.05$)

Tab. 2: Fatty Acid Composition of seed oils obatained from different onion cultivars (%)

Fatty Acid	Kantar Topu 3	Imrali Kirmizisi	Güntan	Akgun12	Polat	Tan8	Ertan1	Hasat	Beyaz Sogan	Guntan Moru
C14:0	1.78±0.06	1.22±0.02	1.29±0.05	1.47±0.06	1.74±0.01	1.23±0.18	-	-	-	-
C16:0	12.2±0.09	10.79±0.04	10.89±0.03	10.52±0.05	11.08±0.12	10.83±0.21	7.27±0.03	8.95±0.09	10.24±0.01	7.23±0.15
C18:0	3.74±0.09	2.93±0.04	3.29±0.02	3.18±0.09	3.47±0.09	3.28±0.09	2.79±0.19	2.56±0.12	2.4±0.06	2.01±0.05
C18:1	28.72±0.01	27.05±0.03	27.81±0.09	27.4±0.01	26.44±0.14	28.05±0.09	31.52±0.01	26.59±0.06	28.74±0.06	28.35±0.09
C18:2	49.42±0.02	53.12±0.01	51.79±0.08	53.25±0.00	57.25±0.08	52.51±0.1	58.4±0.08	56.5±0.06	55.27±0.09	60.46±0.04
C22:1	2.94±0.01	3.43±0.09	3.57±0.05	2.87±0.03	-	3.03±0.08	-	3.67±0.08	2.23±0.02	1.32±0.04
C22:2	1.17±0.00	1.44±0.08	1.34±0.01	1.28±0.03	-	1.04±0.04	-	1.7±0.21	1.07±0.03	0.62±0.07
SAT	17.72	14.94	15.47	15.17	16.29	15.34	10.06	11.51	12.64	9.24
MUFA	31.66	30.48	31.38	30.27	26.44	31.08	31.52	30.26	30.97	29.67
PUFA	50.59	54.56	53.13	54.53	57.25	53.55	58.4	58.2	56.34	61.08
Total	99.45	99.98	99.98	99.97	99.98	99.97	99.98	99.97	99.95	99.99

Mean ± standard deviation
SAT:total saturated FA (g/100g oil); MUFA:total monounsaturated FA (g/100g oil); PUFA: total polyunsaturated FA (g/100g oil).

(2011) found that 24.5 % oil and 20.8 % crude protein was determined in cv. Akgun12. In another study (Dini et al., 2008b), chemical analysis of *Allium cepa* L. var. *Tropeana* (red onion) seeds showed 10.5 % moisture, 20.4 % oil and 24.8 % crude protein. We found 6.49-9.79 % moisture content in our samples, the highest level in cv. Tan8. Considering the oil content, samples contained high amounts of oil, the lowest level with 21.86 % in cv. Hasat and the highest total oil content with 25.86 % in cv. Kantartopu3. Seeds contained high amounts of crude protein as well as oil. The lowest amounts of crude protein with 15.7 % was detected in cv. Kantartopu3 which has the highest level in oil content. The highest amounts of crude protein with 26.16 % was determined in cv. Hasat which has the lowest level of oil.

Fatty acid composition and refractive index

Tab. 2 shows the fatty acid composition of the analysed onion seed oils. Onion seed oils contained about 9.24-17.72 g of saturated fatty acids, 26.44-31.66 g of monounsaturated fatty acids and 50.59-61.08 g of polyunsaturated fatty acids per 100 g total fatty acids. These seed oils had high PUFA contents. In these seed oils cv. Guntan Moru, was characterized by a high polyunsaturated/saturated (P/S) ratio of 6.6. A high ratio of P/S is regarded affirmative for the reduction of serum cholesterol and atherosclerosis and prevention of heart diseases (Oomah et al., 2002; Yehuda, 2001). Hence, cv. Guntan Moru is the most suitable onion seed for the oil industry.

The main fatty acid of this seed oils was linoleic acid (18:2n-6) at a level of 49.42-60.46 %. While cv. Guntan moru has the highest amount of linoleic acid, cv. Kantartopu3 has the smallest amount of this fatty acid. The cold-pressed onion seed oil had 64-65 % and Indian onion seed oil contained 45 % linoleic acid (Rao, 1994). Various reports suggested that cold- pressed oils present higher yield compared to oils obtained by solvent extraction (Zia-Ul-Haq et al., 2007). In oil ındustry linoleic acid rich oils such as sunflower and soybean oils are highly demanded. The second abundant fatty acid is oleic acid (18:1n-9) which has the highest amount in cv. Ertan1 (31.52%) and the lowest amount in cv. Polat (26.44%). The oleic acid level is lower compared to the value (34 %) reported by Rao (1994) and higher (25-26 %) than formerly reported by Parry et al. (2006). Linoleic acid content varies depending on the environmental conditions rather than the genetic background. As in many oily seeds, while reducing the amount of linoleic acid, an increasing amount of oleic acid has been observed in our samples. There is a complementary proportion between oleic and linoleic acids in these fatty acid rich oils (Yalcin et al., 2011). In onion seed, the most abundant fatty acids are unsaturated fatty acids which comprise approximately no less than 80 % of all the fatty acid in the onion seed. Saturated fatty acids were found in small amounts. Palmitic and stearic acids were the most abundant saturated fatty acids but the total amount of these two fatty acids was not more than 16 %. Palmitic and stearic acids exist in onion seed at a ratio of 7.23 % (cv. Guntan moru), 12.2 % (cv. Kantartpu3), 2.01 % (cv. Guntan moru), and 3.74 % (cv. Kantartopu3), respectively. The palmitic acid level is higher than the 6.4-7.1 % reported by Parry et al. (2006).

According to the specification described in the Turkish Food Codex, the ratio of the linoleic acid of the cotton seed and soybean oils are 46.7-58.2 % and 48.0-59.0 %, respectively and also the limits of oleic acids for these two oils are 14.7-21.7 % and 17.0-30.0 %, respectively. The linoleic acid proportions of our onion seeds oils

Tab. 3: Total phenolic contents and DPPH scavenging capacity of onion seed cultivars

Cultivar	Total Phenolic Contents (mg GAE/g dry extract)	% Inhibitions
Polat	2.01±0.21 f	4.59±0.71 c
Hasat	1.84±0.33 f	5.25±0.91 c
Guntan Moru	2.36±0.25 f, e	13.57±0.93 b
Beyaz Sogan	3.04±0.24 d, e	6.34±1.62 c
Guntan	4.14±0.40 c	8.89±4.05 b, c
Tan8	2.35±0.40 f, e	13.58±1.03 b
Kantartopu3	3.22±0.47 d, c, e	6.99±0.68 c
Akgun12	3.51±0.21 c, e	7.76±1.41 c
Ertan1	6.87±0.48 a	38.26±2.07 a
Imrali Kirmizisi	5.35±0.23 b	4.69±0.54 c

Mean ± standard deviation
Different letters indicate the statistical difference in the same column ($p<0.05$)

were similar to these limits. We can say that onion seed oil is similar to cotton seed and soybean oils in this regard. Cotton seed oil has less amount of oleic and high amount of palmitic acid than the onion seed oil. Corn oil has a similar linoleic acid content but compared with our results it has high amounts of oleic acid according to the food codex mentioned above.

The refractive index values, a frequently standard parameter used for characterization of oils, ranged from 1.4555 to 1.4771. Refractive index values of onion seed oils were found in the following order: 1.4555 (cv. Polat) < 1.4624 (cv. Hasat) < 1.4632 (cv. GuntanMoru) < 1.4699 (cv. Tan8) < 1.4700 (cv. Ertan1) < 1.4701 (cv. Akgun12) < 1.4702 (cv. Guntan) < 1.4713 (cv. Beyaz Sogan) < 1.4727 (cv. Kantartopu3) < 1.4771 (cv. Imrali Kirmizisi). The refractive index value of cold-pressed onion seed oils is 1.4752 reported by PARRY et al. (2006).

Total phenolic contents and DPPH scavenging capacity

Total phenolic contents and DPPH scavenging capacity of the onion seeds are shown in Tab. 3. The total pheolic content of the onion seeds range from 1.84 to 6.87 mg gallic acid equivalents per gram dry extract (mg GAE/g dry extract). Analyses of DPPH scavenging capacity showed that onion seeds have 13.58-38.26 % inhibition at concentration of 100,000 µg/g. A synthetic antioxidant, BHA shows 38.26 % inhibition at a concentration of 395 µg/g.

This is a prove that the presence of compounds are not reactive towards DPPH (PRZYBYLSKI et al., 1998). It is in agreement with the results reported by GAZZANI et al. (1998), that the antioxidant activity of vegetables increased by boiling because of pro-oxidant activity of peroxidases which were inactivated at high temperatures. Considering the total phenolic content and DPPH radical scavenging activity, the antioxidant activity is low in these onion seeds.

Volatile components

Composition of the volatile components in onion seeds are shown in Tab. 4. As to be seen here, a total of 48 compounds were detected in the volatile fraction of onion seeds. The highest percentage of the individual compounds is represented by 2-phenylethanol, an alcohol, with rates varying from 0.42 % to 41.17 %. Only in cv. Tan8 this substance was not detected and here 1-hexanol, varying from 5.85 % to 31.61 % , was detected as main component in the volatile fraction. Moreover, beside these, other alcoholic substances were determined such as 1-pentanol, 2-heptanol, 2-octanol, 1-octen-3-ol, 1-heptanol, phenylmethanol, 1-dodecanol. 1-pentanol, 2-heptanol, 1-octen-3-ol and phenylmethanol were detected in all samples and 1-dodecanol was only determined in cv. Hasat accounting 0.66 %.

In the volatile fraction, hydrocarbons have been also identified. Aromatic hydrocarbons such as *p*-xylene and mesitylene, ranging from 0.13 to 0.90 % and 0.10 to 0.85 %, respectively, were found. Limonene as a monocyclic monoterpene varied from 0.75 to 3.17 % in the samples. The cyclic monoterpene α-phellandrene was determined in cv. Akgun12, Cv. Imrali Kirmisizi and cv. Polat accounting 3.42, 0.17 and 1.43 %, respectively. A bicyclic monoterpene, *p*-cymene was detected in all samples except cv. Tan8.

Hexylacetate, nonylacetate, ethyloctanoate, methylhexanoate were the main esters determined in onion seeds. Nonylacetate was detected only in cv. Hasat with a concentration of 5.44 %.

The characteristic flavor compounds occurring in the individual species of the genus *Allium* are dominated by various biologically active organosulfur substances (GYAWALI et al., 2006). Onion seeds in this study, contained especially carbondisulfide, 4-phenyl-2-thiazolethiol, methylsulfonylmethane, and dipropyl disulfide. The most abundant carbon disulfide was determined in cv. Polat achieving a concentration of 4.74 %.

Conclusion

The higher total oil content and the fatty acid composition rich in polyunsaturated fatty acids of onion seed oil makes it desirable in terms of nutrition and the oil may be used as edible oil. However, the safety of this oil must be tested before possible applications for human consumption are discussed. Furthermore, volatile aroma components have beed found in onion seed oils, which could be of special interest for the production of natural aroma extracts applying appropriate extraction techniques.

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Tab. 4: Volatile components detected in different cultivars of onion seed oils

Compounds	Akgun12	Beyaz Sogan	Ertan1	Guntan	Hasat	Tan8	Kantar-topu3	Imrali Kirmizisi	Guntan Moru	Polat
Carbondisulfide	—	0.02	0.59	—	0.04	0.39	—	—	0.12	4.74
2,2,4,6,6-Pentamethylheptane	2.68	3.53	—	—	—	—	—	—	—	—
Chloroform	0.53	—	—	—	—	—	0.58	0.35	0.85	0.05
2-Phenylethanol	32.65	0.42	41.17	17.71	19.77	—	29.31	19.78	25.83	29.20
α-Phellandrene	3.42	—	—	—	—	—	—	0.17	—	1.43
p-Xylene	0.61	0.13	0.29	0.35	—	—	0.36	0.90	0.18	—
Methylhexanoate	0.60	0.38	—	—	0.53	0.51	0.31	—	0.29	—
Limonene	1.23	0.75	0.75	0.82	2.90	—	0.56	—	3.17	2.90
Acetophenone	0.58	—	—	0.19	—	—	0.34	—	—	0.13
2-Pentylfuran	2.57	4.82	0.33	1.06	2.54	3.86	1.82	1.19	1.56	1.21
1-Pentanol	1.60	3.09	2.56	1.99	1.62	2.36	1.71	1.41	1.87	0.91
Styrene	1.70	2.13	3.25	2.68	0.86	0.26	1.00	0.52	1.41	0.93
p-Cymene	0.53	0.12	0.22	0.28	0.54	—	0.03	0.07	0.75	0.83
Mesitylene	0.85	—	0.18	—	—	—	0.30	0.11	0.10	—
2-Heptanol	0.24	0.89	0.34	0.35	1.51	1.65	0.20	0.20	0.70	0.19
1-Hexanol	8.97	26.31	16.42	14.96	15.78	31.61	12.12	10.91	14.25	5.85
2-Octanol	0.26	—	2.67	0.24	0.32	0.77	0.27	0.18	0.56	0.29
1-Octen-3-ol	0.96	0.92	2.23	0.66	0.44	0.98	0.92	0.61	0.69	0.65
Methoxycyclooctane	0.61	—	—	—	—	0.96	—	—	—	—
1-Heptanol	0.15	1.53	—	0.93	0.95	2.82	0.38	0.36	0.73	0.15
1-Anthracenamine	0.30	—	0.17	0.61	—	—	0.54	0.61	0.63	0.42
(E)-2-Hepten-1-ol	0.40	—	—	—	—	1.02	1.14	0.56	—	0.08
(E)-2-Octen-1-ol	0.44	3.01	0.54	1.41	—	2.68	—	—	1.31	0.59
γ-Hexalactone	0.15	0.27	—	—	0.16	0.24	—	0.11	—	—
Methoxyphenyloxime	0.58	1.92	1.28	1.30	0.48	0.58	0.94	1.73	0.98	1.34
Hexanoic acid	0.66	1.59	0.41	1.29	1.55	0.46	1.19	1.24	1.25	0.97
Phenylmethanol	0.17	0.54	1.02	0.83	0.44	0.56	0.36	0.34	0.45	0.34
Naphthalene	1.16	0.23	2.55	—	0.27	0.21	0.74	0.73	0.24	0.38
n-Octadecane	0.67	0.77	0.18	0.93	0.50	0.74	0.88	0.33	0.76	—
Icosane	0.51	0.24	0.45	0.75	1.15	0.40	0.84	0.25	0.80	0.98
Toluene	—	0.96	0.23	—	0.05	0.10	—	4.15	—	6.60
Ethyloctanoate	—	0.27	—	—	0.53	0.44	—	—	—	—
Hexylacetate	—	0.21	—	—	0.94	0.42	—	—	0.87	0.65
Sulfurous acid	—	0.08	—	0.10	—	—	—	—	0.12	0.15
4-Phenyl-2-thiazolethiol	—	0.49	0.96	—	0.36	0.42	—	0.85	—	—
Nonanol	—	2.05	1.52	0.41	0.50	0.99	0.42	0.22	0.78	0.15
1-Dodecanol	—	—	—	—	0.66	—	—	—	—	—
Hexane	—	—	1.91	2.50	3.32	—	1.65	3.35	0.79	2.94
γ-Nonalactone	—	0.62	—	—	1.00	1.25	—	0.07	—	—
Methylsulfonylmethane	—	0.12	—	—	0.14	—	—	0.09	—	—
Dodecane	—	—	—	—	3.11	—	—	0.88	—	—
Dipropyl disulfide	—	—	—	0.48	0.14	0.40	—	—	0.16	—
Nonylacetate	—	—	—	—	5.44	—	—	—	—	—
Linalool	—	—	—	—	0.20	—	—	—	0.48	0.36
Dodecanal	—	—	—	—	2.27	0.35	2.09	1.24	—	—
3-Methylbutanoic acid	—	—	—	—	—	0.44	2.28	—	—	—
Phenol	—	—	—	0.34	—	0.26	—	—	—	—
Total % identified	65.79	58.41	82.28	53.17	70.98	58.14	63.29	53.52	63.14	65.76

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