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Egg yolk phospholipids: a functional food material to generate deep-fat frying odorants

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Abstract

BACKGROUND

Phospholipids are an important precursor for the generation of carbonyl compounds which play a significant role in the characteristic aroma of deep-fat fried foods.

RESULTS

Phospholipids extracted from hen egg yolks were added into sunflower oil (2.0 g/kg) and heated with or without chicken meat at 160 °C for 10 min, and then dynamic headspace extraction and GC-MS were used to extract and analyze the volatiles. The results showed that the characteristic deep-fat frying odorants, such as (*E,E*)-2,4-decadienal, (*E,Z*)-2,4-decadienal, as well as 1-octen-3-one, (*E*)-2-nonenal, octanal, methional, dimethyl disulfide and alkylpyrazines had increased by 3-65 times in the sunflower oil with added phospholipids, and increased up to 6 times in chicken meat which had been treated with phospholipids prior to heating.

CONCLUSION

There is potential for the food industry to use low levels of phospholipids, particularly egg yolk phospholipids, to increase deep-fat frying odorants in a wide range of deep fried products.

Keywords: deep-fat frying; odorants; phospholipids; egg yolk; chicken meat; 2,4-decadienal.

Introduction

Deep-fat frying is a popular cooking method, and the deep-fat frying aroma is very attractive for the consumer. Deep-fat frying aroma comes from the oxidation and decomposition of the lipids, as well as Maillard reaction, and it always occurs at high cooking temperatures.[1] (*E*,*E*)-2,4-Decadienal (deep-fried), (*E*,*Z*)-2,4-decadienal (deep-fried), pyrazines (roasty), 2- and 3-methylbutanal (malty), and methional (cooked potato-like odor) are the key odorants in fried potato chips.[1-3]

Thuerer et al showed that the fatty acid profile of the frying oil significantly influenced the concentration of 2,4-decadienals.[3] They found that the concentration of 2,4-decadienals in safflower oil was about 12 times higher than in coconut oil, as safflower oil is richer in linoleic acid, the main precursor of 2,4-decadienals. The concentration of the Strecker aldehydes and alkylpyrazines were not clearly influenced by the frying oils, but frying temperature is an important parameter as it has a great influence on their formation.[4] Compared with conventional fried (at 165 °C) crisps, vacuum frying (at 120 °C) crisps reduced the formation of lipid-derived compounds and Maillard reaction products, especially alkylpyrazines.[4]

Egg yolk phospholipids are rich in linoleic acid and arachidonic acid,[5] and it can be used as a source of important precursors for the generation of lipid-derived odorants.[6,7] For example, hexanal, (*E*,*E*)-2,4-decadienal, 1-octen-3-one, (*E*)-2-decenal and (*E*)-2-undecenal were produced when egg yolk phospholipids were thermally treated at 145 °C for 20 min.[6] In our previous work,[7] the lipid-derived compounds contributing to the characteristic chicken meat aroma

increased sharply when egg yolk phospholipids were heated in water at 100 °C for 20 min, and chicken meat aroma was improved when egg yolk phospholipids were added to minced chicken meat prior to heating under the same conditions.

The hypothesis of this work is that egg yolk phospholipids can be the primary precursors of deep-fat frying odorants, which could be used specifically to increase the key odorants of deep-fried food. Although deep-fat frying odorants have been widely studied and produced by different methods, to the best of our knowledge, no research has been published where egg yolk phospholipids have been used in the deep-fried food. The objective of this work is to study the impact on deep-fried odorants when egg yolk phospholipids are added into sunflower oil and heated at frying temperatures with and without chicken meat.

Materials and methods

Reagents and Chemicals

Authentic chemicals of reference aroma compounds were purchased from a range of laboratory chemical suppliers in U.K.. 1,2-Dichlorobenzene in methanol (130.6 ng/μL) and alkane standard C5−C25 (100 ng/μL in diethyl ether), used as GC-MS standards, were obtained from Sigma-Aldrich Co. Ltd. (Gillingham, U.K.).

Phospholipids extraction

Commercial fresh hen eggs were bought from a local supermarket for this study. The extraction method employed was that reported by Chen et al.[7] Briefly, fresh egg yolk (40 g, obtained from six hen eggs) lipids were extracted with ethanol; then the crude phospholipids were dissolved in hexane; next, cold acetone was used to

precipitate phospholipids; finally the high purity phospholipids were obtained. The minor residual solvents in the phospholipids were removed under high vacuum at room temperature for 10 h.

Phospholipids purity

This method was according to the AOCS Official Method.[8] Firstly, the phospholipids sample was ashed in the presence of zinc oxide, followed by the spectrophotometric measurement of phosphorus as a blue phosphomolybdic acid complex, and finally a conversion factor of 30 was used to convert phosphorus to phospholipids.

Sample preparation

To disperse the phospholipids, 0.50 g phospholipids and 9.50 g salt were ground and thoroughly mixed. Commercial sunflower oil and fresh chicken breast fillets without skin or bone were bought from a local supermarket for this study. The chicken meat (~200 g) was ground in a domestic meat mincer (Kenwood, Havant, UK) and thoroughly mixed. The samples were prepared as follows:

1) Sunflower oil sample: 0.57 g salt, 15.0 g sunflower oil.

2) Sunflower oil & phospholipids sample: 0.60 g phospholipids and salt mixture, 15.0 g sunflower oil.

3) Chicken meat sample: 1.50 g chicken meat, 0.57 g salt, 15.0 g sunflower oil.

4) Chicken meat & phospholipids sample: 1.50 g chicken meat, 0.60 g phospholipids and salt mixture, 15.0 g sunflower oil.

Finally the samples were sealed in 100 mL glass Duran bottles and heated in an oil

bath (160 °C) for 10 min and then cooled in an ice-bath. Each treatment was carried out in quadruplicate and all samples were prepared from the same batch of egg, sunflower oil and chicken mince.

Dynamic Headspace Extraction (DHE)

DHE was used for the extraction of the volatiles, following the method described by Chen et al with minor modifications.[7] The entire contents of each Duran bottle were transferred into a 250 mL conical flask fitted with a Dreschel head. The flask was incubated in a water bath at 50 °C, and the volatiles in the headspace were swept onto Tenax absorbent using a flow of nitrogen (40 mL/min) for 60 min. After sweeping, 1.0 µL 1,2-dichlorobenzene in methanol (130.6 ng/µL) was added as an internal standard to the trap, followed by a purge of 100 mL/min for 10 min to remove excess solvent and moisture.

GC-MS Analysis of Volatile Compounds

The DHE samples were analysed using an Agilent 7890A-5975 GC-MS system (Agilent Technologies Co. Ltd., Palo Alto, CA, USA) equipped with an automated thermal desorber (Turbomatrix ATD), using a DB 5 column (60 m × 0.25 mm i.d., 1 µm film thickness from J&W Scientific, Agilent, Palo Alto, CA, USA) under instrumental conditions described by Chen et al.[7] The identification of the compounds was based on the comparison of their mass spectra with spectra from the NIST 11 Mass Spectral Database.[9] The linear retention index (LRI) was calculated for each volatile using the retention times of a series of C5−C25 n-alkanes. The identities of most of the volatiles were confirmed if their mass spectra and LRI

matched those of authentic compounds run under the same analytical conditions in our laboratory. Volatiles were considered as tentatively identified by matching their mass spectra with the reference mass spectra in the NIST mass spectral library, and by comparison of their LRI to the NIST Chemistry WebBook database.[10] Volatiles were semi-quantitatively determined by comparison of the peak areas against that of the internal standard using a response factor of 1 for each compound.

Statistical Analysis

The GC–MS data were analyzed using Independent-Samples T Tests (SPSS, 23, IBM) comparing the sunflower oil sample with the sunflower oil & phospholipids sample, and comparing the chicken meat sample with the chicken meat & phospholipids sample. Significant differences are shown by **, $p \leq 0.01$; *, $p \leq 0.05$; ns, $p > 0.05$.

Results and Discussion

The purity of the extracted phospholipids

The purity of the extracted egg yolk phospholipids was 95.2±3.0%, which was coincided with the report of Gladkowski et al.[11] According to their report, the purity of the phospholipids extracted by this method was very high (95.9%), and the phospholipids contained phosphatidylcholine (78%) and phosphatidylethanolamine (21%).

Characteristic deep-fat frying odorants derived from lipids

The results are shown in Table 1. The most abundant odorants detected were mainly aldehydes, such as (*E*)-2-heptenal, hexanal and (*E*,*E*)-2,4-decadienal.

(*E,E*)-2,4-Decadienal (fatty, fried), (*E,Z*)-2,4-decadienal (fatty, fried), 1-octen-3-one (mouldy, mushroom-like), (*E,E*)-2,4-nonadienal (fatty, fried, green), are the characteristic deep-fat frying odorants.[1] These compounds are formed from the thermal oxidation of unsaturated fatty acids, especially from the ω-6 fatty acids (linoleate and arachidonate).[12, 13] Both (*E,E*)-2,4-decadienal and hexanal are often used as primary marker compounds of the oxidation of ω-6 fatty acids.[14]

Sunflower oil is widely used for deep-fat frying process,[15] and it is rich in linoleic acid (about 62% of the total fatty acids),[16] and the linoleate residues are present as triglycerides (as there are only trace phospholipids presented in the refined sunflower oil). Both the C9 and C13 position of the linoleate residues in triglycerides are favored positions to form the hydroperoxides during autoxidation,[14, 17] and the C9 and C13 hydroperoxide are the precursors for 2,4-decadienal and hexanal, respectively. So linoleate residues present in triglycerides can produce both 2,4-decadienal and hexanal.

Characteristic odorants derived from the Maillard reaction

Alkylpyrazines, originating via the Maillard reaction, are important contributors to typical roasted, nutty, meaty, earthy, and popcorn-like note of many heated food products. The dominant alkylpyrazines in the present study were methylpyrazine and 2,5-dimethylpyrazine. The Strecker aldehydes, for example, 2- and 3-methylbutanal (malty), methional (cooked potato-like odor), as well as phenylacetaldehyde (green, sweet), are the key odorants in fried potato chips, which are originated from isoleucine, leucine, methionine and phenylalanine, respectively. 2-Methylpropanal

(pungent) is formed from valine.[18] Benzaldehyde (almond) is formed from phenylacetaldehyde,[19] and methional may degrade to methanethiol, which in turn could produce dimethyl disulfide and dimethyl trisulfide.[20]

Sunflower oil samples

The contents of hexanal and (*E*,*E*)-2,4-decadienal in the headspace collected from the heated sunflower oil sample were approximately 800 ng and 2 ng respectively. When the phospholipids were added to the sunflower oil prior to heating, hexanal increased by about 20% whereas the concentratrion of (*E*,*E*)-2,4-decadienal was 65 times higher than in the heated sunflower oil alone. As both (*E*,*E*)-2,4-decadienal and hexanal are the markers of oxidation, this shows that the egg yolk phospholipids under the present frying condition (160 °C, 10 min) were more prone to oxidation. It also demonstrates how the chemical environment of the linoleate residue influences the relative rates of formation of hexanal and (*E*,*E*)-2,4-decadienal.

The presence of phospholipids in the oil has two effects. Firstly it is clear that incorporation of the phospholipids increased the rate of oxidation. Owing to the amphiphilic nature of phospholipids, they tend to be present in a dispersed form, increasing their surface area, and increasing their exposure to water soluble pro-oxidants. In meat, these are likely to be pro-oxidant metals, rendering the phospholipids highly susceptible to oxidation and to the generation of large quantities of lipid-derived volatiles.[21] Linoleic acid is the predominant PUFA (about 14% of the total fatty acids) in egg yolk phospholipids.[5] Secondly, phospholipids direct the position of oxidation, promoting formation of the C9

hydroperoxide-derived volatiles in linolate residues over those derived from C13 hydroperoxides.[22] It was reported that for linoleate residues bound in a phospholipid, autoxidation at the C9 position is the most favored position for formation of hydroperoxides.[22] The C9 hydroperoxide is the precursor for 2,4-decadienals, so 2,4-decadienals are the dominant product for linoleate assembled in phospholipids. When the phospholipids were added to the sunflower oil sample, there was a sharp increase in (*E*,*E*)-2,4-decadienal (130 ng vs. 2 ng) and only a relatively small increase in hexanal (988 ng vs. 804 ng) which corroborates the finding of Reis and Spickett.[22] In our previous study,[7] we also observed a much greater increase in (*E*,*E*)-2,4-decadienal than in hexanal when phospholipids were added to water prior to a mild heating procedure.

Once the lipid oxidation process has been initiated by the more reactive fatty acids, this can promote the oxidation of the less reactive fatty acids.[23] The oxidised phospholipids not only produced lipid-derived aldehydes, but also promoted the oxidation of sunflower oil, explaining the increase in ω-3 and ω-9 derived volatiles in the sunflower oil & phospholipids sample.

The presence of some Maillard reaction products in the sunflower oil & phospholipids sample was not surprising, as low levels of Maillard reaction precursors are co-extracted with the phospholipids when polar solvents (ethanol and acetone) are used. In addition, both the primary amine group present in phosphatidylethanolamine and aldehydes produced from lipid oxidation can serve as Maillard reaction substrates.[21] It is also consistent with the previous reports[24, 25] that

199 the products of phospholipids oxidation can contribute to the Maillard reaction.

200 **Sunflower oil samples with chicken meat**

201 The trends in odorants in the heated chicken meat samples were consistent with
202 those in the heated oil samples, but the magnitude of the increases were significantly
203 diminished. Some lipid-derived aldehydes and most of the Maillard reaction
204 products were significantly higher in the chicken meat & phospholipids sample
205 compared to the chicken meat sample. The presence of meat provides a rich source
206 of precursors and reactive intermediates which can influence the formation of
207 volatiles and explain the changes in both lipid- and Maillard-derived compounds. In
208 the chicken meat systems, the smaller increase in lipid-derived compounds with
209 added phospholipids is consistent with previous findings.[7] Examination of Table 1
210 shows that some odorants, such as 2,4-alkadienals, had much smaller increases when
211 chicken meat was added to the samples. This apparent "loss" of 2,4-decadienals in
212 the presence of meat could be attributed to the following. Firstly, the temperature
213 was lower in the frying meat system than in the frying oil system (because of water
214 evaporation), and the formation of those odorants were highly associated with the
215 temperature.[4] Secondly, those odorants may get trapped within the meat.[26] Thirdly,
216 there may be interaction with other components of the meat (such as NH_3, H_2S, free
217 amino groups and reactive dicarbonyls). For example 2,4-decadienal reacts with
218 ammonia to form 2-pentylpyridine via Maillard reaction.[27] Finally, the degradation
219 of this highly reactive alkadienal, such as 2,4-decadienal can undergo
220 retroaldolisation to form hexanal and 2-octenal.[28] The higher productions of

2-pentylpyridine, 2-octenal and hexanal in the chicken meat & phospholipids sample could indicate more extensive degradation of 2,4-decadienal.

The small increase in 3-methylbutanal, and a similar trend for the other Strecker aldehydes, is due to the participation of unsaturated lipid-derived compounds in the Strecker degradation.[29] The parallel formation of α-aminoketones may also promote the formation of pyrazines. This increase is observed for 4 of the 5 pyrazines detected.

The key odorants in chicken & phospholipids sample

Both isomers of 2,4-decadienal not only impart characteristic deep-fried odor,[1] but were also the odorants with highest flavour dilution factor in chicken meat broths.[30, 31] (*E*,*E*)-2,4-Decadienal contributes a fatty chicken note with a very low odour detection threshold (0.07 μg/kg).[32] In the present study, the contents of both isomers of 2,4-decadienal had a 3-4 times increase in the chicken meat & phospholipids samples, which indicated that the characteristic fatty fried chicken notes could arise from the increases in 2,4-decadienals. Besides (*E*,*E*)-2,4-decadienal, 1-octen-3-one, alkylpyrazines and the Strecker aldehydes are also the most significant contributors to deep-fried chicken meat flavor. Under the present processing conditions, the content of most of alkylpyrazines and the Strecker aldehydes had significantly increased, especially methional had a about 4 times increase in the phospholipids added chicken meat samples, which means that the fried meat note was enhanced by egg yolk phospholipids.

Conclusion

It has been demonstrated that the characteristic deep-fat frying odorants and fried chicken meat odorants, such as (*E*,*E*)- and (*E*,*Z*)- 2,4-decadienal, 1-octen-3-one, (*E*)-2-nonenal, octanal, methional, disulfide dimethyl, methylpyrazine and trimethylpyrazine significantly increased when a small amount (2.0 g/kg) of egg yolk phospholipids was added into sunflower oil samples with or without chicken present prior to heating at frying temperatures. This is of potential interest to the food industry and catering industry, however, its usage and effects on the deep-fat frying aroma need further sensory research, as food aroma is a delicate balance of the odorants.

Acknowledgements

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Conflict of interest

There is no conflict of interest about this article.

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338 Table 1. Mean Values (approx ng/sample extraction) (n=4) of the Volatile Compounds Identified in Headspace of the Samples.

			Sunflower oil	Sunflower oil & Phospholipids		Chicken meat	Chicken meat & Phospholipids	
Compound Name	**LRI DB5[1]**	**ID[2]**	**Mean±SD[3]**	**Mean±SD[3]**	**Sig[4]**	**Mean±SD[3]**	**Mean±SD[3]**	**Sig[5]**
ω-3 derivatives								
2-Hexenal, (*E*)-	857	A	112±19	310±57	**	106±48	116±51	ns
2,4-Heptadienal, (*E,Z*)-	1000	B	1.73±0.30	3.82±1.09	*	0.79±0.52	0.91±0.26	ns
2,4-Heptadienal, (*E,E*)-	1015	A	5.52±0.79	8.89±2.39	*	2.33±1.32	2.77±0.91	ns
5-Ethyl-1-cyclopentene-1-carboxaldehyde	1036	A	0.80±0.18	81.5±15.5	**	17.7±5.2	28.5±13.5	ns
ω-6 derivatives								
Pentane	500	A	59.9±35	282±99	*	53.3±12.2	69.2±32.9	ns
Pentanal	706	A	156±43	257±39	**	201±100	150±48	ns
1-Pentanol	765	A	23.7±2.2	47.6±7.2	**	191±60	214±86	ns
Hexanal	813	A	804±121	988±158	*	352±110	423±278	ns
1-Hexanol	869	A	8.07±1.14	10.5±2.6	ns	10.6±1.8	22.1±4.3	**
2-Heptanone	889	A	9.43±1.01	25.9±5.4	**	8.12±3.94	13.6±3.6	ns
Heptanal	904	A	35.6±3.5	135±36	**	36.2±21.6	53.5±14.9	ns
2-Heptenal, (*E*)-	966	A	655±260	1456±286	**	603±297	608±181	ns
1-Octen-3-one	978	A	10.2±3.7	55±22	**	11.8±4.5	22.9±4.6	*
1-Octen-3-ol	983	A	101±16	174±26	**	72.8±45.4	63.7±37.0	ns
2,3-Octanedione	984	A	1.42±0.28	33.9±8.6	**	4.48±2.25	9.54±4.11	*
2-Pentylfuran	990	A	16.7±3.6	33.2±13.5	*	9.71±7.35	13.1±6.9	ns

2-Octenal, (*E*)-	1060	A	25.8±3.2	145±48	**	40.1±27.9	57.2±18.5	ns
2-Octen-1-ol, (*E*)-	1067	A	1.49±0.50	7.59±1.44	**	3.15±0.89	4.37±1.61	ns
3-Nonen-2-one	1142	A	1.05±0.21	7.30±1.65	**	1.34±0.39	2.09±0.62	ns
2,4-Nonadienal, (*E*,*Z*)-	1200	B	0.27±0.05	1.15±0.36	**	0.35±0.20	0.25±0.11	ns
2,4-Nonadienal, (*E*,*E*)-	1222	A	0.79±0.12	4.22±1.31	**	1.11±0.59	1.33±0.68	ns
2,4-Decadienal, (*E*,*Z*)-	1299	B	1.20±0.20	47.92±26.53	*	3.29±1.36	10.4±3.6	*
2,4-Decadienal, (*E*,*E*)-	1325	A	2.01±0.83	130±70	*	5.68±1.91	22.4±7.6	*
ω-9 derivatives								
1-Octene	791	A	20.7±3.8	184±50	**	15.4±12.4	40.88±28.67	ns
Octane	800	A	43.2±6.9	147±32	**	73.0±23.1	70.6±20.6	ns
2-Octene, (*Z*)-	815	A	22.4±3.8	160±45	**	28.3±22.4	93.4±57.0	ns
Octanal	1004	A	16.4±1.8	59.0±19.0	**	18.5±6.2	28.5±6.7	ns
1-Octanol	1070	A	2.21±0.46	6.86±2.55	**	3.70±0.94	3.79±0.91	ns
Nonanal	1108	A	51.8±8.2	113±28	**	41.5±14.7	57.4±18.1	ns
2-Nonenal, (*E*)-	1164	A	2.79±0.39	10.9±2.1	**	2.66±0.64	5.14±1.29	*
1-Nonanol	1173	A	3.50±0.62	2.88±0.82	ns	2.94±0.67	2.73±0.52	ns
Decanal	1208	A	25.2±2.9	17.9±7.20	ns	22.8±6.5	22.3±1.4	ns
2-Decenal, (*E*)-	1266	A	3.60±0.81	17.4±7.3	**	5.42±1.59	8.21±2.79	ns
2-Undecenal	1368	A	3.55±1.35	3.11±1.5	ns	2.15±0.60	0.96±0.64	*
Maillard reaction products								
2-Methylpropanal	555	A	65.5±44.6	118±18	ns	45.8±11	74.8±20.0	ns
3-Methylbutanal	665	A	3.55±1.39	660.±90	**	420±65	664±138	**
2-Methylbutanal	674	A	2.50±0.75	275±50	**	144±9.8	170±29	ns
Methylpyrazine	829	A	0.17±0.11	7.78±2.38	**	8.41±0.64	17.4±5.6	**

Methional	912	A	nd	33.0±4.5	**	24.0±5.7	90.8±26.1	**
2,5-Dimethylpyrazine	917	A	nd	7.05±1.52	**	4.03±1.1	12.3±0.8	**
2-Ethylpyrazine	969	A	0.07±0.02	0.95±1.41	ns	0.12±0.23	0.18±0.35	ns
2-Ethy-6-methylpyrazine	1001	A	nd	0.35±0.14	**	0.34±0.16	0.69±0.01	*
Trimethylpyrazine	1006	A	1.60±1.09	6.79±4.12	*	0.19±0.11	1.05±0.26	**
Benzeneacetaldehyde	1049	A	3.72±1.86	17.3±4.8	**	36.7±4.1	102±25	**
2-Pentylpyridine	1204	B	0.04±0.02	2.20±0.63	**	0.05±0.01	0.44±0.24	*
Miscellaneous								
Dimethyl disulfide	745	A	0.05±0.00	14.3±10.9	*	12.1±1.7	30.9±9.9	*
Toluene	767	A	9.66±8.01	11.8±0.87	ns	10.1±2.7	25.6±28.5	ns
Acetylacetone	788	B	5.85±0.85	25.3±41.1	ns	3.35±1.58	16.±33	ns
3-Cyclohepten-1-one	826	C	4.52±0.51	8.47±16.8	ns	5.14±2.38	9.7±3.9	ns
2-Methylcyclopentanone	844	A	3.46±0.57	25.7±14.6	*	5.43±2.61	6.35±2.94	ns
α-Pinene	934	A	11.0±1.2	9.97±0.27	ns	8.26±2.68	5.02±1.51	ns
Benzaldehyde	971	A	42.4±18.8	25.0±4.0	ns	61.7±11.9	21.3±9.0	**
Dimethyl trisulfide	976	A	0.04±0.01	1.28±1.48	ns	14.2±6.23	14.1±2.7	ns
D-Limonene	1031	A	0.38±0.11	0.32±0.09	ns	10.1±4.3	14.0±7.8	ns
Undecane	1100	A	2.35±0.33	4.31±1.23	*	2.84±0.27	2.29±0.19	*
Dodecane	1199	A	1.11±0.38	1.02±0.17	ns	0.92±0.17	0.64±0.12	*
Undecanal	1309	A	2.26±0.34	1.02±0.41	**	2.07±0.64	1.47±0.19	ns
Tetradecane	1399	A	1.23±0.39	0.53±0.29	*	0.79±0.39	0.55±0.21	ns
Dodecanal	1411	A	2.24±0.40	0.75±0.40	**	2.38±1.14	1.06±0.04	*
Pentadecane	1499	A	1.05±0.27	0.44±0.32	*	1.07±0.73	0.36±0.03	ns

[1]Linear retention indices determined on a DB 5 column.

[2]Confirmation of identity where A = mass spectrum and LRI agree with those of an authentic compound; B = mass spectrum agrees with reference spectrum in the NIST mass spectral database and the LRI value agrees with that in the database (NIST Chemistry WebBook, 2017); C = mass spectrum agrees with reference spectrum in the NIST mass spectral database (NIST/EPA/MSDC, 1992).

[3]Approximate amount (mean, n=4) collected from the headspace, calculated by comparison of peak area with that of 1,2-dichlorobenzene (130.6 ng) with a response factor of 1, nd = not detected.

[4]Independent-Samples T Tests was used to compare group samples (sunflower oils sample vs. sunflower oils & phospholipids sample), significant differences are shown by **, $p \leq 0.01$; *, $p \leq 0.05$; ns, $p > 0.05$.

[5]Independent-Samples T Tests was used to compare group samples (chicken meat sample vs. chicken meat & phospholipids sample), significant differences are shown by **, $p \leq 0.01$; *, $p \leq 0.05$; ns, $p > 0.05$.