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Research Article

Analysis of Volatile Components in *Tremella fuciformis* by Electronic Nose Combined with GC-MS

Lijun Fu,[1] Jing Tian,[2,3] Li Liu,[1] Yongzheng Ma,[1] Xiumin Zhang,[1] Changyang Ma,[3,4] Wenyi Kang,[2,3,4] and Yong Sun[1]

[1]*Beijing Academy of Food Sciences, Beijing 100050, China*
[2]*Kaifeng Key Laboratory of Functional Components in Health Food, Kaifeng 475004, China*
[3]*National R and D Center for Edible Fungus Processing Technology, Henan University, Kaifeng 475004, China*
[4]*Joint International Research Laboratory of Food and Medicine Resource Function, Kaifeng 475004, Henan Province, China*

Correspondence should be addressed to Changyang Ma; macaya1024@sina.com, Wenyi Kang; kangweny@hotmail.com, and Yong Sun; sy183509@163.com

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In order to quickly evaluate the quality of *Tremella fuciformis*, the volatile components of *T. fuciformis* from 4 provinces in China, including Hebei, Henan, Fujian, and Sichuan, were analyzed by electronic nose combined with gas chromatography-mass spectrometry (GC-MS), and the key aroma compounds were determined by relative odor activity value (ROAV). The results showed that the electronic nose combined with the principal component analysis method could distinguish the samples from four regions with good discrimination. At least 117 volatile components were detected in *T. fuciformis* by GC-MS and a total of 58, 59, 62, and 55 volatile components were identified from Hebei, Henan, Fujian, and Sichuan, respectively, of which there were 18 common components. The volatile components in *T. fuciformis* were mainly hydrocarbons, followed by aldehydes, acids, and esters, while acetic acid and hexanal were relatively rich in *T. fuciformis*. Based on the ROAV, 8 key components affecting the aroma of *T. fuciformis* strongly were found. Among them, hexanal, nonanal, and pentanal were the common components of *T. fuciformis*, while butyrolactone, 1-octen-3-ol, and 2-carene were the unique key aroma components of *T. fuciformis* in Hebei Province. Besides, octanal and butyrolactone were the special key components absent in the Sichuan and Henan samples, respectively.

1. Introduction

Edible fungi are rich in species and contain more nutrients, which have broad research prospects and potential application value in healthy food and medicine [1–3]. *Tremella fuciformis*, known as white fungus or snow fungus, mainly grows in the subtropical zone, as well as the tropical zone, temperate zone, and frigid zone [4]. As recording about a traditional and valuable edible fungus in China, *T. fuciformis* is rich in protein, amino acids, crude fiber, trace elements, and other nutrients and has the functions of nourishing body fluid and lungs, tonifying the brain and heart, moisturizing skin, antitumor, treating chronic bronchitis, and postpartum weakness [5–12].

Usually, consumers mainly use their own olfactory systems with less reliability and more subjectivity to evaluate the sensory quality of *T. fuciformis*. At present, GC-MS and other methods are often used to detect its volatile components [13], but the sensory evaluation is not subjective, with individual differences, abstraction, and other shortcomings. An electronic nose is often used to simulate the human olfactory system, with the characteristics of high automation, low operating cost, short detection time, and good repeatability. And, it can be directly applied to the rapid odor determination of most substances and has been widely applied in the field of internal quality detection of agricultural products [14]. The combined application of the electronic nose and GC-MS can well realize the comprehensive analysis of volatile components in samples [15–17]. In this paper, electronic nose and GC-MS were used to detect and analyze the volatile components of *T. fuciformis* collected from four different regions, and the differences among the regions would be analyzed based on the compound content and ROAV value. The research on the volatile components of *T. fuciformis* could provide scientific and theoretical guidance for inspectors to analyze the quality and a reference for consumers to choose suitable products, benefiting the market of *T. fuciformis*.

2. Materials and Methods

2.1. Materials

2.1.1. Instruments and Equipment. Instruments and equipment used were as follows: SuperNose-14 electronic nose (ISENSO Inc., USA), HH-S4 digital thermostatic water bath (Kunlun Ultrasonic Instruments Co., Ltd, China), multi-function grinder (Yongkang Bo'ou Hardware Products Co., Ltd., China), GCMS-QP2010UL GC-MS (Shimadzu Inc., Japan), and AB135-S electronic balance (Sartorius Scientific Instruments (Beijing) Co., Ltd., China). The Unscrambler X 10.4 statistical analysis software (CAMO Inc., Norway).

2.1.2. Samples. The *T. fuciformis* was commercially available from Fujian, Henan, Sichuan, and Hubei provinces of China, the specific origin information of different batches of *T. fuciformis* is shown in Table 1. The research group only selected the samples from Hebei, Henan, Fujian, and Sichuan provinces because the output of *T. fuciformis* in these four provinces has a large yield and high quality. In the same province, we selected samples from different urban areas and different brands, which are representative. Among them, *T. fuciformis* from Gutian in Fujian is the most famous.

Table 1: Origin regions of *T. fuciformis*.

No.	City, province
1	Ningde, Fujian
2	Ningde, Fujian
3	Datian, Fujian
4	Ningde, Fujian
5	Ningde, Fujian
6	Gutian, Fujian
7	Ningde, Fujian
8	Ningde, Fujian
9	Datian, Fujian
10	Gutian, Fujian
11	Gutian, Fujian
12	Ningde, Fujian
13	Ningde, Fujian
14	Gutian, Fujian
15	Ningde, Fujian
16	Zhangzhou, Fujian
17	Ningde, Fujian
18	Ningde, Fujian
19	Putian, Fujian
20	Gutian, Fujian
21	Gutian, Fujian
22	Ningde, Fujian
23	Gutian, Fujian
24	Xiamen, Fujian
25	Ningde, Fujian
26	Putian, Fujian
27	Sanmenxia, Henan
28	Zhengzhou, Henan
29	Shangqiu, Henan
30	Xinxiang, Henan
31	Xinxiang, Henan
32	Luoyang, Henan
33	Longfeng, Henan
34	Longfeng, Henan
35	Xinxiang, Henan
36	Guangyuan, Sichuan
37	Guangyuan, Sichuan
38	Tongjiang, Sichuan
39	Qingchuan, Sichuan
40	Jianyang, Sichuan
41	Bazhong, Sichuan
42	Tongjiang, Sichuan
43	Cangzhou, Hebei
44	Hebei
45	Cangzhou, Hebei
46	Langfang, Hebei
47	Langfang, Hebei
48	Cangzhou, Hebei
49	Langfang, Hebei
50	Cangzhou, Hebei

2.2. Experimental Methods

2.2.1. Electronic Nose Detection. The odor of *T. fuciformis* was determined by the modified method [18–21]. The powder of *T. fuciformis* (5.0 g) was put in the headspace bottle, and the injection needle was inserted into the headspace vial at room temperature.

2.2.2. GC-MS Testing. The volatile components of *T. fuciformis* [22–24] were determined by the GC-MS. The GC-MS condition was a DB-5MS capillary column ($0.1\,\mu m \times 30.0\,m \times 250\,\mu m$). The temperature of the program was as follows: the initial column temperature was 50°C and the temperature was raised to 180°C at the rate of 5°C/min, kept for 2 minutes, then was raised to 120°C at the rate of 8°C/min, kept for 2 minutes, and raised to 220°C at 5°C/min for 3 minutes. The total flow is 7.0 mL/min while the column flow is 1.00 mL/min. The temperature of the ion source of the mass spectrometer was set at 230°C and the interface temperature was 250°C. The MS scan range was 20~450 *m/z*.

2.2.3. Identification of Compounds. For the qualitative and quantitative analysis of volatile compounds, the National Institute of Standards and Technology (TNIST) mass spectral library was used for compound identification (similarity between the peaks ≥85%), and the peak area normalization method was adopted to calculate the relative content of each volatile component. The retention time and MS were used for qualitative analysis of volatile components in the samples.

2.2.4. Evaluation of Volatile Aroma Substances. The relative odor activity value (ROAV) was used to evaluate the contribution of volatile components to the total aroma of samples [25]. The ROAV calculation formula was as follows:

$$\mathrm{ROAVi} = \frac{\mathrm{Cri}}{\mathrm{Crstan}} \times \frac{\mathrm{Tstan}}{\mathrm{Ti}} \times 100. \quad (1)$$

C_{ri} T_i were relative contents of volatile components/% and odor threshold/(μg/kg); C_{rstan} and T_{stan} were the relative content/% and odor threshold/(μg/kg) of the components contributing most to the overall aroma of the sample, respectively.

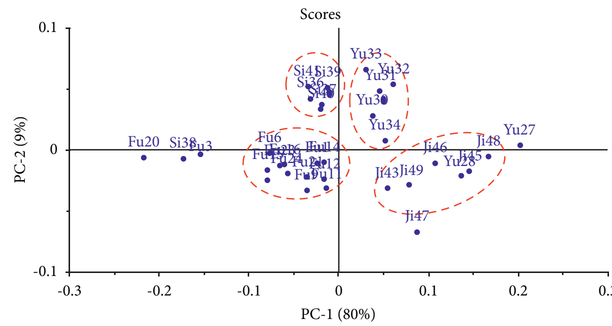

Figure 1: PCA result of *T. fuciformis* from different regions.

3. Results and Discussion

3.1. The Results of *T. fuciformis* from Different Regions Based on Electronic Nose

3.1.1. PCA Analysis of T. fuciformis. Principal component analysis (PCA) is a common method which could extract the characteristic information of samples from complicated information through reducing dimensions and data transformation without loss of original information. The factors with the large and leading contribution rates extracted from the electronic nose sensor data of *T. fuciformis* originating from four different regions (Figure 1) could inhibit the differences in the samples among different regions in the PCA distribution map [26, 27].

Note: "Fu, Si, Yu and Ji" represent "Fujian, Sichuan, Henan and Hebei," respectively, and the numbers represent different sample batches.

In Figure 1, the cumulative variance contribution rate of PC-1 (80%) and PC-2 (9%) reached 89%, which indicated the two principal components could retain most of the information of these samples and was sufficient to analyze the similarity relationship between samples [28]. It could be seen that the spatial distribution of principal components of *T. fuciformis* samples was relatively scattered, and those from each origin region were relatively concentrated and separated. Therefore, the two principal components could distinguish the samples from the four regions well. The samples from Hebei and Henan Province were located in the upper right and lower right of Figure 1, respectively, while those from Fujian Province and Sichuan Province were located in the upper left and lower left, respectively. These results also confirmed the differences of *T. fuciformis* from different regions.

Note: "C" represents the gas sensor and numbers indicate the different sensor types.

3.1.2. Loading Analysis of T. fuciformis. Loading analysis is a similar method with PCA to extract the principal components from the origin data. However, the PCA algorithm is special for sample analysis, while loading analysis is for sensors of electronic noses. In this part, loading analysis was used to analyze the contribution of each sensor to the distinguishment of *T. fuciformis* (Figure 2) [26, 29]. It could be seen that C_1, C_3, C_4, C_5, C_6, C_8, and C_9 sensors contributed a large proportion to the 1st principal component for the *T. fuciformis*.

3.2. GC-MS Results of *T. fuciformis*

3.2.1. Components Analysis of T. fuciformis. The volatile components of *T. fuciformis* from four regions were analyzed by GC-MS in Table 2.

A total of 117 volatile components, including 68 hydrocarbons, 12 esters, 10 alcohols, 10 aldehydes, 7 acids, and 10 other compounds, were detected from *T. fuciformis*. However, the relative contents of acids and aldehydes were the highest, which was consistent with Li Xiang's research on *T. fuciformis* and bag cultivated *T. fuciformis* [13]. Moreover, 58, 59, 62, and 55 volatile components were detected from Hebei, Henan, Fujian, and Sichuan Provinces, respectively. Within them, there were a total number of 18 common components. However, a variety of volatile components were detected in *T. fuciformis* for the first time, such as eucalyptol, 2-butyl-1-octanol, 2-ethyl-1-pentanol, benzeneacetaldehyde, 4-methylvaleric acid, gamma-butyrolactone, n-hexyl formate, bute hydrocarbon, hydroxylamine, 2-carene have not been reported.

Among the 68 hydrocarbon compounds of *T. fuciformis*, most of them belonged to the saturated hydrocarbons, such as 5-methyltetradecane, bute hydrocarbon, 2, 6, 10, 14-tetramethylhexadecane, 4, 6-dimethyldodecane, and 2, 6, 10-trimethyldodecane. However, these compounds had generally low relative content in the samples with high threshold values, which contributed less to the overall odor of *T. fuciformis*. In contrast, unsaturated hydrocarbons such as (5E)-5-octadecene, camphene, and 2-carenecontribute more for its relatively low thresholds [34]. Besides, no unique compounds with high relative content (≥1) were found for the samples from different regions.

Esters are usually one type of compound with a fruit aroma and contribute to the overall aroma of *T. fuciformis* [35]. A total of 12 ester compounds were detected from *T. fuciformis*. Of them, butyrolactone (6.08%) and γ-butyrolactone (2.79%) were the top 2 esters of Hebei samples, while γ-butyrolactone, heptadecyl trifluoroacetate, and hydrazinecarboxylic acid, ethyl ester were the unique volatile constituents. For the Sichuan samples, the unique ester components included sulfurous acid, 2-ethylhexyl isobutyl ester, 2-ethylhexyl acrylate, hexatriacontyl

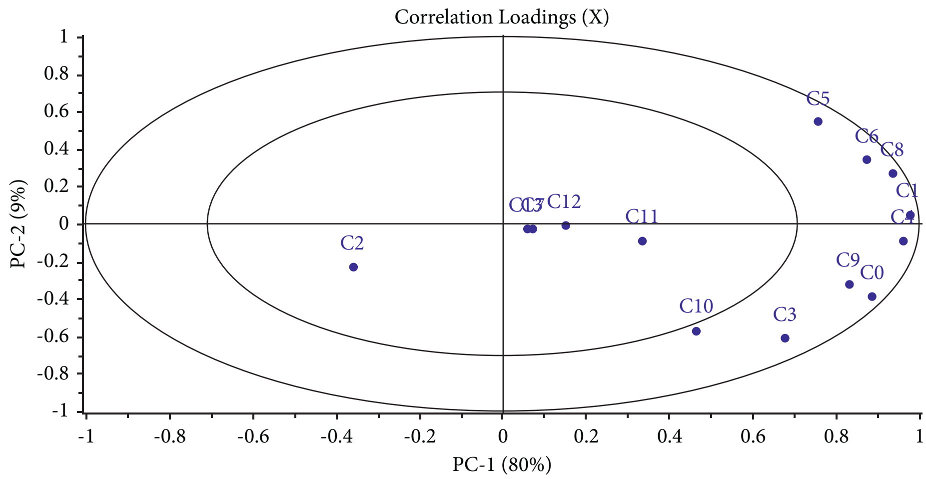

Figure 2: Loadings analysis of *T. fuciformis* from different regions.

Table 2: Composition of volatile components of *T. fuciformis*.

Number	Compound name	Molecular formula	Relative content/% Hebei	Henan	Sichuan	Fujian	RI value	Literature
			Alcohols					
1	Pentyl alcohol	$C_5H_{12}O$	1.22	1.12	—	0.95	761	[30]
2	2-Ethyl-1-decanol	$C_{12}H_{26}O$	0.02	—	—	—	1393	
3	1-Hexanol	$C_6H_{14}O$	0.57	—	—	0.02	860	[20]
4	1-Octen-3-ol	$C_8H_{16}O$	0.38	—	—	—	969	[20]
5	Eucalyptol	$C_{10}H_{18}O$	5.00	—	—	—	1059	
6	Linalol	$C_{10}H_{18}O$	0.05	—	—	—	1082	[31]
7	Isotridecyl alcohol	$C_{13}H_{28}O$	0.01	—	—	—	1492	
8	2-Tetradecyloxyethanol	$C_{16}H_{34}O2$	—	0.01	0.03	—	1930	
9	2-Butyl-1-octanol	$C_{12}H_{26}O$	—	0.03	—	0.03	1393	
10	Isopentyl alcohol	$C_5H_{12}O$	—	—	—	0.21	697	[20]
			Aldehyde					
11	Hexanal	$C_6H_{12}O$	27.35	25.21	23.60	21.60	806	[20]
12	Furfural	$C_5H_4O_2$	0.01	0.17	—	0.02	831	
13	Heptanal	$C_7H_{14}O$	0.43	1.04	—	—	905	[20]
14	2-Furancarboxaldehyde, 5-methyl-	$C_6H_6O_2$	—	0.08	—	—	920	
15	Octanal	$C_8H_{16}O$	1.03	0.04	—	0.04	1005	[30]
16	Benzeneacetaldehyde	C_8H_8O	0.82	0.01	—	—	1081	[20]
17	Nonanal	$C_9H_{18}O$	2.58	0.19	0.07	1.06	1104	[20]
18	Benzaldehyde	C_7H_6O	0.23	0.02	—	0.08	982	[20]
19	Pentanal	$C_5H_{10}O$	5.05	0.38	0.01	0.23	707	[20]
20	2-Ethyl-1-pentanol	$C_7H_{16}O$	—	—	—	0.03	896	
			Acids					
21	Acetic acid	CH_3COOH	35.36	49.42	39.92	40.85	576	[31]
22	4-Methylvaleric acid	$C_6H_{12}O_2$	1.73	—	—	—	910	
23	Nonanoic acid	$C_9H_{18}O_2$	0.40	—	—	—	1272	
24	Octanoic acid	$C_8H_{16}O_2$	—	1.52	1.52	—	2069	[32]
25	Pentanoic acid	$C_5H_{10}O_2$	—	0.21	—	—	1161	
26	Heptanoic acid	$C_7H_{14}O_2$	—	2.01	1.33	—	1078	[30]
27	Hexanoic acid	$C_6H_{12}O_2$	—	0.69	—	3.72	1856	[32]

Table 2: Continued.

Number	Compound name	Molecular formula	Relative content/%				RI value	Literature
			Hebei	Henan	Sichuan	Fujian		
		Esters						
28	Butyrolactone	$C_4H_6O_2$	6.08	—	1.06	0.11	825	
29	gamma-Butyrolactone	$C_5H_8O_2$	2.79	—	—	—	886	
30	Heptadecyl trifluoroacetate	$C_{19}H_{35}F_3O_2$	0.52	—	—	—	1812	
31	Hydrazinecarboxylic acid, ethyl ester	$C_3H_8N_2O_2$	0.14	—	—	—	928	
32	Sulfurous acid, hexyl pentadecyl ester	$C_{21}H_{44}O_3S$	—	0.42	—	0.18	2732	
33	n-Hexyl formate	$C_7H_{14}O_2$	—	0.65	—	0.01	981	[20]
34	Docosyl pentafluoropropionate	$C_{25}H_{45}F_5O_2$	—	0.01	—	—	2369	
35	Sulfurous acid, 2-ethylhexyl isobutyl ester	$C_{12}H_{26}O_3S$	—	—	0.02	—	1709	
36	2-Ethylhexyl acrylate	$C_{11}H_{20}O_2$	—	—	0.01	—	1208	
37	Hexatriacontyl pentafluoropropionate	$C_{39}H_{73}F_5O_2$	—	—	0.02	—	3761	
38	Formic acid, ethenyl ester	$C_3H_4O_2$	—	—	25.12	—	574	
39	1-Methyl-2-oxocyclohex-3-enecarboxylic acid, methyl ester	$C_9H_{12}O_3$	—	—	—	0.01	1274	
		Hydrocarbons						
40	2, 10-Trimethyldodecane	$C_{15}H_{32}$	—	0.01	0.01	0.02	1320	
41	Bute hydrocarbon	$C_{19}H_{40}$	—	0.72	—	0.03	1653	
42	3-Methylheptadecane	$C_{18}H_{38}$	—	0.02	—	—	1746	
43	3-Methylundecane	$C_{12}H_{26}$	0.03	0.02	0.04	0.03	1150	[33]
44	Dodecane	$C_{12}H_{26}$	0.15	0.09	0.10	0.30	1214	[30]
45	Tetradecane	$C_{14}H_{30}$	0.15	0.06	—	0.54	1413	[20]
46	4,6-Dimethyldodecane	$C_{14}H_{30}$	0.19	0.05	0.02	—	1285	
47	Dodecamethylcyclohexasiloxane	$C_{12}H_{36}O_6Si_6$	0.04	0.03	—	0.10	1240	
48	Heptadecane	$C_{17}H_{36}$	0.07	1.16	0.04	0.21	1711	
49	2,5-Dimethyltridecane	$C_{15}H_{32}$	—	0.01	0.02	0.02	1384	
50	6-Methyltridecane	$C_{14}H_{30}$	—	0.01	0.01	0.01	1349	
51	Octadecane	$C_{18}H_{38}$	0.02	0.29	0.03	0.07	1810	
52	10-Methylnonadecane	$C_{20}H_{42}$	—	0.01	—	—	1945	
53	Octacosane	$C_{28}H_{58}$	0.13	0.14	0.01	0.05	2804	
54	3,8-Dimethyldecane	$C_{12}H_{26}$	0.02	0.02	0.03	0.02	1086	
55	Camphene	$C_{10}H_{16}$	0.94	0.25	0.03	0.11	943	
56	Hexadecane	$C_{16}H_{34}$	0.37	0.29	0.09	0.33	1612	[20]
57	5-Methyltetradecane	$C_{15}H_{32}$	—	0.06	—	0.05	1448	
58	4-Methyltetradecane	$C_{15}H_{32}$	—	0.01	—	0.02	1448	
59	3-Methyltetradecane	$C_{15}H_{32}$	0.41	0.02	—	0.06	1448	
60	Eicosane	$C_{20}H_{42}$	0.55	0.14	0.06	0.19	2009	
61	Tetratriacontane	$C_{34}H_{70}$	0.12	0.03	—	0.01	3401	
62	4-Methylpentadecane	$C_{16}H_{34}$	0.02	0.36	—	0.08	1548	
63	2,6,10,15-Tetramethylheptadecan	$C_{21}H_{44}$	0.01	0.02	—	—	1852	
64	Nonadecane	$C_{19}H_{40}$	0.01	0.08	0.04	0.07	1910	
65	8-Hexylpentadecane	$C_{21}H_{44}$	—	0.01	0.01	0.07	2045	
66	2,2,4,6,6-Pentamethylheptane	$C_{12}H_{26}$	0.87	0.63	1.48	0.83	981	[20]
67	2,3-Dimethylundecane	$C_{13}H_{28}$	—	0.01	—	—	1185	
68	2-Bromo dodecane	$C_{12}H_{25}Br$	0.03	0.12	0.05	0.15	1446	
69	(9E)-9-octadecene	$C_{18}H_{36}$	—	0.01	—	—	1818	
70	Heptacosane	$C_{27}H_{56}$	—	0.01	—	—	2705	
71	2,6,10,14-Tetramethylhexadecane	$C_{20}H_{42}$	0.45	1.13	0.02	0.53	1753	
72	2,2,4,4,6,8,8-Heptamethylnonane	$C_{16}H_{34}$	—	0.02	—	—	1294	
73	Pentadecane	$C_{15}H_{32}$	—	0.32	0.01	—	1512	[30]
74	HMN	$C_{16}H_{34}$	0.04	—	0.03	—	1294	
75	Undecane	$C_{11}H_{24}$	0.02	—	0.04	—	1115	[20]
76	2,6,11-Trimethyldodecane	$C_{15}H_{32}$	0.02	—	0.01	—	1320	
77	11-Methyldodecane	$C_{13}H_{28}$	0.01	—	—	—	1249	
78	Heneicosane	$C_{21}H_{44}$	0.02	—	0.01	0.06	2109	
79	2-Carene	$C_{10}H_{16}$	0.01	—	—	—	948	
80	gamma-Terpinen	$C_{10}H_{16}$	0.21	—	—	—	998	
81	1-Tridecene	$C_{13}H_{26}$	1.01	—	0.02	—	1304	
82	5-Methyl-5-propylnonane	$C_{13}H_{28}$	0.02	—	0.01	—	1229	
83	2,5-Dimethyldecane	$C_{12}H_{26}$	0.03	—	0.01	—	1086	

Table 2: Continued.

Number	Compound name	Molecular formula	Relative content/%				RI value	Literature
			Hebei	Henan	Sichuan	Fujian		
84	2,4-Dimethyldecane	$C_{12}H_{26}$	0.01	—	—	—	1086	
85	Docosane	$C_{22}H_{46}$	0.01	—	0.03	—	2208	
86	Benzene, 1-methyl-2-(phenylmethyl)-	$C_{14}H_{14}$	—	—	0.02	—	1580	
87	1-Benzyl-3-methylbenzene	$C_{14}H_{14}$	—	—	0.02	—	1580	
88	Dotriacontane	$C_{32}H_{66}$	—	—	0.01	—	3202	
89	2,3,7-Trimethyldecane	$C_{13}H_{28}$	—	—	0.01	—	1121	
90	2,5-Dimethylundecane	$C_{13}H_{28}$	—	—	0.03	—	1185	
91	1-Sec-butyl-1-(2-methylbutyl)cyclopropane	$C_{12}H_{24}$	—	—	0.02	—	1062	
92	2,6,11,15-Tetramethylhexadecane	$C_{20}H_{42}$	—	—	0.01	0.02	1753	
93	4-Ethylundecane	$C_{13}H_{28}$	—	—	0.01	—	1249	
94	(5E)-5-octadecene	$C_{18}H_{36}$	—	—	0.01	0.01	1818	
95	3-Ethyl-3-methyldecane	$C_{13}H_{28}$	—	—	0.01	—	1229	
96	5-Isobutylnonane	$C_{13}H_{28}$	—	—	0.02	0.04	1185	
97	5-Butylnonane	$C_{13}H_{28}$	—	—	0.01	0.04	1249	
98	2,2-Dimethyldecane	$C_{12}H_{26}$	—	—	—	0.04	1130	
99	2-Methyltetradecane	$C_{15}H_{32}$	—	—	—	0.01	1448	
100	2-Methylhexadecane	$C_{17}H_{36}$	—	—	—	0.01	1647	
101	9-Methylnonadecane	$C_{20}H_{42}$	—	—	—	0.01	1945	
102	2-Methyl-6-propyldodecane	$C_{16}H_{34}$	—	—	—	0.01	1483	
103	Decamethylcyclopentasiloxane	$C_{10}H_{30}O_5Si_5$	—	—	—	0.01	1034	
104	Tetratetracontane	$C_{44}H_{90}$	—	—	—	0.02	4395	
105	2,2-Dimethylundecane	$C_{13}H_{28}$	—	—	—	0.27	1229	
106	4-Methyldodecane	$C_{13}H_{28}$	—	—	—	0.02	1249	
107	Undecylcyclohexane	$C_{17}H_{34}$	—	—	—	0.01	1775	
		Categories						
108	Nickel tetracarbonyl	C_4NiO_4	0.09	2.20	0.16	0.29	—	
109	4,7-Dimethylbenzofuran	$C_{10}H_{10}O$	0.02	—	—	—	1244	
110	Hydroxylamine	H_3NO	2.42	4.88	3.51	—	—	
111	4-Hexen-3-one	$C_6H_{10}O$	5.66	—	—	—	762	
112	2-Undecanone	$C_{11}H_{22}O$	—	0.16	—	—	1251	
113	Didecyl ether	$C_{20}H_{42}O$	—	0.07	—	0.03	2085	
114	Oxygen	O_2	—	3.57	—	25.26	—	
115	Carbon monoxide	CO	—	—	0.06	0.10	—	
116	p-(1-Propenyl)anisole	$C_{10}H_{12}O$	—	—	0.01	—	1190	[30]
117	2-Cyclohexen-1-one	C_6H_8O	—	—	—	0.01	873	

Note. "—"means not detected. In Table 2, the constituents marked red were first detected from *T. fuciformis*.

pentafluoropropionate and formic acid, and ethenyl ester, of which the relative content of formic acid, ethenyl ester was as high as 25.12%. These unique components identified for corresponding regions would be used to distinguish the samples from this region from other regions.

Volatile acids are usually derived from the oxidation or biosynthesis of fatty acids [36, 37]. In this research, 7 kinds of acid compounds were detected in *T. fuciformis*. Acetic acid is a common acid with a fishy smell of oil [38] and exists in *T. fuciformis* at a high relative content (35.36%~49.42%). However, due to its high aroma threshold, it has little contribution to the overall odor of *T. fuciformis*.

Volatile alcohols in plants mainly come from the decomposition of secondary hydroperoxides of fatty acids and the reduction of sugars and amino acids [36]. Most alcohols are generally floral and fruity aromas [39]. According to the above GC-MS analysis results, 10 kinds of alcohol were detected, including 7 kinds in Hebei, 3 kinds in Henan, 4 kinds in Fujian, and 1 kind in Sichuan. Not only that, the relative content of volatile alcohols was also high in the Hebei region. 2-ethyl-1-decanol, 1-octen-3-ol, eucalyptol, linalol, and isotridecyl alcohol were special to the samples of the Hebei region, while isopentyl alcohol to the samples in Fujian. These unique volatile components of different samples might be taken as a mark for the distinguishment of different regions.

Aldehyde compounds are mainly derived from fatty acid oxidation and amino acid metabolism [40], and their aroma thresholds are usually low. Therefore, it usually plays an important role in the overall aroma, although the content of aldehyde compounds is low [41]. There were 10 kinds of aldehydes in *T. fuciformis*, and 8 species were detected in Hebei province, nine in Henan province, seven in Fujian province, and three in Sichuan province. Among them, hexanal, nonanal, and pentanal were the common aldehyde volatile components of *T. fuciformis*, while 5-methyl-2-furancarboxaldehyde and 2-ethyl-1-pentanol were the unique aldehyde volatile components of Henan and Fujian provinces, respectively.

Besides, *T. fuciformis* also included phenols, ketones, furans, and so on. In addition, gases were detected in *T. fuciformis*. Because the whole detection environment was gaseous, the components in the air may have been detected in the sample, such as oxygen and carbon monoxide. But these gases are colorless and tasteless and did not affect the aroma quality of *T. fuciformis*. Among them, the detected ketones included 4-hexen-3-one, 2-undecanone, and 2-cyclohexen-1-one, and the relative content of 4-hexen-3-one, a unique component in Hebei samples, was relatively high. Nickel tetracarbonyl was the common component detected in all the 4 regions, while hydroxylamine was also detected in the samples from considerate regions except Fujian.

3.2.2. Analysis of Volatile Components of T. fuciformis among Different Regions. In Figure 3, there was no obvious difference in the types of volatile substances contained in *Tremella* among the 4 regions. The most abundant volatile component type was hydrocarbons, which were about 3 times as many as the other types. By comparing these substances among the samples from the 4 regions, it could be found that more types of hydrocarbons were detected in the *T. fuciformis* from Fujian, while more aldehyde types and acid types were detected in the Henan samples, more alcohol types from Hebei samples, and more ester from Sichuan samples.

In general, the relative contents of acid in the 4 regions (in Figure 4) were the highest of the detected volatile components, followed by aldehydes. However, the proportion varied from region to region. Also, it can be seen that the *T. fuciformis* from Henan owned more contents of acids while the Hebei samples had more aldehyde and Sichuan had more esters.

3.3. ROAV Analysis of Key Aroma Compounds. ROAV is used as one common index, which may range from 0 to 100 and reflects the aroma contribution degree of each volatile component. The higher the ROAV value of the compound, the greater the contribution of the compound to the overall odor of the sample [42–44]. By referring to the researched 29 compounds with the given aroma threshold values from relevant literature and combining, the corresponding ROAV analysis results were calculated and are shown in Table 3.

Overall, there were 8 compounds (ROAV ≥1) including 1-octen-3-ol, heptanal, octanal, nonanal, pentanal, hexanal, butyrolactone, and 2-carene, which were taken as the key aroma compounds of *T. fuciformis*. Among them, hexanal and nonanal were the common key aroma compounds and could be used as the characteristic identification components of *T. fuciformis*. As a basic product of the oxidative decomposition of linoleic acid, hexanal is a common volatile oil with the fragrance of green, grass, and fruit [51], contributing greater than the others to the overall aroma of *T. fuciformis*. Nonanal is also a common aroma compound with the fragrance of flowers, fat, and wax, and a low threshold value, and it offers people a pleasant feeling [52]. 1-Octene-3-ol, also known as agaritol with the aroma of fresh

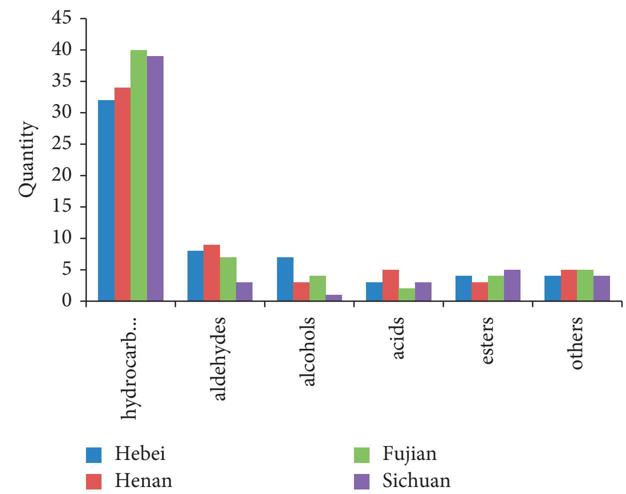

Figure 3: Volatile components types of *T. fuciformis* from different producing areas.

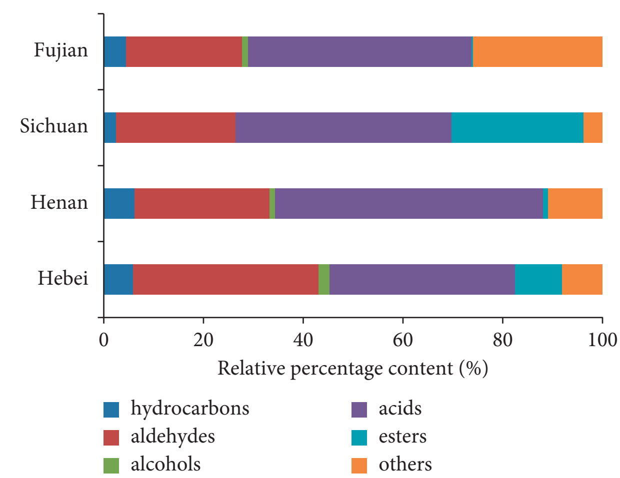

Figure 4: Relative contents of volatile compounds in *T. fuciformis*.

mushroom, licorice, and rose, was the unique key aroma compound of Hebei samples. This compound was mainly used as pharmaceutical raw materials and in aromatics [53]. Besides, butyrolactone generally has the fragrance characteristics of coconut or peach [40, 42], while heptanal has the odor of fat or fish [36]. These substances play an important role in the overall fragrance of *T. fuciformis*.

In Hebei *T. fuciformis*, all the 8 key aroma compounds were discovered, of which butyrolactone (ROAV = 100) is the compound with the highest ROAV, and it can be used as the aroma base of *T. fuciformis*, followed by hexanal, nonanal, octanal, 2-carene, 1-octen-3-ol, pentanal, and heptanal. But on the other hand, 1-octen-3-ol and 2-carene were the special compounds of these samples and could be used to distinguish the Hebei samples from the other 3 regions. The modified aroma compounds were eucalyptol, linalool, and γ-butyrolactone, which were also unique for Hebei samples. The potential aroma compound, nonanoic acid, was unique for the Hebei sample, while the other 3 compounds, acetic acid, dodecane, and hexadecane, were common for all the collected *T. fuciformis*.

Table 3: ROAV value of 29 components in *T. fuciformis* from different regions.

Number	Compound name	Aroma threshold (μG/L) [31, 45–50]	ROAV Hebei	Henan	Sichuan	Fujian
		Alcohols				
1	1-Hexanol	250	<0.1	—	—	<0.1
2	1-Octen-3-ol	1	5.5	—	—	—
3	Eucalyptol	1.3	0.22	—	—	—
4	Linalol	1.5	0.48	—	—	—
5	Pentyl alcohol	4000	<0.1	<0.1	—	<0.1
6	Isopentyl alcohol	120	—	—	—	<0.1
		Aldehydes				
7	Hexanal	4.5	87.97	100	100	100
8	Furfural	3000	<0.1	<0.1	—	—
9	Heptanal	3	2.07	6.19	—	—
10	Octanal	0.7	21.3	1.02	—	1.19
11	Benzeneacetaldehyde	4	<0.1	<0.1	—	—
12	Nonanal	1	37.34	3.39	1.33	22.08
13	Benzaldehyde	350	<0.1	<0.1	—	<0.1
14	Pentanal	20	3.65	0.34	<0.1	0.24
		Acids				
15	Acetic acid	22000	<0.1	<0.1	<0.1	<0.1
16	Nonanoic acid	3000	<0.1	—	—	—
17	Octanoic acid	500	—	—	<0.1	—
18	Pentanoic acid	3000	—	—	—	—
19	Heptanoic acid	100	—	—	0.25	—
20	Hexanoic acid	3000	—	—	—	<0.1
		Esters				
21	Butyrolactone	0.88	100	—	22.97	2.6
22	gamma-Butyrolactone	100	0.81	—	—	—
23	n-Hexyl formate	19800	—	<0.1	—	<0.1
		Hydrocarbons				
24	Dodecane	2040	<0.1	<0.1	<0.1	<0.1
25	Tetradecane	1000	<0.1	<0.1	—	<0.1
26	Hexadecane	300	<0.1	<0.1	<0.1	<0.1
27	2-Carene	0.01	14.47	—	—	—
		Others				
28	2-Undecanone	255	—	<0.1	—	—
29	p-(1-Propenyl)anisole	15	—	—	<0.1	—

Note. "—"means not detected.

The ROAV value of hexanal in the samples from Sichuan, Henan, and Hebei was 100, indicating that this component contributed the most to the aroma of tremella from these three regions. For the *T. fuciformis* of Henan province, there were 4 key aroma compounds, and hexanal was the highest, followed by heptanal, nonanal, and octanal. However, the samples from Henan province lacked butyrolactone, compared with the other three regions, so the compound could be used to distinguish other samples from Henan province. Pentanal and 2-undecanone were the modified and potential aroma compound in Henan province.

Three key volatile aroma compounds with threshold values were identified in Sichuan samples, which were hexanal, butyrolactone, and nonanal from high to low. Heptanoic acid was the modified aroma compound of *T. fuciformis*, while octanoic acid and p-(1-propenyl) anisole were the potential aroma compounds unique to Sichuan samples. On the other hand, octanal was a key aroma compound for the samples from Hebei, Henan, and Fujian, but not for the Sichuan samples.

Four kinds of key volatile aroma compounds detected in Fujian samples with the ROAV from high to low were hexanal, nonanal, octanal, and butyrolactone. The modified aroma compound was pentanal as well as Henan samples, and the potential aroma compounds special to Fujian samples were isopentyl alcohol and hexanoic acid.

4. Conclusion

The difference between *T. fuciformis* from different regions existed, and the electronic nose is a good technology to distinguish *T. fuciformis* from different regions. During the determination, the sensors of C_1, C_3, C_4, C_5, C_6, C_8, and C_9 contributed much more to distinguish the overall odor of *T. fuciformis*. Electronic nose (PCA) combined with GC-MS (ROAV) suggested that the types and contents of volatile aldehydes might contribute significantly to the aroma degree of *T. fuciformis* from different regions. In the PCA results, the samples from Hebei and Henan were distributed on the right of the origin of coordinates. On the contrary, the samples from Sichuan and Fujian were and distributed on the left. In ROAV, aldehydes from Hebei and Henan provinces had more kinds of aroma components, higher content, and higher aroma activity. 1-Octen-3-ol, heptanal, octanal, nonanal, pentanal, hexanal, butyrolactone, and 2-carene were the key aroma compounds contributing to the aroma of *T. fuciformis*. 1-Octen-3-ol, 2-carene, eucalyptol, linalool, γ-butyrolactone, and nonanoic acid were special to the Hebei samples, while octanoic acid and p-(1-propenyl) anisole were special to the Sichuan samples, as well as isopentyl alcohol and hexanoic acid were special to the Fujian samples. On the other hand, butyrolactone was the missing aroma compound for the Henan samples, while octanal was for the Sichuan samples [54].

Data Availability

All the data used are included in this paper.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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References

[1] Z. Yin, Z. Liang, C. Li, J. Wang, C. Ma, and W. Kang, “Immunomodulatory effects of polysaccharides from edible fungus: a review,” *Food Science and Human Wellness*, vol. 10, no. 4, pp. 393–400, 2021.

[2] Z. Yin, D. Sun-Waterhouse, J. Wang, C. Ma, G. I. N. Waterhouse, and W. Kang, “Polysaccharides from edible fungi Pleurotus spp: advances and perspectives pleurotus spp: advances and perspectives,” *Journal of Future Foods*, vol. 1, no. 2, pp. 128–140, 2021.

[3] Y. Zhang, D. Wang, Y. Chen et al., “Healthy function and high valued utilization of edible fungi,” *Food Science And Human Wellness*, vol. 10, no. 4, pp. 408–420, 2021.

[4] T. Ma, L. Y. Zhang, Z. Lin et al., “Analysis and evaluation on main nutritional components in different tremella products,” *Edible Fungi of China*, vol. 38, no. 11, pp. 57–60, 2019.

[5] W. X. Liu, B. Du, W. D. Ma, and T. Sun, “Study and actualities of tremella fucitormis Standards in China,” *Farm Products Processing*, vol. 02, 2015.

[6] T. J. Barzee, L. Cao, Z. Pan, and R. Zhang, “Fungi for future foods,” *Journal of Future Foods*, vol. 1, no. 1, pp. 25–37, 2021.

[7] C. Xu, J. Y. Diao, and S. M. Wang, “Recent progress in pharmacological studies of polysaccharide from tremella fuciformis berk,” *Pharmacy Today*, vol. 28, no. 03, pp. 207–210, 2018.

[8] B. B. Li, H. Long, E. H. Wu et al., “Protective effects of polysaccharides extracted from tremella on cell membrane and sugar metabolism enzymes of freeze-dried Lactobacillus plantarum,” *Modern Food Science and Technology*, vol. 37, no. 11, pp. 85–95, 2021.

[9] L. G. Liu, S. J. Ma, P. Han, B. Che, L. Lin, and Z. Y. Du, “Optimization of *extracting Tremella fuciform* polysaccharide and its protection against SDS-induced damage of HaCaT cells,” *Edible Fungi of China*, vol. 40, no. 1, pp. 97–102, 2021.

[10] J. W. Wang, D. Q. Yin, X. Y. Li et al., “Preparation of quercetin microemulsion with Tremella fuciformis polysaccharide as emulsifier,” *Chinese herbal medicine*, vol. 52, no. 02, pp. 378–385, 2021.

[11] Y. H. Wang, Q. Wu, Y. L. Chi, K. Yao, and D. Y. Jia, “Properties of crude polysaccharides extracted from Tremella fuciformis by acid, alkali and enzyme-assisted methods,” *Food Science and Technology*, vol. 44, no. 04, pp. 200–204, 2019.

[12] M. Yang, Z. Zhang, Y. He, C. Li, J. Wang, and X. Ma, “Study on the structure characterization and moisturizing effect of *Tremella* polysaccharide fermented from GCMCC5.39,” *Food Science and Human Wellness*, vol. 10, no. 4, pp. 471–479, 2021.

[13] X. Li, H. Xu, J. Deng et al., “HS-SPME/GC-MS analysis on volatile components of tilia tremella with different cultivation methods,” *Edible Fungi of China*, vol. 38, no. 01, pp. 45–50+63, 2019.

[14] D. S. Zhu, X. F. Wu, L. N. Wang Lina et al., “Studies on volatile compounds of red sea bream at cold storage by electronic nose coupled with and HS-SPME/GC-MS,” *Journal of Chinese Institute of Food Science and Technology*, vol. 16, no. 12, pp. 227–234, 2016.

[15] H. M. Zhou, S. L. Zhang, Y. F. Hao et al., “Analysis of major flavor components of Tuotuo pork, a traditional meat product iIl Liangshan, southwest China’s Sichuan, by HS-SPME-GC-MS-O combiIled with electronic nose,” *Food Science*, vol. 42, no. 2, pp. 218–226, 2021.

[16] T. T. Zhang, X. L. Guo, and X. Y. Huang, “GC-MS analysis and antioxidant and antimicrobial properties of volatile oil from flos magnoliae,” *Food Science*, vol. 37, no. 10, pp. 144–150, 2016.

[17] X. W. Yan, Y. P. Zhong, S. S. Lu, and Q. X. Meng, “Pattern recognition analysis of tieguanyin oolong tea and ruanzhi oolong tea based on the volatile components and chemometrics methods,” *Food Research and Development*, vol. 40, no. 20, pp. 155–163, 2019.

[18] J. H. Lu, Y. L. Zhang, J. Liang, L. Zhang, and H. W. Zhang, “Effects of three drying processes on volatile substances and sensory characteristics in lentinus edodes,” *Science and Technology of Food Industry*, vol. 40, no. 24, pp. 262–269, 2019.

[19] L. J. Fu, G. Yang, L. Liu et al., “Analysis of volatile components of auricularia auricula from different origins by GC-MS combined with electronic nose,” *Journal of Food Quality*, vol. 2020, Article ID 8858093, 9 pages, 2020.

[20] Q. Ma, J. F. Bou, L. Fang et al., “Effect of drying method on volatile components of Pleurotus eryngii analyzed by combined use of GC-MS and electronic nose,” *Food Science*, vol. 40, no. 14, pp. 276–282, 2019.

[21] S. Y. Wang, F. Zhao, G. H. Rao et al., “Origin difference analysis of aroma components in jasmine tea based on electronic nose and ATD-GC-MS,” *Science and Technology of Food Industry*, vol. 42, no. 15, pp. 234–239, 2021.

[22] K. Lu, X. Y. Wang, X. J. sun et al., “Analysis of the volatile components of fermented hot pepper from different varieties grown in guizhou by electronic nose combined with SPME-GC-MS,” *Food Science*, vol. 39, no. 04, pp. 199–205, 2018.

[23] X. Fan and X. P. Cui, “Analysis of aroma compounds of different peach nesh types during postharvest storage by headspace s01id-phase microextraction combined wim gas

chromatography-mass spectrometry and electronic nose," *Food Science*, vol. 42, no. 20, pp. 222–229, 2021.
[24] C. Y. Liu, D. L. Fang, Y. H. Zhang, H. H. Zheng, Q. H. Hiu, and L. Y. Zhao, "Effect of cooking methods on volatile flavor compounds in lentinus edodes soups analyzed by electronic nose and SPME-GC-MS," *Science and Technology of Food Industry*, vol. 41, no. 20, pp. 6–11, 2020.
[25] C. M. Yin, X. Z. Fan, Z. Fan, D. F. Shi, and H. Gao, "Analysis of volatile flavor compounds in different Pleurotus species using HSSPME-GC-MS," *Food Science*, vol. 39, no. 16, pp. 240–246, 2018.
[26] Q. L. Xu, J. T. Guo, Z. J. Jiang et al., "Analysis and identification of aroma different habitats by HS-SPME-components of tartary buckwheat tea from GC-MS combined with electronic nose," *Food and Fermentation Industries*, vol. 43, no. 08, pp. 233–239, 2017.
[27] W. Jiao, Y. Xu, H. Zhang et al., "Cheddar cheese with different ripening times:analysis of volatile aroma components and electronic nose discrimination," *Food Science*, vol. 41, no. 20, pp. 175–183, 2020.
[28] Y. Liu, L. Q. Ge, and Y. X. Wang, "Analysis of volatile compounds and geographical origin discrimination of Lu mountain clouds-mist tea by principal components analysis," *Food Science*, vol. 38, no. 24, pp. 60–67, 2017.
[29] C. K. Xia, Q. Q. Song, and C. W. Fang, "Distinguish moutan cortex from different producing areas based on electronic nose technology," *Chinese Journal of Modern Applied Pharmacy*, vol. 36, no. 21, pp. 2633–2637, 2019.
[30] Y. P. Zhang, T. G. Liao, B. H. He, Y. W. Nui, J. C. Zhu, and M. F. Wang, "Identification of characteristic aroma compounds in prunes using gas chromatography-olfactometry, odor activity value and S-curve method," *Food Science*, vol. 41, no. 22, pp. 271–278, 2020.
[31] H. Z. Cheng, Z. P. Cai, J. Wang et al., "Combined use of GC-MS, GC-O and electronic nose technology to evaluate the aroma characteristics of passion fruit wine," *Food Science*, vol. 42, no. 6, pp. 256–264, 2021.
[32] C. Chen, Z. Liu, K. Huang, and H. X. Tian, "Effects of different processing methods on the flavor of dairy fan evaluated using GC-MS, GC-O and electronic nose," *Food Science*, vol. 42, no. 16, pp. 108–117, 2021.
[33] X. Liu, B. D. Mu, M. Ju, G. H. Li, C. X. Piao, and M. X. Ciu, "Characterization of flavor components of dry-cured ham with different salt substitute formulations using solid phase microextraction-gas chromatography-mass spectrometry, electronic nose and electronic tongue," *Food Science*, vol. 43, no. 06, pp. 246–256, 2022.
[34] Z. Q. Zhang, M. W. Zang, K. H. Zhang et al., "Effect of key processing steps on formation of volatile flavor components in steamed pork with rice," *Food Science*, vol. 40, no. 4, pp. 222–228, 2019.
[35] L. Huang, Z. Sun, X. Q. Zeng, D. D. Pan, J. He, and J. L. Shen, "Effects of multi-ingredients for nitrite on the volatile flavor compounds in cured meat," *Journal of Chinese Institute of Food Science and Technology*, vol. 21, no. 03, pp. 324–333, 2021.
[36] D. Melucci, A. Bendini, F. Tesini et al., "Rapid direct analysis to discriminate geographic origin of extra virgin olive oils by flash gas chromatography electronic nose and chemometrics," *Food Chemistry*, vol. 204, pp. 263–273, 2016.
[37] L. Fu, Y. L. Liu, X. Q. Gao, B. J. Yang, and S. W. Song, "Analysis of volatile flavor compoumds in different sterilization sauce beef with HSPME and GC-MS," *Modern Animal Husbandry*, vol. 4, no. 02, pp. 18–23, 2020.
[38] H. Wang, Y. H. Zhao, and K. Yang, "Comparative analysis of volatile profiles in kernel oils of ten Korean pine (Pinus koraiensis) varieties by headspace solid phase microextraction-gas chromatography-mass spectrometry and electronic nose," *Food Science*, vol. 42, no. 18, pp. 178–184, 2021.
[39] R. G. Jiang, Y. Huang, Y. L. Jin et al., "Analysis of characteristic aroma components of different grades of yellow tea," *Food Science*, vol. 42, no. 16, pp. 89–98, 2021.
[40] T. T. Li, M. Z. Huang, W. Y. Tang, Q. Y. Li, and K. N. Kang, "Determination of volatile components in Rosa roxburghii Tratt juice and the analysis of its contribution for aroma," *Food and Fermentation Industries*, vol. 47, no. 04, pp. 237–246, 2021.
[41] D. L. Li, Y. R. Weng, L. P. Du, C. Wang, L. J. Ma, and D. G. Xiao, "Detection of volatile compounds in different brands of Pu-erh teausing electronic nose and GC-MS," *Food and Fermentation Industries*, vol. 45, no. 03, pp. 237–245, 2019.
[42] T. Wang, Y. N. Shi, X. Li, and A. X. Hang, "Analysis of the effect of curing time on the volatile flavor compounds of dahe black pig ham by SPME-GC-MS and ROAV," *Science and Technology of Food Industry*, vol. 42, no. 18, pp. 317–324, 2021.
[43] Y. Zhang, S. Zhang, W. Fan, M. Duan, Y. Han, and H. Li, "Identification of volatile compounds and odour activity values in quinoa porridge by gas chromatography-mass spectrometry," *Journal of the Science of Food and Agriculture*, vol. 99, no. 8, pp. 3957–3966, 2019.
[44] N. Zhao, X. Y. Wei, M. T. Fan et al., "Analysis of volatile components of kiwifruit wines made from different cultivars using solid phase microextraction-gas chromatography-mass spectrometry combined with electronic nose," *Food Science*, vol. 40, no. 22, pp. 249–255, 2019.
[45] D. X. Liu, Z. H. Tian, Y. L. Zhao, C. Liu, and L. Yu, "Analysis and comparison of the volatile components in common buckwheat different parts with SPME-GC-MS," *The Food Industry*, vol. 42, no. 01, pp. 310–315, 2021.
[46] M. Q. Fan, F. Yang, H. F. Jia, L. Xiao, and G. Q. He, "Effects of pixian douban and douchi on the volatile flavor compounds of fried pork with salted pepper based on GC-MS," *Science and Technology of Food Industry*, vol. 42, no. 13, pp. 274–283, 2021.
[47] M. Q. Wang, Y. Zhu, Y. Zhang, J. Shi, Z. Lin, and H. P. Lu, "Analysis of volatile components and key aroma components of 'Qingxiang' green tea," *Food Science*, vol. 40, no. 22, pp. 219–228, 2019.
[48] C. Schueuermann, C. C. Steel, J. W. Blackman et al., "A GC-MS untargeted metabolomics approach for the classification of chemical differences in grape juices based on fungal pathogen," *Food Chemistry*, vol. 270, pp. 375–384, 2019.
[49] X. A. Chen, H. T. Cai, J. Y. Liu, N. Tang, S. X. Chen, and A. M. Zhou, "Analysis of volatile components in laoxianghuang during fermentation by electronic nose, GC-MS and GC-IMS," *Science and Technology of Food Industry*, vol. 42, no. 12, pp. 70–80, 2021.
[50] Z. H. Han, S. Guo, T. Huang et al., "Difference analysis of volatile flavor metabolite in lactobacillus beverage fermented with complex probiotics," *Journal of Chinese Institute of Food Science and Technology*, vol. 21, no. 03, pp. 300–314, 2021.
[51] H. W. Liu and M. L. Zhang, "Analysis of volatile components in sweet femented oat produced by inoculated and natural

fermentation," *Food Science*, vol. 42, no. 20, pp. 203–207, 2021.

[52] K. He, J. M. Yun, Y. Bi, R. Wang, Y. Q. Mao, and S. J. Wu, "Changes of volatile flavor components in Hysizygus marmoreus packaged with nano-film during storage," *Food Science*, vol. 42, no. 20, pp. 160–166, 2021.

[53] Q. Lu, F. Liu, and J. Bao, "Volatile components of American silver carp analyzed by electronic nose and MMSE-GC-MS-O," *Journal of Food Biochemistry*, vol. 43, no. 3, Article ID e13006, 2019.