Food and Nutrition Sciences, 2019, 10, 923-936
http://www.scirp.org/journal/fns
ISSN Online: 2157-9458
ISSN Print: 2157-944X

Effect of *Monascus* Fermentation on Aroma Patterns of Semi-Dried Grass Carp

Kang Wu, Jinghui Xie, Qianqian Wang, Meijing Ling, Jianzhong Wu*

Department of Food Science and Engineering, Jinan University, Guangzhou, China
Email: 15826824041@163.com, *twjzh@jnu.com

How to cite this paper: Wu, K., Xie, J.-H., Wang, Q.-Q., Ling, M.-J. and Wu J.-Z. (2019) Effect of *Monascus* Fermentation on Aroma Patterns of Semi-Dried Grass Carp. *Food and Nutrition Sciences*, **10**, 923-936.
https://doi.org/10.4236/fns.2019.108066

Received: July 7, 2019
Accepted: August 10, 2019
Published: August 13, 2019

Abstract

The aim of the present study is to investigate the effects of *Monascus* fermentation on the aroma pattern of semi-dried grass carp. Semi-dried fish was fermented using *Monascus purpureus* GDMCC3.439. The volatile flavor substances present in fresh fish, semi-dry fish and *Monascus* fermented semi-dried fish were compared by simultaneous distillation and extraction combined with gas chromatograph-mass spectrometer (GC-MS). The results showed that alcohols, aldehydes and ketones were the main components of the flavor of the unfermented and fermented semi-dried grass crap. *Monascus* fermentation could significantly affect the volatile flavor substances of semi-dried grass carp. Moreover, the processing of semi-dried fish fermented by *Monascus* could not only effectively improve the fishy smell of fresh fish, but also make up for the defect of the pickled flavor of semi-dried fish. Eighteen of the main volatile components in semi-dried fish fermented by *Monascus* were identified by relative odor activity value (ROAV), as follows: 1-octene-3-ol, phenylethanol, hexanal, heptanal, nonanal, (E)-2-octenal, 3-Methyl-1-butanal, benzaldehyde, (E)-2-nonenal, (E,E)-2,4-heptadienal, (E)-2-Decenal, phenylacetaldehyde, (E,E)-2.4-decadienal, tetradecanal, 2,3-butanone, 2,3-octanedione, alpha-pinene, 2-pentane furan.

Keywords

Monascus, Fermentation, Semi-Dried Grass Carp, ROAV, Flavor

1. Introduction

Grass carp (*Ctenopharyngodon idellus*), one of the four largest freshwater fish in China, is very popular among consumers because of its rapid growth, high yield, and low price [1]. Grass carp is mainly freshly sold due to the high cost of storage [2]. Moreover, the production of fresh fish is greatly influenced by seasonal and regional weather conditions. To prevent fresh fish from deterioration, it is commonplace for the fish to be processed into salted fish. However, the traditional salted fish has high salt content and poor taste, which does not meet the dietary habits of modern people.

In recent years, a kind of low salt semi-dried fish has come into the markets. It has been welcomed by many people because of low salt content and good taste [3]. The grass carp processed into the low salt semi-dried fish has the broad market prospect. However, it suffers from having fewer flavor substances than traditional salted fish as a result of lower salt content, shorter drying time and the lack of natural inoculation and fermentation process. This problem paves the need for improvement in the flavor of fish meat. For instance, You gang *et al.* [4] inoculated compounded *Lactobacillus* on ornate threadfin bream. The results showed that a lot of carbonyl and alcohol compounds present in the flavor substances of fermented fish, which added the unique flavor of fermented fish on the basis of traditional salted fish flavor. Furthermore, Wu haiyan *et al.* [5] made use of *Lactic acid bacteria* and *Staphylococcus* to ferment the white cloud mountain minnows. Compared with the salted fish marinated by traditional techniques, the content of small molecules in the fermented fish meat was significantly increased, and the flavor of the final fermentation product was improved. To add on, Udomsil *et al.* [6] utilized *Staphylococcus* isolated from the traditional fish sauce as a starter culture to prepare fish sauce, which induced sauce black chocolate aroma and improved the flavor of fish sauce.

Monascus belongs to Eurotiales, Euascomycetes, Ascomycota, and Eumycophyta. It is one of the traditional fermentation moulds used by human beings and is mainly used in fermented food in some Asian countries. Monascus has been used for more than 1000 years in the production of wine, vinegar, and soy sauce in China. GDMCC3.439 *Monascus purpureus* is a kind of *Monascus*. It can produce *Monascus* red pigment in large quantities and has strong inhibition effect on alcohol, salinity and bacteriostasis [7].

In order to further enhance the flavor of semi-dried fish, *Monascus* was inoculated to ferment the semi-dried fish. The aroma-producing effect of *Monascus* fermentation on low salt semi-dried grass carp was analyzed. The present study attempted to provide some new ideas for the traditional salted fish technology.

2. Materials and Methods

2.1. Materials and Reagents

Grass carp was purchased from China Resources Vanguard Supermarket. *Monascus purpureus* GDMCC3.439 was purchased from Guangdong Culture Collectioncenter of Microbiology. C_7-C_{30} normal paraffins were purchased from the American Supelco Company. Potato dextrose agar (PDA) medium was purchased from Guangdong Huankai Microbiology Co., Ltd. Soy protein isolate was purchased from Shanghai Maclean Biochemical Technology Co., Ltd. All other chemicals and solvents used in the study were of analytical grade.

2.2. Main Instruments

7890A-5975C Gas Chromatography-Mass Spectrometer was purchased from Agilent Company. Chromatographic column was HP-INNOWAX (60 m × 0.25 mm × 0.25 um). Simultaneous distillation and extraction (SDE) was obtained from Guangzhou Dongju Experimental Instrument Co., Ltd. Vigreux column was purchased from Guangzhou Congyuan Experimental Instrument Co., Ltd.

2.3. Processing Craft

2.3.1. Preparation of Starter Cultures

The activated *Monascus* were inoculated into the slope composed of PDA medium in a test tube and cultured at 30˚C for 7 - 10 days. Then 5 mL of sterile water was pumped into the tube, shaken for 15 minutes, and the red-brown spores were washed into the *Monascus* culture medium with the 6 g of rice powder as a carbon source, 2.5 g of soybean protein as nitrogen source, and 0.05 g of $MgSO_4$ and 0.1 g KH_2PO_4 as the mineral elements to incubate *Monascus* in the shaker for 5 days under 35˚C, shaking at 150 r/min. after which *Monascus* starter cultures were prepared. The concentration of *Monascus* was 10^9 CFU/mL [7].

2.3.2. Craft of Low Salt Semi-Dried Fish

The Scale, head, tail, fin and viscera of grass carp were removed and cut into small pieces. They were marinated at 4˚C for 2 hours after 3% of salt (W/W) was added to them, then put into a heat pump drier, and dried at 27˚C and 20% humidity until the moisture content of the fish was about 50%. Finally, after vacuum packaging, they were unfermented group samples.

2.3.3. Craft of Low Salt Semi-Dried Fish Fermented by *Monascus*

The Scale, head, tail, fin and viscera of grass carp were removed and cut into small pieces. They were marinated at 4˚C for 2 hours after 3% (W/W) of salt was added to them. Monascus starter cultures were evenly applied to ferment them, and the inoculation amount was 5 mL/100g. Then, they were fermented at 30˚C for 18 hours, and transferred to a heat pump dryer. Next，they were dried at 27˚C and 20% humidity until the moisture content of the fish was about 50%. Finally, after vacuum packaging, they were fermented group samples.

2.4. Collection of Volatile Compounds

30 g of fish meat was placed in a 1000 mL round-bottom flask with 400 mL of purified water and the flask attached to the side of the SDE device. A 500 mL round-bottom flask containing 50 mL of dichloromethane was linked to the other side of the SDE device. The steams were cooled due to the circulation of water at 4˚C, the content of two round-bottom flasks were heated to a boil. The temperature of the dichloromethane flask was maintained by a water bath at

55˚C. The extraction was continued for 3 h, the extracts were collected and refrigerated overnight with 10 g of anhydrous sodium sulfate. The volume of the extract was then concentrated to 3 mL with a Vigreux column. 600 uL of sample concentrates were accurately absorbed into a 1.5 mL of sample bottle with 300 uL of butanol (the concentration was 400 ug/mL) as the internal standard. The sample bottle was frozen in the refrigerator for GC-MS analysis.

2.5. GC-MS Analysis Condition

Chromatographic columns used HP-INNOWAX (60 mm × 0.25 mm × 0.25 um). Helium was used as the carrier gas, the gas at a flow rate of 1.0 mL/min. The column temperature was maintained at 50˚C for 2 min, programmed at 5˚C/min to 220˚C and maintained for 5 min. The mass spectrometer was operated in electron impact (EI) ionization mode with electron energy of 70 eV and temperature at 230˚C. The four-stage bar temperature was 150˚C. Scan range was 30 - 550 m/z.

2.6. Qualitative Analysis

Unknown compounds were matched with the NIST08 library. Only compounds with mass greater than 75 were reported. Using the same heating program and taking saturated alkanes from C_7 to C_{30} as the standard, the Retention Index (RI) of the corresponding compounds was calculated and qualitatively analyzed with the database retrieval results [8].

$$\mathrm{RI} = 100n + 100 \times \frac{t_x - t_n}{t_{n+1} - t_n} \quad (1)$$

t_x: the retention time of the volatiles to be tested (min).

t_n, t_{n+1}: the retention time of saturated alkanes containing n and n + 1 carbon atoms (min)

2.7. Quantitative Analysis

Butanol was used as an internal standard, and the peak area of each test substance and internal standard were compared. The concentration of the volatile substance in the sample was calculated.

$$C = \frac{S \times 133.3\ \mathrm{ug/mL} \times 3\ \mathrm{mL}}{3\ \mathrm{kg}} \times 1.5 \quad (2)$$

S: the ratio of peak area of volatile matter measured to that of internal standard butanol.

C: the concentration of the volatile substance (μg/kg).

2.8. Evaluation of Volatile Flavor Components by ROAV Method

Relative odor activity value (ROAV) was used to evaluate the contribution of volatile flavor components to the flavor of *Monascus* fermented semi-dried fish [9] [10]. ROAV of each compound was calculated according to the following formula:

$$\mathrm{ROAVi} \approx \frac{C_i}{C_{stan}} \times \frac{T_{stan}}{T_i} \times 100 \tag{3}$$

ROAVi: the relative odor activity value of a volatile component.

C_i: the concentration of a volatile component (ug/kg).

T_i: the sensory threshold of a volatile component (ug/kg).

C_{stan}: the concentration of the component with maximum contribution to odors (ug/kg).

T_{stan}: the sensory threshold of the component with maximum contribution to odors. (ug/kg)

3. Results and Analysis

3.1. Detection Results of SDE-GC-MS

The total ion chromatograms of the fresh fish group, unfermented semi-dried fish group and the fermented semi-dried fish group were determined by SDE-GC-MS, respectively, as shown in Figure 1, Figure 2 and Figure 3.

Specific substances were identified by searching the NIST08 spectral library and the retention index was calculated according to Equation (1). Compared with the concentration and peak area of the internal standard, the concentration of other substances was calculated by Equation (2), as shown in Table 1. The types and relative contents of volatile substances in fish meat under different processing methods were further studied, as shown in Table 2.

From Table 1, compared with the fresh fish group, the contents of hexanal, Heptanal, nonanal, (E)-2-octenal, (E)-2-nonenal, (E)-2-decenal, (E,E)-2,4-decadienal, (E,E)-2,4-heptadienal, 1-pentene-3-ol and 1-octen-3-ol significantly decreased in the fermentation group. Based on the literature analysis, these low molecular

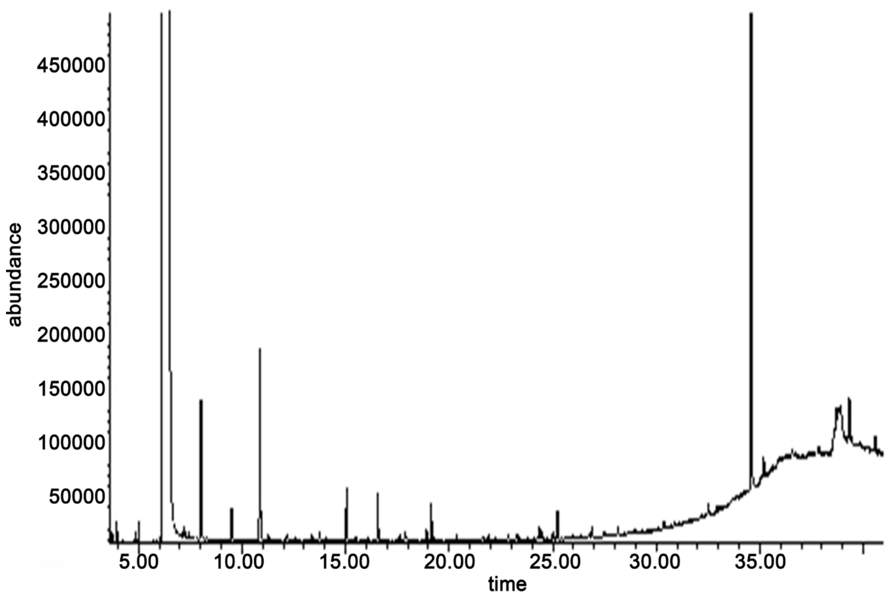

Figure 1. The total ion count (TIC) chromatogram of fresh fish sample.

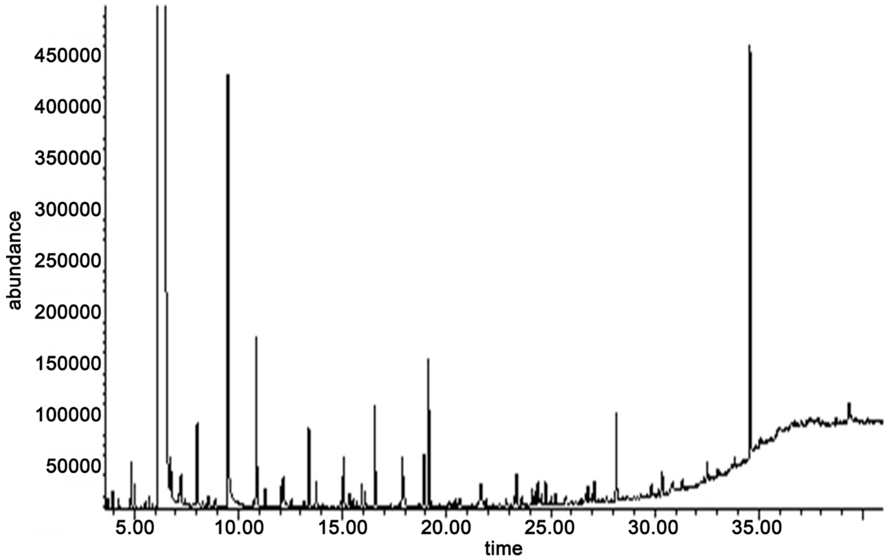

Figure 2. The total ion count (TIC) chromatogram of unfermented semi-dried fish sample.

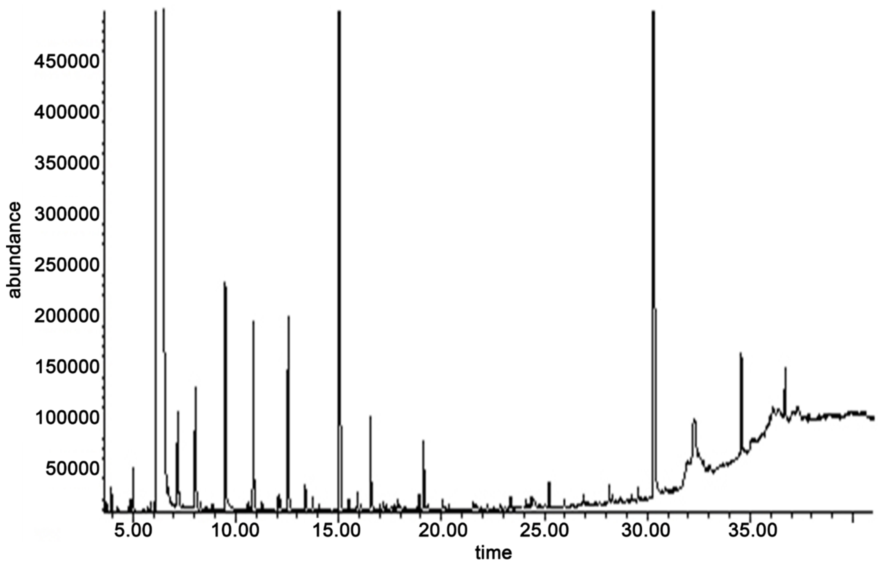

Figure 3. The total ion count (TIC) chromatogram of semi-dried fish sample fermented by *Monascus.*

weight aldehydes and alcohols, especially hexanal, heptaldehyde, nonanal, (E,E)-2,4-decadienal, (E,E)-2,4-heptadienal were typical fishy odor-causing compounds [11] [12] [13] [14] [15]. Moreover, 1-octene-3-alcohol had mushroom aroma and earthy odor [16]. The results showed that the processing of semi-dry grass carp could effectively improve the fishy smell.

Compared with the non-fermented group, the contents of 3-methyl butanol, pentanol, hexanol, heptanol, benzaldehyde and 3-Methyl-1-butanal increased in the fermented group. It had been reported that 3-methyl butanol, 1-pentene-3-alcohol, 1-octen-3-ol, pentanol, hexanol, hexanal, heptanal, benzaldehyde and 3-Methyl-1-butanal were the main flavor substances of salted fish [17] [18] [19] [20]. The results showed that the *Monascus* fermentation could enhance the

Table 1. Volatile components and contents of fish meat processed in different ways.

RT/min	Element	Fresh fish group (ug/kg)	Unfermented group (ug/kg)	Fermented group (ug/kg)	RI
7.186	3-Methyl-3-buten-2-ol	68.25	-	-	982
8.294	Propanol	-	-	83.40	1038
10.855	Butanol	1999.95	1999.95	1999.95	1144
11.270	1-Penten-3-ol	135.30	-	126.45	1160
13.162	Trans-2-Hexenal	-	87.00	184.80	1231
13.739	Pentanol	186.45	-	697.95	1252
15.042	3-Methyl-2-Pentanol	-	741.15	757.50	1300
16.081	3-Methylbutan-1-ol	-	1857.80	2124.45	1338
16.554	Hexanol	2625.90	-	742.95	1356
17.615	3-Octanol	42.75	-	-	1395
17.880	(E)-2-Methylcyclopentanol	-	-	187.20	1404
19.138	1-Octen-3-ol	3135.45	958.80	1827.30	1460
20.245	Fenipentol	-	30.75	-	1495
21.895	Octanol	302.70	3703.50	391.50	1561
21.884	Nonanol	71.10	666.30	198.75	1562
23.360	(E)-2-decen-1-ol	22.65	-	-	1621
24.283	2-Butyloctan-1-ol	-	-	44.10	1625
24.387	2,2-Dimethyl-3-Octanol	-	335.25	-	1664
24.560	2-Furanmethanol	-	125.85	-	1671
25.829	Ethanol, 2-(dodecyloxy)	-	-	116.10	1726
27.029	2-Hexyl-1-decanol	6.75	78.75	81.75	1780
25.956	3-Methylthiopropanol	-	-	127.35	1732
29.555	Benzyl alcohol	-	-	112.65	1896
30.328	Phenylethyl alcohol		637.80	3995.40	1933
	Grand total	8597.25	11,222.90	13,799.55	
4.787	Propanal	-	131.40	48.45	791
5.721	Butanal	-	97.20	32.85	872
7.255	Pentanal	33.45	252.00	288.00	987
7.256	Butanedial	46.05	-	-	994
9.493	Hexan al	2730.45	2092.50	2263.50	1091
12.170	Heptanal	1153.90	859.00	1003.50	1194
16.081	(Z)-2-ptenal	6.00	-	63.90	1338
16.681	3-Hydroxy-butanal	6.00	-	-	1360
17.881	Nonanal	2778.95	2046.50	2767.50	1404
18.919	(E)-2-octenal	314.15	250.25	203.10	1444

Continued

20.372	3-Methy-1-butanal	-	502.00	666.00	1500
20.465	2-Methylundecanal	-	91.800	-	1504
21.549	Benzaldehyde	78.45	64.50	117.00	1547
21.641	(E)-2-nonenal	114.15	-	63.00	1551
20.649	(E,E)-2,4-heptadienal	327.15	126.00	288.00	1511
24.272	(E)-2-decenal	46.65	-	36.00	1659
24.491	Phenylacetaldehyde	-	58.50	945.00	1668
28.159	(E,E)- 2,4-decadienal	354.15	369.00	117.00	1824
34.574	Tetradecanal	3999.45	3754.95	3000.00	2148
	grand total	11,988.95	10,695.60	11,902.80	
5.017	Acetone	187.20	241.65	-	814
5.813	4-Hydroxy-2-butanone	-	-	101.70	879
6.067	2-Butanone	-	-	130.50	900
7.186	2,3-Butanedione	90.15	243.60	886.05	980
10.647	(E)-3-penten-2-One	-	-	93.75	1136
12.078	2-Heptanone	81.30	330.60	167.25	1191
14.904	6-Methylheptan-2-One	-	80.10	-	1235
15.054	3-Hydroxy-2-Butanone	261.30	-	3905.85	1300
15.331	Cyclohexanone	-	226.35	-	1310
15.504	1-Hydroxy-2-Propanone	-	132.45	-	1317
15.919	2,3-Octanedione	1205.40	1233.00	1363.95	1332
24.756	3,6-Dimethyl-4-octanone	-	256.65	53.85	1680
27.306	1-Hepten-3-one	-	-	53.10	1792
	Grand total	1825.35	2744.40	6756.00	
3.956	3-Methyl-1-butene	133.35	151.35	166.20	600
4.244	Heptane	-	113.55	-	702
4.798	2,4-Dimethyl-heptane	91.50	-	-	792
4.821	Octane	85.05	384.00	82.95	796
5.444	(Z)-3-octene	-	91.20	-	849
5.629	(Z)-2-octene	-	33.60	-	863
8.051	Alpha-Pinene	-	-	1799.40	1027
8.559	Toluene	-	126.15	-	1050
17.292	1-Ethyl-2,4-dimethylbenzene	-	59.85	-	1383
17.765	2,3,3-Trimethyloctane	-	73.80	-	1400
25.229	Heptadecane	289.05	124.80	250.65	1699
29.324	2-Methyl-naphthalene	49.65	-	-	1885

Continued

	Grand total	648.60	1158.30	2299.20	
5.848	Ethyl acetate	-	-	74.70	801
6.044	Formic acid, ethenyl ester	37.50	-	-	898
17.304	N'-Ethyl-hydrazinecarboxylic acid methyl ester	-	-	69.00	1383
22.472	Methoxyacetic acid, tridecyl ester	-	-	129.60	1584
23.291	Oxalic acid, cyclobutyl heptadecyl ester	-	94.65	-	1618
24.375	1-Methyltridecyl cyclobutanecarboxylate	-	-	143.85	1664
36.708	Hexadecanoic acid, ethyl ester	-	-	593.25	2260
	Grand total	37.50	94.65	1010.40	
22.253	2-Hexynoic acid	3.00	37.20	33.90	1575
29.844	Nonahexacontanoic acid	-	99.75	-	1910
	Grand total	3.00	136.95	33.90	
21.641	Ethanedial, dioxime	-	-	100.80	1551
26.890	2,4-Dimethyl-benzenamine	125.10	-	-	1773
27.017	3-butenamide	-	-	56.10	1779
27.306	(Z)-2-butenediamide	-	30.00	-	1792
27.929	1-octadecanamine	-	13.20	-	1820
7.336	N-carboxal-4-carboxychloropi-peridine	6.15	4.65	6.00	992
13.381	2-Pentyl-furan	72.30	932.10	263.10	1239
18.469	(Z)-aconitic anhydride	3.30	3.30	9.15	1427
19.276	2-methylpiperazine	34.65	-	-	1458
19.357	1-(aminoacetyl)-Piperazine	-	-	66.00	1461
19.876	3-Furan-2-yl-1-methyl-propyla-mine	-	18.00	-	1481
20.165	1-Fluoro-dodecane	11.85	-	151.20	1492
21.480	2-N-octylfuran	-	39.45	-	1543
22.068	N-methyl-1,3-Propanediamine	-	-	10.05	1568
22.253	5-Methyl-2-furancarboxaldehyde	-	-	48.75	1575
24.122	4-Methylthiazole	-	247.20	-	1653
24.756	Pentanoic acid, 2-methyl-, anhydride	-	298.95	-	1680
28.713	1-Sec-butyldiaziridine	-	-	83.40	1857
32.358	1,54-Dibromotetrapentacontane	-	-	71.85	2033
		253.35	1586.85	866.40	

"-": The corresponding substance was not detected by the instrument. "RT": Retention time.

Table 2. Species and relative contents of volatile substances in fish meat under different processing methods.

	Unfermented group		Fermented group	
	Type	Relative content	Type	Relative content
Alcohols	12	40.60%	18	37.63%
Aldehydes	14	38.70%	16	32.46%
Ketones	8	9.93%	9	18.42%
Hydrocarbons	9	4.19%	4	6.27%
Esters	1	0.34%	5	2.76%
Acids	2	0.50%	1	0.09%
Heteroatoms/Heterocycles	9	5.74%	11	2.36%

aroma of salted fish and make up for the shortage of pickled flavor of semi-dried fish.

According to Table 1 and Table 2, 55 and 64 of volatile compounds were detected in fresh fish, non-fermented fish and fermented fish, most of which were alcohols, aldehydes and ketones, accounting for 89.23% and 88.51% respectively. As a result, alcohols and carbonyl compounds were the main volatile components of grass carp fish flavor. The total contents of alcohols and aldehydes in semi-dried grass carp after fermentation were 9.21% lower than those in non-fermented fish. Moreover the contents of ketones, hydrocarbons and esters were significantly increased, indicating that the fermentation of *Monascus* had a significant effect on the flavor of the semi-dried grass carp.

3.2. Identification of Key Aroma Substances

Why did fresh fish, unfermented fish and fermented fish have similar flavor components while the overall flavor was significantly different? Some data showed that the flavor contribution of volatile flavor substances was determined by their concentration and flavor threshold. The flavor characteristics of fermented fish could not be accurately described by the content of flavor substances alone [21] [22] [23].

The volatile substance of which the concentration was highest in the fermentation group was the nonanal with 2767.5 ug/kg, and the sensory threshold of it was 1 ug/kg [24], which contributed the most to the flavor of fermentation group. Thus, the nonanal was defined as the component with maximum contribution to odors. The sensory thresholds of some substances were not found in this paper. Most of them were hydrocarbons, esters and heteroatoms with high boiling point or high threshold, which had little effect on the overall flavor of fish. Volatile compounds of ROAV > 0.1 were counted in Table 3. Some researches suggested that the components of ROAV > 1 were key flavor compounds, those of 0.1 < ROAV < 1 were modified flavor compounds, and those of ROAV < 0.1 were potential flavor compounds [9].

Table 3 showed that the main flavor substances (ROAV > 1) of *Monascus* fermented semi-dried grass carp were as follows: 1-octene-3-ol, phenylethanol, hexanal, heptanal, nonanal, (E)-2-octenal, 3-Methyl-1-butanal, benzaldehyde, (E)-2-nonenal, (E,E)-2,4-heptadienal, (E)-2-Decenal, phenylacetaldehyde, (E,E)-2.4-decadienal, tetradecanal, 2,3-butanone, 2,3-octanedione, alpha-pinene, 2-pentane furan. The content of saturated straight-chain alcohols in alcohols was higher, which contributed little to the flavor of fermented fish meat because of their high sensory threshold. However, some unsaturated alcohols had low threshold, such

Table 3. Aroma characteristics, threshold and relative activity value of volatile components in semi-dried fish fermented by Monascus.

	Compound name	Sensory threshold (ug/kg) [21] [23] [24] [25] [26]	ROAV	Fragrance Description [21] [23] [27] [28]
Alcohols	3-Methyl-1-butanol	300.00	0.26	Nutty, herbaceous
	Hexanol	500.00	0.05	Green, grassy, fatty
	1-Octen-3-ol	1.00	66.03	Mushroom, earthy
	Octanol	190.00	0.07	Earthy, metallic
	Nonanol	50.00	0.14	Chamomile, flowery, musty
	Phenylethanol	86.00	1.68	Honey, rose, lilac, spicy
Aldehydes	Butanal	5.26	0.23	Special
	Pentanal	27.00	0.34	Irritant
	Hexanal	4.50	18.18	Green, fresh
	Heptanal	3.00	12.09	Green
	Nonanal	1.00	100	Green, citrus-like
	(E)-2-octenal	3.00	2.45	Gramineous, fatty
	3-Methyl-1-butanal	1.10	21.88	Malt
	Benzaldehyde	3.00	1.41	Bitter almonds, cherries nuts
	(E)-2-nonenal	0. 08	28.46	Fatty, tallow
	(E, E) -2,4-heptadienal	10.00	1.04	Fatty, hay, fishy odor
	(E)-2-decenal	0.4	3.25	Wax, fat and mushroom
	Phenylacetaldehyde	4.00	8.54	Floral
	(E,E)- 2,4-decadienal	0.2	21.14	Fatty, waxy
	Tetradecanal	5.00	21.38	Fishy smell
Ketones	2,3-Butanedione	5.00	6.40	Fishy smell
	2,3-Octanedione	2.52	19.56	Creamy, caramel, butter scotch
	3-Hydroxy-2-butanone	800.00	0.18	Milky, fatty
Hydrocarbons	Alpha-pinene	6.00	10.84	Turpentine
Esters	Ethyl acetate	5.00	0.54	Fruity, buttery, orange
Heterocycles	2-Pentyfuran	6.00	1.58	Bean, grass

as 1-octene-3-alcohol and phenylethanol, which gave fermented fish meat mushroom and rose fragrance. Aldehydes, due to their low sensory threshold, accounted for the largest proportion of the main flavor substances in fermented fish meat, giving fish a variety of flavors. Ketones gave fermented fish fragrance, creamy fragrance and ester fragrance. Alpha-pinene and 2-pentylfuran gave the fermented fish oil and bean fragrance.

4. Conclusion

The volatile components of fresh fish, semi-dried fish and semi-dried fish fermented by *Monascus* were analyzed by SDE combined with GC-MS, and 43, 56 and 64 of volatile substances were detected respectively. The results showed that alcohols, aldehydes and ketones were the main components of the flavor of grass crap. The semi-dried fish fermented by *Monascus* could significantly affect the flavor of semi-dried grass carp. Furthermore, the processing could not only effectively improve the fishy smell of fresh fish, but also enhance the aroma of salted fish, and make up for the shortcomings of the pickled flavor of semi-dried fish. 18 of the main flavor components of semi-dried fish fermented by *Monascus* were identified by relative odor activity value (ROAV). They were as follows: 1-octene-3-ol, phenylethanol, hexanal, heptanal, nonanal, (E)-2-octenal, 3-Methyl-1-butanal, benzaldehyde, (E)-2-nonenal, (E,E)-2,4-heptadienal, (E)-2-decenal, phenylacetaldehyde, (E,E)-2.4-decadienal, tetradecanoaldehyde, 2,3-butanone, 2,3-octanedione, a-pinene, 2-pentane furan. The main aroma characteristics were mushroom, rose, gramineous, citrus taste, Vegetable-flavored, malt, bitter almond-flavored, cherry and nut-flavored, the fragrance of a flower, cream-flavored, fruit-flavored and wine-flavored.

References

[1] Zhang, L., Li, X., Lu, W., Shen, H.-X. and Luo, Y.-K. (2011) Quality Predictive Models of Gress Carp (*Ctenopharyngodon idella*) at Different Temperatures during Storage. *Food Control*, **22**, 1197-1202. https://doi.org/10.1016/j.foodcont.2011.01.017

[2] Kang, C.-C., Shi, W.-Z., Fang, L. and Wang, X.-C. (2018) Effects of Different Freezing Methods on the Volatile Components of Grass Carp Meat. *Food Science*, **39**, 229-235.

[3] Jin, J., Wu, L.-F., Wang, Q.-D., Wu, J.-Z. and Zeng, S.-D. (2011) Effects of Fermentation by Lactic Acid Bacteria on the Volatile Components of Damp-Dry Tilapia. *Journal of Jinan University* (*Natural Science & Medicine Edition*), **32**, 473-479.

[4] You, G. and Niu, G.-G. (2016) Study on the Volatile Flavor Compounds of *Nemipterus virgatus* Inoculated with Complex Lactic Acid Bacteria. *Food and Fermentation Industries*, **42**, 167-173.

[5] Wu, H.-Y., Yang, L., Li, S.-D., Wang, G. and Yang, X.-H. (2010) Effects of Mixed Starter Cultures on the Quality of Fermented Cured Fish. *Guangzhou Chemical Industry*, **38**, 73-77.

[6] Udomsil, N., Rodtong, S., Tanasupawat, S. and Yongsawatdigul, J. (2015) Improvement of Fish Sauce Quality by Strain. *Journal of Food Science*, **80**, M2015-M2022.

https://doi.org/10.1111/1750-3841.12986

[7] Zhang, C., Song, Z.-L., Li, F.-E. and Wu, J.-Z. (2017) Influence of *Monascus* Fermentation on Storage Characteristics of Semidry Salted Tilapia. *Journal of Aquatic Food Product Technology*, **10**, 1122-1133. https://doi.org/10.1080/10498850.2014.914116

[8] Moradi, P., Ford-Lloyd, B. and Pritchard, J. (2017) Metabolomic Approach Reveals the Biochemical Mechanisms Underlying Drought Stress Tolerance in Thyme. *Analytical Biochemistry*, **527**, 49-62. https://doi.org/10.1016/j.ab.2017.02.006

[9] Niu, D.-Y., Zhou, G.-H. and Xu, X.-L. (2008) "ROAV" Method: A New Method for Determining Key Odor Compounds of Rugao Ham. *Food Science*, **29**, 370-374.

[10] Frauendorfer, F. and Schieberle, P. (2006) Identification of the Key Aroma Compounds in Cocoa Powder Based on Molecular Sensory Correlations. *Journal of Agricultural and Food Chemistry*, **54**, 5521-5529. https://doi.org/10.1021/jf060728k

[11] Maurizio, B., Gianluca, G., Gandini, G., Caccialanza, G., Finzi, P.V., Vidaric, G., *et al.* (2007) Determination of the Threshold Odor Concentration of Main Odorants in Essential Oils Using Gas Chromatography-Olfactometry Incremental Dilution Technique. *Journal of Chromatography A*, **1150**, 131-135. https://doi.org/10.1016/j.chroma.2007.02.031

[12] Wu, J.-Z., Wang, Q.-Q., Liao, S., Wu, K. and Zhang, M.-M. (2019) Causes Analysis of Deodorization of Saury Soup by Angel Yeast Fermentation. *Food and Fermentation Industries*, **45**, 213-220.

[13] Zhou, Y.-Q. and Wang, Z.-J. (2006) Extraction and Analysis on Fishy Odor-Causing Compounds in the Different Part of Carp. *Chinese Journal of Analytical Chemistry*, **34**, 165-167.

[14] Wang, X., Huang, J., Hou, Y.-D. and Wang, Q.-J. (2012) Analysis of Volatile Components in Yellowfin Tuna by Electronic Nose and GC-MS. *Food Science*, **33**, 268-272.

[15] Qian, P., Ma, X.-T., Xu, G., Xue, J., Jin, R.-Y. and Dai, Z.-Y. (2016) Study on Volatile Components and Deodorization of Silver Carp. *Journal of Chinese Institute of Food Science and Technology*, **16**, 169-173.

[16] Huang, Z.-B., Ming, T.-H. and Dong, L.-S. (2019) Studies on the Deodorization during Fermentation of Tuna's Milt by *Lactobacillus plantarum*. *Journal of Chinese Institute of Food Science and Technology*, **19**, 147-154.

[17] Wu, H.-Y., Xie, W.-C., Yang, X.-H., Yang, L., Li, S.-L. and Zhang, C.-H. (2009) SPME-GC-MS Analysis of Volatile Components in Cured Golden Thread (*Nemipterus virgatus*) Meat. *Food Science*, **30**, 278-281.

[18] Li, L.-H., Ding, L.-L., Wu, Y.-Y., Yang, X.-Q., Deng, J.-Z. and Liu, F.-J. (2012) Analysis of the Volatile Flavor Compounds in Salted-Dried Fish. *Journal of Fisheries of China*, **36**, 979-988. https://doi.org/10.3724/SP.J.1231.2012.27682

[19] Wu, Y.-Y., Li, L.-H., Yang, X.-Q., Niu, F.-J., Diao, S.-Q. and Deng, J.-C. (2011) Changes of Volatile Flavor Compounds during Salted Hairtail (*Trichiurus haumela*) Processing. *Food Science*, **32**, 208-212.

[20] Wang, Y., Wang, R.-D., Xue, Y., Zhao, Y.-N. and Xue, C.-H. (2018) Analysis of Volatile Flavor Compounds Changes during Traditional Processing of Salted Spanish Mackerel. *Modern Food Science and Technology*, **34**, 268-276.

[21] Cai, R.-K., Wu, J.-J., Zhu, J.-L., Qian, P. and Dai Z.-Y. (2017) Analysis of Volatile Compounds and Odor-Active Compounds in Fermented Large Yellow Croaker. *Journal of Chinese Institute of Food Science and Technology*, **17**, 264-273.

[22] Gao, J.-C., Ye, P. and Huan, Y.-J. (2019) Effects of Single Bacteria and Compounded Bacteria Fermentation on Volatile Compounds of Pork Jerky. *Food and Fermentation Industries*, **1**, 128-136.

[23] Lu, C.-X., Wong, L,-P., Wang, H.-H., Yang, R.-H., Wang, X.-F. and Dai, Z.-Y. (2010) Investigation on the Key Odor Compounds of Three Cage-Farming Fishes. *Food and Fermentation Industries*, **36**, 163-169.

[24] Pino, J.A. and Mesa, J. (2006) Contribution of Volatile Compounds to Mango (*Mangifera indica* L.) Aroma. *Flavour and Fragrance Journal*, **21**, 207-213. https://doi.org/10.1002/ffj.1703

[25] Zhu, L.-L., Yang, F., Gao, P., Jiang, Q.-X., Xu, Y.-S. and Yu, P.-P. (2018) Effect of Fermentation Conditions on Flavor of Yeast-Fermented and Wine-Aroma Sturgeon (*Acipenser dabryanus*). *Food and Fermentation Industries*, **44**, 110-117.

[26] Selli, S. and Gayhan, G.C. (2009) Analysis of Volatile Compounds of Wild Gilthead Sea Bream (*Sparus aurata*) by Simultaneous Distillation-Extraction (SDE) and GC-MS. *Microchemical Journal*, **93**, 232-235. https://doi.org/10.1016/j.microc.2009.07.010

[27] Anupam, G., Kazufumi, O., Akira, O. and Toshiaki, O. (2010) Olfactometric Characterization of Aroma Active Compounds in Fermented Fish Paste in Comparison with Fish Sauce, Fermented Soy Paste and Sauce Products. *Food Research International*, **43**, 1027-1040. https://doi.org/10.1016/j.foodres.2010.01.012

[28] Morales, M.T., Rios, J.J. and Aparicio, R. (1997) Changes in the Volatile Composition of Virgin Olive Oil during Oxidation: Flavors and Off-Flavors. *Journal of Agricultural and Food Chemistry*, **45**, 2666-2673. https://doi.org/10.1021/jf960585+