Original Article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.1590/fst.93622

Processing optimization and quality assessment for the innovative product of canned soybean paste oyster

Kaiqiang LI[1], Zhixin ZHANG[1], Hongru YE[1], Wenwen REN[1], Luqiang HUANG[1,2,3], Huibin CHEN[1,2,3]*

Abstract

Oysters have high nutritional value but are rare in processing products. In this study, we developed an innovative product of oyster combined with soybean paste. The processing conditions and flavoring formulations of canned oysters were optimized using orthogonal experiments. Headspace solid-phase microextraction (HP-SPME) combined with gas chromatography-mass spectrometry (GC-MS) was applied to evaluate the volatile compounds related to the aroma. The results showed that the optimal canned oyster was oyster dried at 90 °C for 20 min and oil-fried at 150 °C for 6 min with the adding flavoring formula of 20% soybean paste, 0.5% vinegar, and 0.01% I+G (disodium 5'-presenting nucleotide) based on the weight of oyster. Canned soybean paste oysters enrich volatile components related to aroma including 2-octanol, 2-furanmethanol, benzaldehyde, and 2-pentylfuran. The canned soybean paste oyster is a high-valued nutrient including protein, fat, zinc, and taurine. This study will provide processing conditions for favorite instant processed oysters with soybean paste supplementary and deep insight into the flavor formation.

Keywords: oyster; soybean paste; process optimization; volatile compounds.

Practical Application: Adding soybean paste to reduce fishy smell while enriching the flavor in canned oysters. Fast and easy evaluation of volatile compounds related to aroma in canned oysters by HP-GC-MS.

1 Introduction

Oyster, known as "ocean milk", is a popular seafood specie and greatly consumed worldwide. Oyster has a high content of protein and fat up to 52.6% and 12.0%, respectively (Cruz-Romero et al., 2007). Consumer preference for food has been primarily associated with its nutritional composition and taste profile (Zheng et al., 2015). Seafood could provide superior macronutrients, such as essential amino acid (EAA), n-3 long-chain polyunsaturated fatty acids (n-3 PUFA), and several bioavailable micronutrients (McManus & Newton, 2011). However, high bacterial communities that thrive in oysters deteriorate the quality of raw with long-term transportation to the hinterlands (Chen et al., 2017). To keep the quality and safety of oysters, Heat treatment such as steamed, baked, grilled, fried, and canned food are the main ways of oyster processing in China and other Asian countries (Ghribi et al., 2017; Liu et al., 2021). Among these processes, the canning process is considered that will not materially affect the essential amino acid content in foods such as fish and meat. Canned oyster can reach a prolonged shelf life but has the disadvantages of tasting soft, rotten, and "fishy" and "metal" odor. Therefore, the improvement of canned oysters based on processing conditions and flavor formulation needs to be further studied.

Soybean paste is a traditional fermented food and one of the most popular excipients used worldwide due to its unique flavor-enhancing effect and has antioxidant, cholesterol-lowering, anti-cancer, and anti-hypertensive effects (Jung et al., 2006; Kim et al., 2018). Furthermore, many studies have reported the volatile compounds composition of soybean paste, such as 3-butanedione (yogurt), ethyl butanoate (fruity), 3-methylbutanoic acid (chess-like), 3-methyl-1-propanol (cooked potato-like), and 1-octen-3-ol (mushroom-like) as the contribution of some most important flavors (Zhang et al., 2021). Therefore, the effect of oysters combined with soybean paste is worth exploring.

The objectives of this study were to optimize the processing parameters and seasoning formulations using a combination of orthogonal experiments and sensory analysis to screen the optimal processing and seasoning programs. The headspace solid-phase microextraction (HP-SPME) combined with gas chromatography-mass spectrometry (GC-MS) to detect volatile compounds of the two types of soybean paste samples. The advantage of headspace sampling technology is that it doesn't require complex sample preparation, and it combines with GC-MS to quickly and easily detect volatile compounds, such as analysis of volatile compounds in stewed beef (Wang et al., 2022). In addition, chemistry analysis was used to test the protein, fat, zinc, and taurine content in canned oysters, and microbial enumeration was used to evaluate the shelf life of canned oysters. This study will provide an understanding of canned soybean paste oysters and contribute to the flavor improvement of canned oyster products.

Received 18 July, 2022
Accepted 22 Sept., 2022
[1] *College of Life Science, Fujian Normal University, Fuzhou, China*
[2] *Southern Institute of Oceanography, The Public Service Platform for Industrialization Development Technology of Marine Biological Medicine and Product of State Oceanic Administration, Fujian Normal University, Fuzhou, China*
[3] *Marine Active Substance and Product Technology R&D Center of Ocean Research Institute of Fuzhou, Fujian Normal University, Fuzhou, China*
*Corresponding author: huibin@fjnu.edu.cn; vipin_chen@163.com

2 Materials and methods

2.1 Materials

Oysters are purchased from local markets in Putian city, Fujian Province, China. Soybean paste and condiments are purchased from local markets. Samples are classified as experimental samples (canned soybean paste oyster) and control samples (without soybean paste).

2.2 Canned oyster processing

Oysters were cleaned, soaked in 5% salt water for 10 min, drained, steam-heated for 30 min, and the steaming liquid was reserved. The steaming oysters were soaked in 2% sodium citrate for 20 s and removed in 5% salt water for 1 min. The steaming liquid was seasoned according to the optimal conditions determined by the orthogonal experiment. The processed oyster has emerged in the seasoned steaming liquid for 10 min. After drained, the seasoned oyster was dried for 20 min and fried in hot oil at 150 °C, and the selection of drying temperature and frying time needed to be optimized. Oysters and seasoned steaming liquid were mixed at the ratio of 9:1 by weight.

2.3 Optimization of the oyster processing and seasoning conditions

Based on single factor experiments, seasoning formulations orthogonal experiment was designed, and the factors and levels are listed in Table1. Under the same oyster processing conditions, it was dried at 90 °C for 20 min and fried in hot oil at 150 °C for 5 min. Seasoning formulation includes the amount of soybean paste, I + G (Disodium 5'-presenting nucleotide), and vinegar addition, experiments design was three levels with nine test groups. The assays were carried out according to $L_9(3^4)$, experiment was designed according to four factors at three levels of a rectangular matrix, a total of nine test groups, and each test was repeated 3 times. Two factors affect oyster processing. In our experiment, two single factors were examined to observe the effects of each factor on the oyster meat quality. The experimental conditions were set as follows: drying temperature at 80 °C, 90 °C, and 100 °C, and frying time for 4, 5, and 6 min. The best combination of levels was chosen as the processing conditions for further study.

2.4 Volatiles composition analysis

Canned oyster samples were took and homogenized. Two-point five gram of sample were weighed and added to 40 mL chilled headspace vials, then 2.5 mL of saturated NaCl aqueous solution and 80 μL of cyclohexanone (1 μg/mL) internal standard solution were added to each vial. The solid-phase microextraction head (Supelco SPME Fiber Assembly 50/30 μm DVB/CAR/PDMS, Sigma Aldrich Technologies Inc, USA) was placed in the chilled headspace vials, and the extraction was performed at 65 °C for 30 min under magnetic stirring. All vials were immediately sealed for GC-MS analysis.

Determination of volatile compounds using headspace solid-phase microextraction (HS-SPME) coupled with gas chromatography-mass spectrometry (GC-MS). The analyses of volatiles compounds were carried out using an Agilent Model 6980N/5975C gas chromatography-mass spectrometer (Agilent Technologies Inc, California, USA) and HP-INNOwax Polyethylene Glycol (60 m × 0.25 mm × 0.25 μm), and compound analysis using NIST17 library for alignment. Headspace and GC-MS operating conditions were described in previous studies with slight modification (Rahman et al., 2022). The chromatographic conditions were as follows: inlet temperature 250 °C, carrier gas He, and flow rate 1 ml/min. The temperature was increased to 60 °C and maintained for 6 min, further elevated to 100 °C at the rate of 3 °C/min, increased again to 230 °C at 5 °C/min, and maintained for 10 min. The MS conditions were as follows: MS ion source scanning at 230 °C, ionization mode EI, electron energy 70 eV, and scanning mass range of 33-550 amu.

Table 1. Factors and levels in the orthogonal experiment of seasoning formulations.

Levels	Factors		
	Soybean paste (%)	I + G (%)	Vinegar (%)
1	15	0	0.3
2	20	0.01	0.5
3	25	0.02	0.7

2.5 Sensory analysis

Sensory quality assessment of canned oysters was carried out to optimize oyster frying time, drying temperature, and flavoring formulation. Panel members (n = 30, fourteen female, fifteen male; ages 20-40; mean age 31) were received about sensory examinations of training. After the training phase, samples were evaluated using 0-10 scores range with 0 (denoting an unacceptable condition) and 10 (well content). The assessors evaluated canned oyster sample in two processing session, evaluating two replications of each sample. Each time 25 g of oyster was evaluated, and testing took place in a sensory laboratory. Still mineral water was used for rinsing between samples. The descriptors are shown in Table 2.

2.6 Determination of nutrient composition

The proximate compositions of canned oysters were performed according to the following methods. Protein was accessed using micro-Kjeldahl method (Mæhre et al., 2018). Fat content was determined using Soxhlet method (Fernandes & Salas-Mellado, 2017). Zinc and taurine was evaluated according to Chinese Standard Method (2016, 2017) GB5009.14, 2017 and GB5009.169, 2016.

2.7 Microbial enumeration

Microbial enumeration was measured as described by Li et al. (2020) with some modifications. Twenty-five grams of canned oyster with soybean paste was combined with 225 mL of sterile physiological saline (0.85%; w/v) homogenized for 3 min. Then, 10 mL of several serial 10-fold dilutions. 1 mL of each dilution concentration was spread on the surface of plate count agar (Beijing Aobox Biotechnology, co. Ltd., Beijing, China). After being incubated at 30 °C for 48 h, colony-forming units

Table 2. Oyster attributes and their definition with reference standards of score.

Attribute	Description	Score	
		Unaccepted (0)	Well content (10)
Plumpness	How well-rounded and full in form oyster meat is (visual)	wrinkled	plump
Salty	Taste estimated by sodium salts, such as NaCl	Overly salty	Moderate salty
Sweet	Taste stimulated by sucrose and other sugars	Overly sweet	Moderate sweet
Firmness	Refer to the consistency of how soft and the how firm resistance the (mouth) oyster meat	Soft and rotten	Firm and whippy
Color	Refer to the color and shine of oyster meat (in visual)	Overfocus or over white	Slightly golden, shiny
Scent	Relating to characteristics to flavor like seaweed(flavor)	No significant fragrance	Strong fragrance
Fishy	Relating to the smell of fish	Serious fishy smell	No obvious fishy smell
Sour	The taste is stimulated by acids, such as citric, malic, phosphoric, etc. (flavor) the in mouth)	Overly sour	No sour
Tangy	Having a strong, tart, pleasantly stimulating flavor	Stronger smell	Moderate smell
Bitter	The taste is stimulated by substances such as caffeine and hop bitters (flavor)	Stronger bitter	No bitter

Table 3. Orthogonal experimental design L_9 (3^4) and experimental results.

Run	Variable conditions				Sensory score
	Soybean paste %	I+G %	Vinegar %	Blank	
1	1(15)	1(0)	1(0.3)	1	82.34
2	1	2(0.01)	2(0.5)	2	83.53
3	1	3(0.02)	3(0.7)	3	83.21
4	2(20)	1	2	3	85.78
5	2	2	3	1	86.14
6	2	3	1	2	85.16
7	3(25)	1	3	2	85.32
8	3	2	1	3	84.76
9	3	3	2	1	84.05
K_1	248.09	253.45	252.26	252.53	
K_2	257.08	254.43	253.36	254.01	
K_3	254.14	252.42	254.67	253.75	
$K_1/3$	82.69	84.48	84.09	84.18	
$K_2/3$	85.69	84.81	84.45	84.67	
$K_3/3$	84.71	84.14	84.89	84.58	
Range	2.99	0.67	0.80	0.49	

The blank indicates the error of the experiment. K_1, K_2, and K_3 represent the sum of all Level 1, Level 2, and Level 3 sensory scores for each factor, respectively; $K_1/3$, $K_2/3$, and $K_3/3$ refer to the average of K_1, K_2, and K_3, respectively. The range indicates the difference between $K_1/3$, $K_2/3$, and $K_3/3$. The sensory score was the average panel number (n = 30).

counted the number of colonies for each plate. The detection of *Escherichia. coli* in canned oyster according to the microbiology of food and animal feeding stuff - Horizontal method for the detection and enumeration of presumptive *Escherichia coli* - Most probable number technique (International Organization for Standardization, 2005).

3 Results and discussion

3.1 Optimization of oyster processing and seasoning condition

The results of the experiments and the analysis of the range was shown in Table 3 and Figure 1. The optimum processing condition was the combined drying temperature at 90 °C for 20 min and frying time for 6 min at 150 °C, with the highest

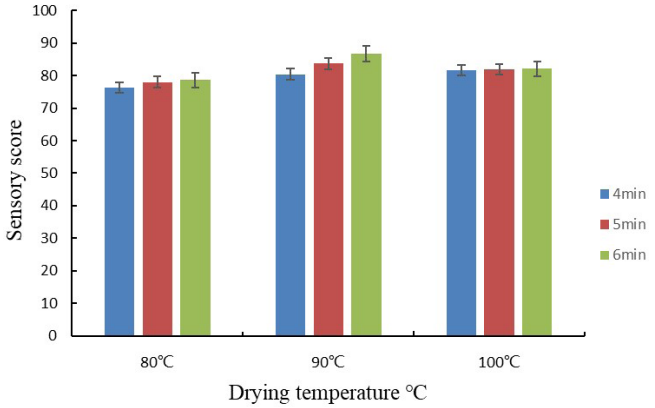

Figure 1. Oyster meat processing optimization by single factor experiment. 4 min, 5 min and 6 min represent the frying time.

Table 4. Analysis of volatile compounds of the canned oyster.

No	Volatile compounds	Total area (%)[a]		Odor description	References
		COSP	CO		
	Alcohols				
1	1-Pentanol	0.21 ± 0.00	0.86 ± 0.31	Green, wax, roasted	(Giri et al., 2010a)
2	2-Octanol	26.90 ± 3.59	ND		
3	1-Octen-3-ol	0.99 ± 0.07	0.68 ± 0.21	Fishy, grassy, rose and hay aroma, mushroom	(Zhang et al., 2010)
4	Linalool	0.16 ± 0.00	ND		
5	1-Octanol	0.17 ± 0.02	ND	Citrus, sweet orange, sweet floral, green incense	(Zhang et al., 2010)
6	2-furanmethanol	9.42 ± 0.62	ND	Cameral, sweet, bitter, and spicy smell	(Zhang et al., 2010)
7	3-methyl-1-propanol	0.09 ± 0.01	ND	Raw potato	(Giri et al., 2010a)
8	Phenylethyl alcohol	1.01 ± 0.07	0.36 ± 0.11	Honey, rosy	(Giri et al., 2010a)
9	Ethanol	ND	9.23 ± 1.09	Alcoholic, bread dough	(Giri et al., 2010a)
10	Propanol	ND	1.6 ± 0.17	Plastic, musty	(Giri et al., 2010a)
11	1-Pentanol-4-methyl	ND	0.91 ± 0.24		
	Aldehydes				
12	Pentanal	0.65 ± 0.33	0.47 ± 0.00	Almond, malt, pungent	(Kaseleht et al., 2011)
13	Hexanal	0.65 ± 0.09	1.17 ± 0.00	Fishy, Grassy	(Giri et al., 2010a)
14	Heptanal	0.95 ± 0.09	ND	Fishy, oily, fatty, sweet, nutty	(Giri et al., 2010a)
15	2-Hexenal	0.11 ± 0.03	ND	Bitter, almond	(Giri et al., 2010a)
16	Octanal	2.19 ± 0.04	ND	Fatty, nutty	(Giri et al., 2010a)
17	Nonanal	1.86 ± 0.13	ND	Green, fatty	(Giri et al., 2010a)
18	(E)2-Octenal	0.43 ± 0.02	ND	Dirty, stale, dry-cured ham	(Whetstine et al., 2005)
19	3-Methy-propanal	0.25 ± 0.07	ND	Meaty, potato	(Giri et al., 2010a)
20	Furfural	2.70 ± 0.38	ND	Sweet	(Zhang et al., 2010)
21	Decanal	2.90 ± 0.10	ND	Gas, stewed, gravy	(Machiels et al., 2003)
22	Benzaldehyde	3.90 ± 0.38	ND	Bitter almond, burnt sugar, fruit	(Zhang et al., 2010)
23	(E)2-Nonenal	0.18 ± 0.02	ND		
24	5-Hydroxymenthyl-2-furaldehyde	0.17 ± 0.00	ND		
25	Phenylethanoid	2.06 ± 0.23	ND		
26	Myrtanal	0.19 ± 0.09	ND		
	Esters				
27	Octanoic acid ethyl ester	0.11 ± 0.00	ND	Brandy aroma, wax incense, fruit	(Zhang et al., 2010)
28	Furfuryl acetate	0.61 ± 0.02	ND		
29	Methyl salicylate	0.09 ± 0.02	ND		
30	Ethyl phenylacetate	0.12 ± 0.00	ND	Strong and sweet fragrance of honey	(Zhang et al., 2010)
31	Ethyl palmitate	0.19 ± 0.00	ND	Incense wax smell, butter aroma	(Zhang et al., 2010)
	Acids				
32	Acetic acid	0.12 ± 0.02	0.99 ± 0.64	Pungent, vinegar like	(Niu et al., 2011)
33	Guanidine acetic acid	0.13 ± 0.01	ND		
	Phenols				
34	Guaiacol	0.13 ± 0.00	ND	Aromatic smell, burnt, smoky	(Zhang et al., 2010)
35	Phenol	0.15 ± 0.04	ND	Special smell, sweet smell,	(Zhang et al., 2010)
36	2-Methoxy-4-vimlphenol	0.22 ± 0.01	ND		
	Alkenes				
37	3-Carene	0.49 ± 0.00	ND		
38	D-Terpene diene	ND	2.94 ± 0.83		
39	Caryophyllene	1.79 ± 0.07	ND		
	Ketones				
40	2-Heptanone	0.23 ± 0.00	2.09 ± 0.71		
41	2-Octanone	0.63 ± 0.06	ND	Soapy, floral, gas, green	(Giri et al., 2010a)
42	2-Nonanone	0.17 ± 0.01	ND		
43	3-Hydroxy-2-butanone	ND	2.36 ± 0.41		
	Pyrazine				
44	2-Menthyl pyrazine	0.14 ± 0.00	1.08 ± 0.31		
45	2,5-Dimethyl pyrazine	0.31 ± 0.00	4.65 ± 0.91	Pungent aroma of fried flowers and chocolate, butter odor	(Zhang et al., 2010)
46	2,6-Dimethyl pyrazine	ND	0.83 ± 0.15	Roasted, coffee, peanut	(Zhang et al., 2010)
47	2,3,5-Thrimthyl pyrazine	ND	2.14 ± 0.553	Baked goods, coffee and pork, beef peanut odor	(Zhang et al., 2010)
	Pyridine				
48	2-Pentyl pyridine	0.31 ± 0.02	ND		
	Pyrrole				
49	2-Aertylpyrrole	0.39 ± 0.01	ND	Bread aroma, bakery aroma	(Zhang et al., 2010)
	Furan				
50	2-Pentylfuran	5.44 ± 0.28	1.16 ± 0.46	Bean aroma, fruity, green fragrance, vegetables	(Zhang et al., 2010)
	Others				
51	Isopropyltoluenes	0.17 ± 0.01	ND		

[a]Total area (%) of volatile compound for two Canned oyster samples. ND represent not detectable.

sensory score of 86.73. And the optimum seasoning condition was 20% soybean paste, 0.01% I+G, and 0.7% vinegar. The range value of soybean paste concentration is 2.99, which shows the largest range value and means the greatest influence of all factors. Therefore, the optimum processing and season conditions were operated for the treatment of oysters.

3.2 Identified volatiles compounds in canned oyster

The volatile compounds were identified by MS based on the NIST17 library, and the common volatile compounds of experimental and control samples are presented in Table 4. These compounds might be some of the important aroma compounds in experimental and control samples. Forty-four compounds were identified in the experimental sample. Among them, 2-octanol exhibited the highest concentration in experimental samples, followed by 2-furanmenthanol, 2-pentylfuran, benzaldehyde, and decanal. In contrast, only 17 compounds were detected in the control sample, and dominant compounds include ethanol, 2,5-dimethyl pyrazine, D-terpene diene, 3-hydroxy-2-butanone, and 2-Heptanone. It suggested that the volatile compounds differ greatly between the two types of samples.

In the control sample, Alcohols were detected most frequently and were present in the highest amounts, the result might be consistent with similar to the large amount of n-3 PUFAs found in oysters. The main part of the volatiles oysters were volatiles arising from the fatty acid oxidation, mainly n-3 PUFAs (Piveteau et al., 2000). Four pyrazines were detected in the control sample, including 2-menthyl pyrazine, 2,5-dimethyl pyrazine, 2,6-dimethyl pyrazine, and 2,3,5-trimethyl pyrazine. However, pyrazine has not been reported in fresh oysters and may be produced during the heating treatment process.

Experimental samples had relatively high contents of alcohols, aldehydes, and furan, while a greater number of alcohols, aldehydes, esters, and furan species were presented than in control samples. Most of the compounds have previously been reported in soy sauce or soybean paste (Inoue et al., 2016). Alcohols, which provide pleasant aromas and sweet flavors, are known as the metabolic products of yeast fermentation (Giri et al., 2010b). Three alcohols of relatively contents were increased in experimental samples, compared with control samples, including 2-octanol, 1-octen-3-ol, phenylethyl alcohol, and 2-furanmenthanol. These compounds were commonly identified as the key aroma compounds in soybean paste, suggesting that soybean paste enrich the species and content of aroma compounds in canned oyster (Zhang et al., 2021). Among the alcohols, 2-octanol and 2-furanmethanol were the highest relative content in the experimental sample and were not detected in the control sample, suggesting that these compounds were special aroma compounds in soybean paste. Phenylethyl alcohol and 1-octen-3-ol were detected in the experimental sample with higher relative content compared with the control sample. This indicates that soybean paste enriches the contents of the two compounds. It is worth noting that ethanol was not detected in the experimental sample, greatly eliminating the alcoholic odor of the high content, and the result might be consistent with due to addition of soybean paste.

Aldehydes play an important role in the flavor of soybean paste. The odor threshold of aldehydes is generally lower than that of alcohols, and they can form a special flavor effect when superimposed with other materials (Feng et al., 2015). Similarly, the types and relative contents of aldehydes were richer than those of the control samples. Heptanal, octanal, decanal, and benzaldehyde, which exhibited malty and fruity notes, were identified in soybean paste (Zhang et al., 2021). Furans, as a class of heterocyclic compounds, are generated by Maillard reaction due to high temperatures treatment, such as drying and frying (Flores, 2018). 2-pentylfuran (bean flavor) was the only furan flavor compound in experimental and control samples, which was also reported as an important flavor compound in sauce spareribs (Shi et al., 2020) and roasted pork (Xie et al., 2008). The relative content of 2-pentylfuran is higher in experimental samples compared with control samples, suggesting that the addition of soybean paste increases 2-pentylfuran relative content in the canned oyster. The relative content of pyrazine exhibited a decreasing trend in the experimental compared with the control sample, and 2,6-dimethyl pyrazine and 2,3,5-trimethyl pyrazine were not detected in the experimental sample. The addition of soybean paste may inhibit the production of pyrazine.

3.3 Nutritional ingredient of canned oyster

Oysters are a common and commercially important shellfish and are widely consumed in fresh or processed forms. In this study, the canned oyster was chemically analyzed, as listed in Table 5, the content of protein was the highest (20.60 g/100 g), followed by that of fat (10.10 g/100 g), and zinc (10.30 mg/100 g). Taurine is one of the special amino acids contained in oysters, which plays an important role in the process of human growth and development, and has the function of regulating human immunity and lowering the cholesterol content of the body. In addition, the risk of coronary heart disease was reduced through the effects of both taurine alone and combined with n-3 PUFAs, with the large amount of n-3 PUFAs found in oysters (Yamori et al., 2001). The taurine content is high in canned oysters 73.10 mg/100 g, which is slightly higher than that of fish 40-70 mg/100 g.

Table 5. Nutritional ingredient of canned oyster and result of microbial enumeration.

Nutritional ingredient	Count	NRV (%)	Measurement items	0 d	35 d
Protein (g/100 g)	20.6 ± 1.6	34	TVC (CFU/g)	ND	< 10
Fat (g/100 g)	10.1 ± 0.8	17			
Zinc (mg/100 g)	10.3 ± 1.2	69	*E. coli* counts	ND	< 0.3
Taurine (mg/100 g)	73.1 ± 2.8				

NRV (Nutrient Reference Values) – presented by the proportion of nutrient content in 100 g of food to the daily intake of that nutrient. ND represent not detected.

3.4 Result of microbial enumeration

The microbial count is one of the criteria to determine whether the food is edible and needs to meet national standards. In this study, the total viable counts (TVC) and *E. coli* counts were determined for canned oysters with soybean paste and after 35 d storage. As shown in Table 5, the initial bacterial counts and *E. coli* counts were not detected, and the test results were below the national standard after 35 d. This may indicate that drying and dehydration, and high-temperature frying largely reduce the moisture of the product, and vacuum packaging isolates the air. In this environment, the growth of microorganisms is largely limited, extending the shelf life of canned oysters.

4 Conclusions

The orthogonal experiment could effectively optimize processing and seasoning conditions on the canned oyster. The following optimum conditions for the drying temperature, frying time, and soybean paste addition by orthogonal experiment: drying temperature at 90 °C for 20 min, frying time for 6 min at 150 °C, and soybean paste addition of 20%. Under these conditions, the sensory score is the highest. The addition of soybean paste enriches species and the content of aroma compounds in canned oysters by identification of volatile compounds using GC-MS, and 2-octanol, 2-furanmenthanol, 2-pentylfuran, and benzaldehyde were the main flavor compounds in canned oyster with the addition of soybean paste. Protein, fat, zinc, and taurine contents were evaluated and the nutritional value of canned oysters met the daily needs of people in this experiment. The microbial count is one of the indicators to evaluate shelf life, and the results were obtained that canned oysters could achieve a shelf life of 35 d in this experiment. The present work provides initial insights into the effects of soybean paste addition on canned oysters.

Acknowledgements

This work was supported by the projects of the Distinguished Professor of Minjiang Scholar program (2019); the Science and Technology Department, Fujian, China (University-industry cooperation research fund, NO:2022N5015); National Natural Science Foundation of China (31401564); China Postdoctoral Science Foundation (2015M582030); the scientific research innovation program Xiyuanjiang River Scholarship of College of Life Sciences, Fujian Normal University. We acknowledge the platform support of Key Laboratory of Special Marine Bio-Resources Sustainable Utilization of Fujian Province.

References

Chen, H., Wang, M., & Lin, X. (2017). Optimization and application of spray-drying process on oyster cooking soup byproduct. *Food Science and Technology (Campinas)*, 38(3), 407-412. http://dx.doi.org/10.1590/1678-457x.05017.

Chinese Standard Method. (2016). *GB5009.169: determination of taurine in foods* (in Chinese). Beijing: China Standard Press of China.

Chinese Standard Method. (2017). *GB5009.14: determination of zinc in foods* (in Chinese). Beijing: China Standard Press of China.

Cruz-Romero, M., Kelly, A. L., & Kerry, J. P. (2007). Effects of high-pressure and heat treatments on physical and biochemical characteristics of oysters (Crassostrea gigas). *Innovative Food Science & Emerging Technologies*, 8(1), 30-38. http://dx.doi.org/10.1016/j.ifset.2006.05.002.

Feng, Y., Su, G., Zhao, H., Cai, Y., Cui, C., Sun-Waterhouse, D., & Zhao, M. (2015). Characterisation of aroma profiles of commercial soy sauce by odour activity value and omission test. *Food Chemistry*, 167, 220-228. http://dx.doi.org/10.1016/j.foodchem.2014.06.057. PMid:25148982.

Fernandes, S. S., & Salas-Mellado, M. L. (2017). Addition of chia seed mucilage for reduction of fat content in bread and cakes. *Food Chemistry*, 227, 237-244. http://dx.doi.org/10.1016/j.foodchem.2017.01.075. PMid:28274428.

Flores, M. (2018). Understanding the implications of current health trends on the aroma of wet and dry cured meat products. *Meat Science*, 144, 53-61. http://dx.doi.org/10.1016/j.meatsci.2018.04.016. PMid:29716761.

Ghribi, F., Bejaoui, S., Rabeh, I., Aouini, F., Chetoui, I., & El Cafsi, M. (2017). Effects of culinary methods on nutritional characteristics of the edible shellfish noah's ark (Arca noae L., 1758) from Tunisian coasts. *Journal of Aquatic Food Product Technology*, 26(10), 1324-1336. http://dx.doi.org/10.1080/10498850.2017.1390714.

Giri, A., Osako, K., & Ohshima, T. (2010a). Identification and characterisation of headspace volatiles of fish miso, a Japanese fish meat based fermented paste, with special emphasis on effect of fish species and meat washing. *Food Chemistry*, 120(2), 621-631. http://dx.doi.org/10.1016/j.foodchem.2009.10.036.

Giri, A., Osako, K., Okamoto, A., & Ohshima, T. (2010b). 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(4), 1027-1040. http://dx.doi.org/10.1016/j.foodres.2010.01.012.

Inoue, Y., Kato, S., Saikusa, M., Suzuki, C., Otsubo, Y., Tanaka, Y., Watanabe, H., & Hayase, F. (2016). Analysis of the cooked aroma and odorants that contribute to umami aftertaste of soy miso (Japanese soybean paste). *Food Chemistry*, 213, 521-528. http://dx.doi.org/10.1016/j.foodchem.2016.06.106. PMid:27451212.

International Organization for Standardization – ISO. (2005). *ISO Standard 7251: microbiology of food and animal feeding stuff - Horizontal method for the detection and enumeration of presumptive Escherichia coli - Most probab;e number technique.* Geneva: ISO.

Jung, K. O., Park, S. Y., & Park, K. Y. (2006). Longer aging time increases the anticancer and antimetastatic properties of doenjang. *Nutrition (Burbank, Los Angeles County, Calif.)*, 22(5), 539-545. http://dx.doi.org/10.1016/j.nut.2005.11.007. PMid:16504476.

Kaseleht, K., Leitner, E., & Paalme, T. (2011). Determining aroma-active compounds in Kama flour using SPME-GC/MS and GC-olfactometry. *Flavour and Fragrance Journal*, 26(2), 122-128. http://dx.doi.org/10.1002/ffj.2032.

Kim, M. S., Kim, B., Park, H., Ji, Y., Holzapfel, W., Kim, D. Y., & Hyun, C. K. (2018). Long-term fermented soybean paste improves metabolic parameters associated with non-alcoholic fatty liver disease and insulin resistance in high-fat diet-induced obese mice. *Biochemical and Biophysical Research Communications*, 495(2), 1744-1751. http://dx.doi.org/10.1016/j.bbrc.2017.12.003. PMid:29222051.

Li, Y., Zhuang, S., Liu, Y., Zhang, L., Liu, X., Cheng, H., Liu, J., Shu, R., & Luo, Y. (2020). Effect of grape seed extract on quality and microbiota community of container-cultured snakehead (Channa argus) fillets during chilled storage. *Food Microbiology*, 91, 103492. http://dx.doi.org/10.1016/j.fm.2020.103492. PMid:32539979.

Liu, C., Ji, W., Jiang, H., Shi, Y., He, L., Gu, Z., & Zhu, S. (2021). Comparison of biochemical composition and non-volatile taste active compounds in raw, high hydrostatic pressure-treated and steamed

oysters Crassostrea hongkongensis. *Food Chemistry*, 344, 128632. http://dx.doi.org/10.1016/j.foodchem.2020.128632. PMid:33229146.

Machiels, D., van Ruth, S. M., Posthumus, M. A., & Istasse, L. (2003). Gas chromatography-olfactometry analysis of the volatile compounds of two commercial Irish beef meats. *Talanta*, 60(4), 755-764. http://dx.doi.org/10.1016/S0039-9140(03)00133-4. PMid:18969100.

Mæhre, H. K., Dalheim, L., Edvinsen, G. K., Elvevoll, E. O., & Jensen, I. J. (2018). Protein determination-method matters. *Foods*, 7(1), 5. http://dx.doi.org/10.3390/foods7010005. PMid:29301260.

McManus, A., & Newton, W. (2011). *Seafood, nutrition and human health: a synopsis of the nutritional benefits of consuming seafood.* Perth: Curtin University of Technology.

Niu, Y., Zhang, X., Xiao, Z., Song, S., Eric, K., Jia, C., Yu, H.,& Zhu, J. (2011). Characterization of odor-active compounds of various cherry wines by gas chromatography-mass spectrometry, gas chromatography-olfactometry, and their correlation with sensory attributes. *Journal of Chromatography. B, Analytical Technologies in the Biomedical and Life Sciences*, 879(23), 2287-2293. http://dx.doi.org/10.1016/j.jchromb.2011.06.015. PMid:21727038.

Piveteau, F., Le Guen, S., Gandemer, G., Baud, J. P., Prost, C., & Demaimay, M. (2000). Aroma of fresh oysters Crassostrea gigas: composition and aroma notes. *Journal of Agricultural and Food Chemistry*, 48(10), 4851-4857. http://dx.doi.org/10.1021/jf991394k. PMid:11052745.

Rahman, F. U., Nawaz, M. A., Liu, R., Sun, L., Jiang, J., Fan, X., Liu, C., & Zhang, Y. (2022). Evaluation of volatile aroma compounds from Chinese wild grape berries by headspace-SPME with GC-MS. *Food Science and Technology (Campinas)*, 42, e54320. http://dx.doi.org/10.1590/fst.54320.

Shi, J., Nian, Y., Da, D., Xu, X., Zhou, G., Zhao, D., & Li, C. (2020). Characterization of flavor volatile compounds in sauce spareribs by gas chromatography–mass spectrometry and electronic nose. *LWT*, 124, 109182. http://dx.doi.org/10.1016/j.lwt.2020.109182.

Wang, L., Chen, Q., Zhong, Z., Yi, Y., Hou, W., & Wang, H. (2022). Research on variation of volatile compounds of Cinnamomum cassia Presl in different processing stage of stewed beef. *Food Science and Technology (Campinas)*, 42, e09322. http://dx.doi.org/10.1590/fst.09322.

Whetstine, M. E. C., Cadwallader, K. R., & Drake, M. (2005). Characterization of aroma compounds responsible for the rosy/floral flavor in cheddar cheese. *Journal of Agricultural and Food Chemistry*, 53(8), 3126-3132. http://dx.doi.org/10.1021/jf048278o. PMid:15826069.

Xie, J., Sun, B., Zheng, F., & Wang, S. (2008). Volatile flavor constituents in roasted pork of Mini-pig. *Food Chemistry*, 109(3), 506-514. http://dx.doi.org/10.1016/j.foodchem.2007.12.074.

Yamori, Y., Liu, L., Ikeda, K., Miura, A., Mizushima, S., Miki, T., & Nara, Y. (2001). Distribution of twenty-four hour urinary taurine excretion and association with ischemic heart disease mortality in 24 populations of 16 countries: Results from the WHO-CARDIAC Study. *Hypertension Research*, 24(4), 453-457. http://dx.doi.org/10.1291/hypres.24.453. PMid:11510759.

Zhang, X., Wei, J., Zhao, S., Jia, H., Guo, C., Wang, Z., Gao, Z., Yue, T., & Yuan, Y. (2021). Flavor differences between commercial and traditional soybean paste. *LWT*, 142, 111052. http://dx.doi.org/10.1016/j.lwt.2021.111052.

Zhang, Y., Li, X., Lo, C. K., & Guo, S. T. (2010). Characterization of the volatile substances and aroma components from traditional soypaste. *Molecules (Basel, Switzerland)*, 15(5), 3421-3427. http://dx.doi.org/10.3390/molecules15053421. PMid:20657491.

Zheng, J. y., Tao, N., Gong, J., Gu, S. Q., & Xu, C. (2015). Comparison of non-volatile taste-active compounds between the cooked meats of pre- and post spawning Yangtze Coilia ectenes. *Fisheries Science*, 81(3), 559-568. http://dx.doi.org/10.1007/s12562-015-0858-7.