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Research Article

Volatile Compounds of Wheat Flour and Steamed Bread as Affected by Wheat Storage Time

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Abstract

To detect volatile compounds in wheat flour and steamed bread and identify the variance of the volatiles as affected by wheat storage time, a strong gluten wheat cultivar was harvested and stored in 2009, 2012 and 2015 and then analyzed by Headspace-Solid Phase Micro Extraction (HS-SPME) coupled with Gas Chromatography-Mass Spectrometry (GC-MS). A total of 60 types of volatiles were detected, of which 39 were in wheat flour, 33 were in steamed bread, and 11 were in both wheat flour and steamed bread. The compounds were alcohols, aldehydes, alkanes, alkenes, ketones, esters, and others. In wheat flour, alkanes were the most represented compounds, whereas in steamed bread, alcohols were the major compounds in each year. In wheat flour, the amounts of alcohols and aldehydes increased significantly with wheat storage time, whereas alkanes showed the opposite trend. In steamed bread, the amounts of alcohols and aldehydes increased and alkanes decreased markedly with storage time.

Introduction

Wheat is a staple cereal in China, and approximately half of the consumed wheat is made into steamed bread. Chinese people, especially the northern Chinese, have eaten steamed bread since ancient times, over 1500 years ago, formulated with wheat flour, water and yeast. Steamed bread has been considered a healthy and popular food in China due to its low oil and sodium content and the lack of toxic Maillard reaction products such as acrylamide and furan [1-6]. The nearly daily consumption of steamed bread around China gives it an important place in human nutrition.

Today, food safety has become much more of a concern, and consumers are more aware of the relationship among food, nutrition and health. For wheat and other cereals, extended storage times may cause a decrease in quality and nutrition or may even cause the production of various toxins [7], which may pose potential risks to human health. Among the factors that influence food quality, the aroma of volatile compounds is considered an important contributor to consumer acceptance [8,9]. A recent review in Science reported that volatile compounds are the essential factors in the aroma of distinctive foods and, on the basis of the relationship between volatiles and nutrient value, could offer significant information concerning the nutritional constitution of food items [10,11]. Additionally, some data suggest that cereal flours could release volatile compounds that impact the aroma of cereal-based foods [8,12]. Thus, the analysis of the volatile aromas can be considered of fundamental importance for wheat and wheat-based foods.

Headspace-Solid Phase Microextraction (HS-SPME) is a solvent-free technique that can quickly and easily extract and enrich volatile compounds from different samples. Gas Chromatography-Mass Spectrometry (GC-MS) coupled with HS-SPME has become an attractive choice to detect volatile compounds in cereals and cereal-based foods. To the best of our knowledge, many studies have analyzed the volatile compounds in wheat flour, dough, bread, steamed bread and other wheat-based foods [8,13-22], but little information is available on the variation of the volatile compounds in wheat flour and steamed bread as affected by wheat storage time. In this study, a strong gluten wheat cultivar, Shiluan 02-1, was collected from fields in Hebei province in 2009, 2012 and 2015 and stored in a laboratory sample room at approximately 20°C. In 2016, the wheat was ground into flour and made into steamed bread, and the volatile compounds from the flour and steamed bread were detected. The aims of this study were to detect volatile compounds of wheat flour and steamed bread and to identify the variance of the volatile compounds as affected by wheat storage time.

Material and Methods

Wheat samples

Wheat (cultivar: shiluan 02-1) was grown and harvested in 2009, 2012 and 2015 in Daming county, Hebei Provence, China. The harvested wheat was cleaned, air-dried, bagged and stored in a laboratory sample room at approximately 20°C until analysis. The wheat samples harvested in 2009,

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2012 and 2015 were milled into flour respectively, using a MLU 202 Bühler laboratory mill (Bühler, Uzwil, Switzerland) in May 2016.

Steamed bread preparation

Steamed bread was made according to the Chinese national standard (SB/T 10139-1993). The wheat flour (400 grams) was briefly mixed with a yeast solution (3.2 grams active dry yeast in 200 mL purified water at 38°C). The mixture was needed for 6 min. using a dough-maker machine. The dough was fermented for 50 min. in fermentation equipment (38°C, 85% RH). The fermented dough was divided into several pieces, rounded and molded by hand for approximately 3 min. and then proofed for 30 min at 38°C and 85% RH. Finally, the proofed dough was steamed for 20 min. in a steamer containing 1000 mL of boiling water. The steamed breads were cooled at room temperature for 1 h and were then sampled for analysis of volatile compounds.

HS-SPME extraction

Volatile compounds in wheat flour and steamed bread samples were extracted by HS-SPME coupled with a CTC automatic sampler (combi PAL, CTC Analytics AG, Switzerland) linked with the GC-MS instrument. Three grams of the samples was placed in 20 mL vials without any solvent, and the vials were then tightly capped with PTFE/silicone septums. The samples were preheated for 20 min at 60°C prior to evaluation. Volatile compounds were extracted using a 30/50 μm divinylbenzene/carboxen/ polydimethylsiloxane (DVB/CAR/PDMS) SPME fiber assembly (Supelco, Bellefonte, PA, USA) at 60°C for 20 min. while shaking the samples. The fiber was desorbed for 7 min in the GC injection port at 250°C in splitless mode, and the GC run was started.

GC-MS analysis

GC-MS analyses were conducted on an Agilent 6890A gas chromatograph equipped with Agilent 5975C VL MSD quadrupole mass spectrometer and a DB-wax capillary column (60 m × 0.25 mm i.d. × 0.25 μm film thickness). The analyses were carried out using helium as the carrier gas at a constant flow rate of 1 mL/min. The injection port temperature was set at 250°C. The column temperature program was set as follows: the initial temperature was at 35°C kept for 6 min, then raised to 40°C at a rate of 2°C/min for 2 min, to 210°C at a rate of 5°C/min and to 250°C at a rate of 10°C/min held for 5 min. The injection volume was 1 μL for each sample.

The mass spectrometer was operated in the full scan mode with a mass range of 35-500 atomic mass units (amu). The spectrometer was recorded in Electron Impact mode (EI) at ionization energy of 70 ev. The ion source, transfer line, four stage lever temperatures were set at 230°C, 280°C, and 150°C, respectively.

Additionally, the identification of the volatile compounds was based on mass spectra matching (matching degree≥800) with the NIST08 library (Version 2.0 d). The contents of the volatile compounds were expressed as the relative peak area counts of the compounds identified (peak area of each compound/ total area × 100). All values were presented as the mean of three repetitions.

Statistical analysis

The data in this study were analyzed using the Statistical Program for Social Sciences (SPSS) (Standard version 19.0). The Least Significant Difference (LSD) test was used to determine the differences for each volatile compound in wheat flour and steamed bread samples among different storage years. The probability level used for the statistical significance was $p<0.05$.

Results and Discussion

Volatile compounds composition

A total of 60 volatile compounds were detected in wheat flour and steamed bread samples, which included alcohols, aldehydes, alkanes, alkenes, ketones, esters, furan, organic acid and an oxime (Figure 1 and Figure 2). They are listed in detail in Table 1 along with their CAS number, retention time and relative content expressed by percentage of peak area. The chemical classes detected in this study were in agreement with previous reports [8,11,13,14,16-25].

In wheat flour samples, 39 volatile compounds were detected, including 10 alcohols, 3 aldehydes, 11 alkanes, 7 alkenes, 3 ketones, 1 ester, 2 furans, 2 acids. Alkanes were the most abundant class of compounds, accounting for 60.971%, 71.393% and 78.788% of the total volatile compounds for the samples stored in 2009, 2012 and 2015, respectively. Undecane was the most represented alkanes, which accounted for 50.164%, 58.892% and 63.655% of the total volatile compounds for the samples collected in 2009, 2012 and 2015, respectively. Alcohols followed alkanes in abundance, and aldehydes were the third. Alkene, ketones, esters and other volatile compounds were present in low amounts.

In steamed bread samples, 33 volatile compounds were detected, including 11 alcohols, 8 aldehydes, 5 alkanes, 4 ketones, 3 esters and 2 furans. Alcohols became the dominant type of compound after steamed bread processing, accounting for 68.647%, 68.355% and 61.796% of the total volatile compounds from 2009, 2012 and 2015, respectively. Ethanol was the key alcohols, which accounted for 45.111%, 47.229% and 43.184% of the total volatile compounds from 2009, 2012 and 2015, respectively. This result was in accordance with the previous studies [13,20,26], which reported that ethanol was most abundant in steamed bread samples. Aldehydes followed alcohols in abundance and were followed by alkanes. Ketone and ester volatile compounds were present in low amounts, whereas alkenes were not detected in steamed bread. The alcohols, ketones and esters produced a sweet and fruity character and aroma [24].

Among all of the volatile compounds detected, 11 compounds were common in both wheat flour and steamed bread samples (Table 1). These 11 compounds included five alcohols, i.e., ethanol, 1-pentanol, 1-hexanol and 1-octen-3-ol. The relative amount of ethanol in steamed bread was 20.0, 36.7 and 77.1 times greater than that in wheat flour from 2009, 2012 and 2015, respectively. 1-Pentanol and 3,5-octadien-2-ol were more abundant in flour than in steamed bread. 1-Hexanol, 1-octen-3-ol and dimethyl-silanediol were less abundant in flour than in steamed bread. Other alcohols, such as 2-methyl-1-decanol, 2-buthyl-1-octanol, 1-hexadecanol and 2-methyl-1-hexadecanol, were only detected in wheat flour, and in contrast, 2-methyl-1-propanol, 3-methyl-1-butanol, 1-heptanol, 1-octanol, (E)-3-nonen-1-ol and phenylethyl alcohol were only detected in steamed bread. Due to the sensitive perception of odor, alcohols were the major source of the aroma in steamed bread and give a pleasant aroma that can be described as sweet, floral or fruity.

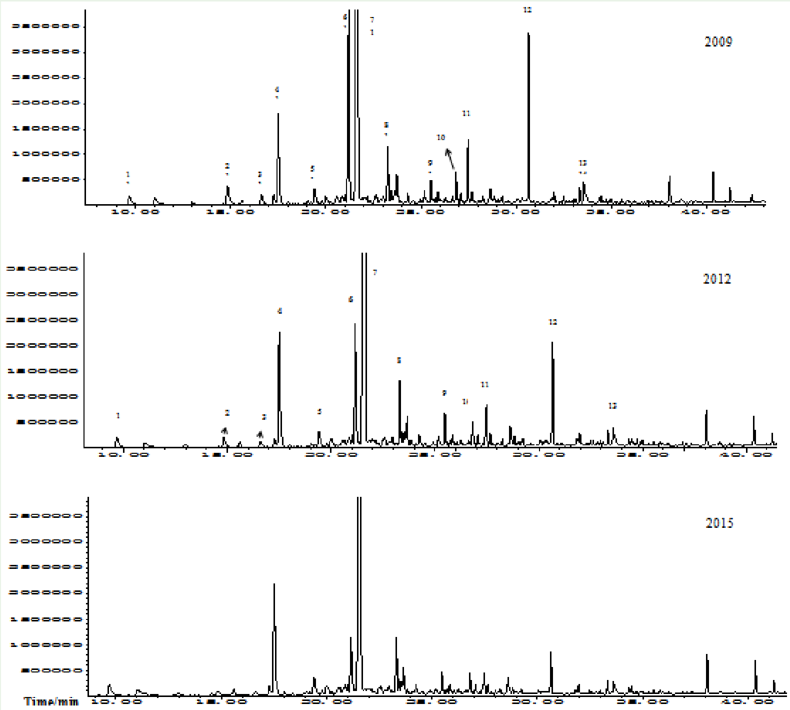

Figure 1: TIC chromatograms of volatile compounds in wheat flour detected by SPME/GC-MS.

Note: Tipical components are as follows: 1 Acetone; 2 Ethanol; 3 Pentanal; 4 Decane; 5 Toluene; 6 Hexanal; 7 Undecane; 8 1-Methoxy-2-propanol; 9 Tetradecane; 10 2-Pentyl-furan; 11 1-Pentanol; 12 1-Hexanol; 13 Acetic acid

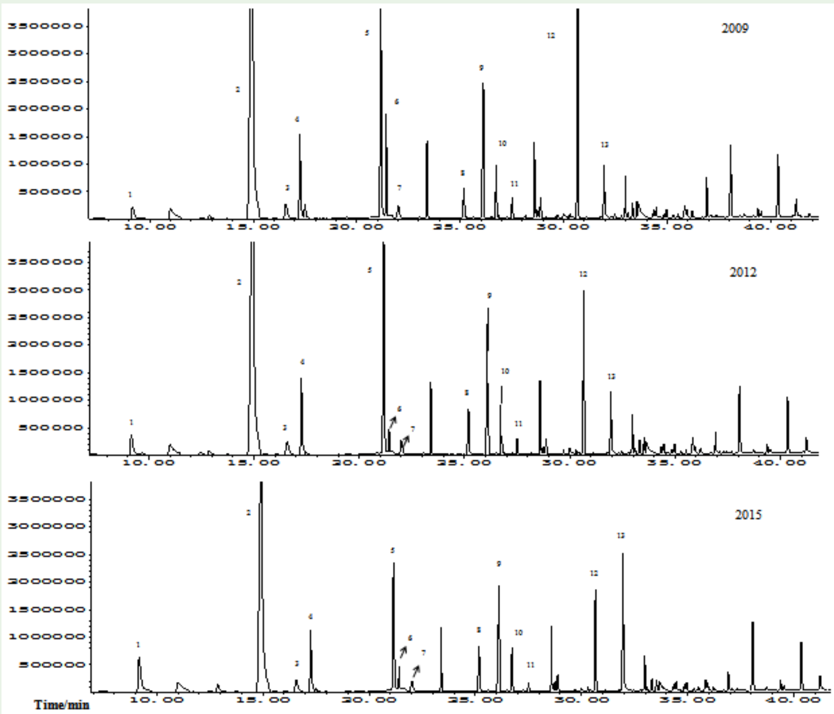

Figure 2: TIC chromatograms of volatile compounds in steamed bread detected by SPME/GC-MS.

Note: Tipical components are as follows: 1 Octane; 2 Ethanol; 3 Acetic acid ethenyl ester; 4 Decane; 5 Hexanal; 6 Undecane; 7 1-Methoxy-2-propanol; 8 Heptanal; 9 3-Methyl-1-butanol; 10 2-Pentyl-furan; 11 1-Pentanol; 12 1-Hexanol; 13 Nonanal

Table 1: Mean values of volatile compounds identified in wheat flour and steamed bread as affected by wheat storage time.

Chemical group	No.	Compounds	RT(min)	CAS number	Relative content (% peak area)					
					Wheat flour			Steamed bread		
					2009	2012	2015	2009	2012	2015
Alcohols	1	Ethanol	14.85	64-17-5	2.258 a	1.286 b	0.560c	45.111 b	47.229 b	43.184 c
	2	2-Methyl-1-decanol	20.88	18675-24-6	0.211 b	0.293 a	0.218 b			
	3	2-Methyl-1-propanol	22.01	78-83-1				1.036 c	1.1977 a	1.158 b
	4	2-Buthyl-1-octanol	22.13	18675-24-6	0.265 a	0.142 c	0.194 b			
	5	3-Methyl-1-butanol	26.2	123-51-3				8.089 b	8.908 a	8.057 b
	6	1-Pentanol	27.48	71-41-0	2.894 a	2.263 b	1.511 c	0.971 a	0.737 b	0.480 c
	7	1-Hexanol	30.66	111-27-3	7.212 a	4.432 b	2.155 c	10.310 a	7.344 b	5.776 c
	8	3,5-Octadien-2-ol	32.48	69668-82-2	0.313 a	0.216 b	0.185 b	0.159 a	0.144 a	0.062 b
	9	2-Methyl-1-hexadecanol	32.63	2490-48-4	0.159 b	0.184 a	0.130 c			
	10	1-Octen-3-ol	33.33	3391-86-4	0.729 a	0.688 a	0.718 a	0.649 b	0.621 b	0.713 a
	11	1-Heptanol	33.55	111-70-6				0.758 a	0.750 a	0.713 a
	12	1-Hexadecanol	34.74	36653-82-4	0.179 b	0.247 a	0.147 c			
	13	1-Octanol	36.22	111-87-5				0.338 a	0.255 b	0.245 b
	14	(E)-3-Nonen-1-ol	39.38	10339-61-4				0.409 b	0.432 b	0.536 a
	15	Phenylethyl alcohol	44.75	60-12-8				0.818 a	0.737 b	0.842 a
	16	1-Methoxy-2-propanol	23.31	107-98-2	2.603 c	3.108 a	3.034 b			
Total (%)					18.823	12.859	8.852	68.647	68.355	61.796
Aldehyde	17	Pentanal	16.6	110-61-3	0.956 a	0.667 b	0.492 c			
	18	Hexanal	21.16	66-25-1	12.564 a	6.622 b	3.908 c	11.392 b	12.111 a	8.721 c
	19	Heptanal	25.1	111-71-7				1.585 c	2.502 b	2.866 a
	20	Octanal	28.76	124-13-0				0.254 c	0.291 b	0.566 a
	21	(Z)-2-heptenal	29.99	57266-86-1				0.182 b	0.236 a	0.231 a
	22	Nonanal	31.98	124-19-6	0.422 b	0.427 b	0.455 a	2.306 c	2.670 b	8.306 a
	23	(E)-2-octenal	33.1	2548-87-0				0.237 a	0.246 a	0.188 b
	24	Benzaldehyde	35.84	100-52-7				0.733 c	0.926 a	0.889 b
	25	(Z)-2-nonenal	35.96	60784-31-8				0.431 b	0.367 c	0.565 a
Total (%)					13.942	7.716	4.855	17.119	19.35	22.332
Alkane	26	Octane	9.2	111-65-9				1.309 c	2.219 b	5.004 a
	27	Nonane	12.87	111-84-2				0.328 c	0.495 b	1.027 a
	28	2,2,4,6,6-Pentamethyl heptane	15.6	13475-82-6	0.433 b	0.434 b	0.582 a			
	29	Decane	17.5	124-18-5	5.854 c	7.175 b	8.982 a	1.029 a	0.113 c	0.353 b
	30	Toluene	19.41	108-88-3	1.145 c	1.212 b	1.600 a			
	31	2,6-Dimethyldecane	20.57	13150-81-7	0.343 b	0.335 b	0.422 a			
	32	Undecane	21.01	1120-21-4	50.164 c	58.892 b	63.655 a	3.346 a	0.764 b	0.966 c
	33	Dodecane	21.64	112-40-3	0.278 c	0.351 b	0.408 a			
	34	2,6,10-Trimethyl-dodecane	22.49	3891-98-3	0.413 b	0.420 b	0.502 a			
	35	3-Ethyl-3-methyl heptane	22.59	17302-01-1	0.512 b	0.461 c	0.616 a			
	36	Tetradecane	25.48	619-59-4	0.937 c	1.259 a	1.134 b			
	37	5-Ethyl-5methyl-decane	25.85	17312-74-2	0.443 b	0.414 c	0.482 a			
	38	Tridecane	28.85	619-50-5	0.449 a	0.441 a	0.393 b			
	39	1-Nitro-hexane	34.95	646-14-0				0.406 c	0.502 b	0.583 a
Total (%)					60.971	71.393	78.788	6.418	4.094	7.933

Alkene	40	(Z)-9-methyl-2-undecene	23.66	74630-45-8	0.742 c	0.873 b	1.070 a			
	41	4-Methyl-undecane	23.73	2980-69-0	0.265 a	0.140 c	0.165 b			
	42	2-Methyl-undecane	23.85	7045-71-8	0.174 c	0.240 b	0.276 a			
	43	3-Methyl-undecane	24.25	1002-43-3	0.426 c	0.577 b	0.666 a			
	44	D-Limonene	25.72	5989-27-5	0.191 c	0.222 b	0.305 a			
	45	(E)-7-methyl-3-undecene	25.93	74630-53-8	0.139 a	0.151ab	0.158 a			
	46	1-Tridecene	27.07	2437-56-1	0.405 b	0.469 a	0.460 a			
Total (%)					2.341	2.671	3.1	0	0	0
Ketones	47	Acetone	9.68	67-64-1	1.162 c	1.299 b	1.857 a			
	48	2-Butanone	12.98	78-93-3	0.311 c	0.368 b	0.454 a			
	49	2-Heptanone	25.17	110-43-0	0.530 a	0.415 b	0.280 c			
	50	2-Octanone	28.66	111-13-7				0.349 a	0.268 b	0.203 c
	51	3-Hydroxy-2-butanone	28.88	513-86-0				0.998 b	0.774 c	1.086 a
	52	2-Methyl-3-octanone	29.7	923-28-4				0.156 a	0.160 a	0.095 b
	53	6-Methyl-5-hepten-2-one	30.31	110-93-0				0.196 b	0.197 b	0.230 a
Total (%)					2.003	2.082	2.591	1.698	1.4	1.615
Ester	54	Ethyl acetate	12.49	141-78-6	0.083	T	T	0.101 c	0.376 a	0.246 b
	55	Acetic acid ethenyl ester	16.56	108-05-4				1.767 b	1.632 c	1.818 a
	56	Hexanoic acid ethyl ester	26.86	123-66-0				0.151 a	0.107 b	0.054 c
Total (%)					0.083	T	T	2.019	2.115	2.118
others	57	2-Ethyl-furan	15.48	3208-16-0	0.135 a	0.085 c	0.120 b			
	58	2-Pentyl-furan	26.82	3777-69-3	1.199 a	1.096 b	0.976 c	2.351 c	3.130 a	2.550 b
	59	Acetic acid	33.63	64-19-7	1.331 a	1.067b	0.157 c	1.748 a	1.556 c	1.656 b
	60	Hexanoic acid	43.29	142-61-1	1.173 a	1.030b	0.561 c			
Total (%)					3.837	3.279	1.814	4.098	4.686	4.206

Some alcohols originated from the wheat flour, whereas others were formed during the dough fermentation process. The loss and formation of alcohols in steamed bread processing are not clear. Evaporation, dissolution, or transformations of alcohols during the steaming process are expected.

Aldehydes and ketones could also endow steamed bread with a strong aroma. According to Liu et al. [14], octanone and nonanal both possessed unique aromas. Hexanal and nonanal were commonly detected in flour and steamed bread. Pentanal was only detected in wheat flour, and heptanal, octanal, (Z)-2-heptenal, (E)-2-octenal, benzaldehyde and (Z)-2-nonenal were only detected in steamed bread. In our study, acetone, 2-butanone, and 2-heptenone were only detected in wheat flour. Octanones, including 2-octanone and 2-methyl-3-octanone, which have different fragrances and fruit-like aromas, 3-hydroxy-2-butanone, and 6-methyl-5-hepten-2-one, were only detected in steamed bread.

Alkanes and alkenes were more abundant in wheat flour than in steamed bread. Decane and undecane were the only two alkanes detected in both flour and steamed bread. The relative contents of alkanes occupied 60.971%, 71.393% and 78.788% of the total volatile compounds in flour from 2009, 2012 and 2015, respectively, and were reduced to 6.418%, 4.094% and 7.933% in steamed bread. Seven alkenes were detected in flour, but none were found in steamed bread. Alkanes and alkenes are associated with lipid oxidation and with flavors such as grassy, fatty and soapy. The more lipid oxidation and breakdown products there are, the more likely the cereal is to have a rancid and off-flavor [23].

Ethyl acetate was detected in trace amounts in the wheat flour from 2009. No other esters were detectable. Three esters including ethyl acetate, acetic acid ethenyl ester and hexanoic acid ethyl ester were detected in steamed bread. Generally, esters are mainly produced by esterification reactions between volatile acids and alcohols. 2-pentyl-furan, acetic acid and were detectable in both wheat flour and steamed bread. 2-ethyl-furan and hexanoic acid were detected in flour but not in steamed bread. The content of 2-pentyl-furan was reported to increase during the cooking process by Beleggia et al.and Kim et al. [8,13], which might be attributed to fatty acid oxidation [8,27].

Storage time effect

Storage time had significant effects on volatile compounds in wheat flour (Table 1). Alcohols, aldehydes, and organic acids increased, whereas alkanes, alkenes, and ketones decreased with storage time. Furans and the oxime showed no trends. Alcohols in the flour from wheat harvested in 2015 represented 8.852% of the total volatile compounds. They increased to 12.859% in the flour from 2012 wheat and to 18.823% in the flour from 2009 wheat. The increasing trend of ethanol, 1-pentanol, 1-hexanol and 3, 5-octadien-

2-ol is obvious as the storage time increased. Aldehydes in the flour from 2015 wheat represented 4.855% of the total volatile compounds. They increased to 7.716% in the flour from 2012 wheat and to 13.942% in the flour from 2009 wheat. The increasing trend of pentanal and hexanal with storage time was significant. As inferred from Table 1, hexanal increased significantly in wheat samples in the order 2015<2012<2009, which expected that wheat samples had higher oxidation compounds. This result was very interesting and no similar significance was observed so far. Organic acids were also showed a slight increase as the storage time increased, although they were lower in abundance. Alkanes in the flour from 2015 wheat represented 78.788% of the total volatile compounds, which decreased to 71.393% in the 2012 flour and to 60.971% in the 2009 flour. Alkenes, ester and furans were lower in amounts and varied slightly with storage time. Both the increases of alcohols, aldehydes and organic acids and the deceases of alkanes demonstrated that the wheat stored in our laboratory had undergone slight aging. As the storage time increased, the increase in alcohols could be attributed to higher sugars levels avilable for fermentation, resulting from starch degradation.

The effect of storage time on volatile compounds of steamed bread was not as significant as that in wheat flour. Alcohols increased considerably in steamed bread, accounting for 61.796% of the total volatile compounds in the flour from 2015 wheat, 68.355% in the flour from 2012 wheat, and 68.647% in the flour from 2009 wheat. Obviously, the increases in alcohols resulted from the fermentation of dough in the bread making process. As shown in Table 1, ethanol, 1-hexanol, and 1-pentanol were the most abundant, which agreed with the results of Kim et al. and Wu et al. [13,20], who reported the most abundant alcohols to be these 3 compounds in all different types of steamed breads.

More aldehydes were detected in steamed bread than in wheat flour. They occupied a large proportion of total volatile compounds, in which hexanal followed by nonanal was the most abundant. The results were in agreement with a previous study, which reported that hexanal was the most abundant aldehyde in pasta samples [8]. With increasing storage time, hexanal showed a significant increase, whereas nonanal exhibited a marked decrease. Pentanal was only observed in wheat flour and showed a slightly increasing trend with storage time. Pentanal has also been found in rice with an increasing trend [28]. Aldehydes were probably being synthesized from oxidative reactions. Some aldehydes, such as hexanal, nonanal, and octanal, universally originate from the degradation of unsaturated fatty acids, and the increased content could be due to enzymatic or thermal oxidation of the lipids [8,28,29].

Five types of alkane, i.e., octane, nonane, decane, undecane and 1-nitro-hexane, were detected in steamed bread, and 11 types of alkanes were detected in wheat flour. It seems that most of the alkanes detected in wheat flour were oxidized during the bread making process. Octane, nonane, and 1-nitro-hexane, which were not detected in wheat flour, were produced in the steamed bread making process. (Z)-9-methyl-2-Undecene, 3-methyl-undecane and 1-tridecene were the most abundant alkenes. A slight decreasing trend of alkenes was observed as the storage time increased.

Three types of ketones were found in wheat flour, and 4 different ketones were detected in steamed bread. It is believed that the ketones in wheat flour are converted into 4 different ketones in the bread making process and give a pleasant flavor to steamed bread. According to Bryant (2011) [23], ketones could be responsible for a pleasant aroma in rice, including banana-like, fruity, caramel-like, and nutty aromas. In wheat flour, acetone and 2-butanone showed a decrease and significant differences ($p<0.05$) over time, whereas 2-heptanone showed an increase and significant differences. In steamed bread, 2-octanone showed an increase and significant differences, whereas 3-hydroxy-2- butanone had an unstable variation. However, significant differences were also found between storage years. 2-methyl-3-octanone and 6-methyl-5-hepten-2-one changed slightly during different years.

Ethyl acetate was detected in both wheat flour and steamed bread. For wheat flour, ethyl acetate was the only ester, and it was found in only trace amounts in the samples collected in the years 2012 and 2015. As the storage time increased, the relative content increased to 0.083% for the samples collected in 2009. For steamed bread, ethyl acetate and acetic acid ethenyl ester had an unstable variation, but significant differences were also found. 2-pentyl-furan and acetic acid were detected in all samples. 2-pentyl-furan was found to increase in wheat flour, whereas in steamed bread, it first increased and then decreased with storage. A similar variation of 2-pentyl-furan in rice storage was found by Tananuwong and Lertsirri (2010) [28] who suggested that the increase of the content could also due to the cumulative effect of slower oxidative degradation of lipids. Acetic acid showed an initial decrease followed by an increase as the storage time increased, for which significant differences were also found in all samples. Furans, including 2-ethyl-furan and 2-pentyl-furan, might be generated from the complex process of Maillard reactions [19,24](Feng et al. 2011, Raffo et al. 2015), the derivatives of which are usually described as having green-beany, sweet, roasted, caramel, malty or chocolate-like odor [19,21,30,31].

Conclusions

A total of 60 volatile compounds were detected by GC-MS combined with SPME in wheat flour and steamed bread. They include alcohols, aldehydes, alkanes, alkenes, ketones, esters, furans, acids and oxime. Overall, 39 volatile compounds were detected in flour, and 33 were found in steamed bread. With aging, wheat flour was characterized by high contents of undecane, 1-hexanol and decane, while steamed bread .was characterized by high contents of ethanol, hexanal and 1-hexanol.

Before this study, we had a preliminary experiment to analyzed the each sample right after harvesting in 2009, 2012 and 2015, and the results showed similar levels and tiny differences of volatile compound, so it's considerd that different weather environments didn't affect chemical compositions in wheat kernels. This study demonstrated that storage do have an affection on volatile compounds. The results showed that a steady increase in the alcohol, aldehyde and organic acid contents and decreases in alkane, alkene and ketones during wheat storage were indicators of wheat aging. In the fermentation and steaming processes, the type and relative amounts of alcohols and aldehydes varied significantly. However, no obvious changes were found among different storage years, which demonstrate that the aged wheat would not affect the flavor of steamed bread. These findings will provide some key information on traditional Chinese fermented wheat food production and help consumers distinguish the quality of steamed bread.

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