

Original Research Articles

Effects of different diets on the edible quality and flavor-related compounds of Chinese mitten crab (*Eriocheir sinensis*)

Wenxiang Yao^{1†}, Ningyang Sun^{1,2†}, Xinze Li¹, Xiaoya Wu¹, Guoan Hua³, Sizhe Zhao³, Chunyan Zhang¹¹ Jiangsu Agri-animal Husbandry Vocational College, Taizhou, China, ² Jiangsu Ocean University, Lianyungang, China, ³ Jiangsu Haorun Biological Industry Group Co., Ltd., Taizhou, ChinaKeywords: Chinese mitten crab, Mealworm, Black soldier fly larvae, Fly maggot, Golden apple snail, Trash fish, *Eriocheir sinensis*<https://doi.org/10.46989/001c.165930>

Israeli Journal of Aquaculture - Bamidgah

Vol. 78, Issue 3, 2026

This study aims to explore the feasibility of trash fish (TF), mealworm (MW), black soldier fly larvae (BSFL), fly maggot (FLM), and golden apple snail meat (GASM) as a diet for Chinese mitten crab (*Eriocheir sinensis*). Five experimental diets (TF, MW, BSFL, FLM and GASM) were fed to crabs with an initial weight of 4.15g for 8 weeks. The results showed that the muscle-free flavor amino acid (FFAA) content in the BSFL and GASM groups was similar to that in the TF group ($P > 0.05$). The hepatopancreas FFAA content in the GASM group was similar to that in the TF group ($P > 0.05$). In the GASM group, only muscle 5'-inosinic acid did not reach the same level as the TF group ($P < 0.05$), while in the MW and BSFL group, only the muscle 5'-adenosine acid and the hepatopancreas 5'-guanosine acid content reached the same level as the TF group, respectively ($P > 0.05$). The proportion of hepatopancreas n-6 PUFAs in the MW and GASM groups reached the same level as the TF group ($P > 0.05$), while the proportion of hepatopancreas n-3 PUFAs in all four groups was significantly lower than the TF group ($P < 0.05$). The proportion of hepatopancreas n-3 PUFAs in the GASM group was significantly higher than that in the BSFL, MW, and FLM groups ($P < 0.05$). In this experiment, the three insect diets have a significant negative impact on the edible quality and flavor of the crabs. The GASM diet shows little effect on muscle and hepatopancreas FFAAs and nucleotides. The proportion of hepatopancreas n-3 PUFAs in the GASM group was significantly lower to the TF group, but it was still significantly higher than those of the three insect groups. In conclusion, based on the measured biochemical indicators, among the four types of diet on the edible quality and flavor, GASM has the greatest potential to replace TF as the diet for *E. sinensis*.

1. INTRODUCTION

The Chinese mitten crab (*Eriocheir sinensis*) is an important commercially farmed crab species in China. In 2023, the national farmed output reached 888,600 tons.¹ *E. sinensis* has a delicious taste and high nutritional value, and is highly favored by consumers. The breeding methods and feed composition will directly affect the taste, nutrition, and health of crabs.² Trash fish (TF) is a traditional diet for *E. sinensis*, playing a crucial role in the growth, nutritional quality, and taste characteristics of the crabs.³ However, using TF as a diet has problems such as unstable sources and uncontrollable quality.⁴ Over-reliance on TF may restrict the development of the *E. sinensis* farming industry. Therefore, numerous studies are exploring a wider range of protein sources.⁵ The 813/2017 EU regulation has approved the use of seven types of insects as animal feed,

namely black soldier fly (*Hermetia illucens*), common housefly (*Musca domestica*), striped cricket (*Gryllobates sigillatus*), field cricket (*Gryllus assimilis*), domestic cricket (*Acheta domestica*), small yellow mealworm (*Alphitobius diaperinus*), and mealworm (*Tenebrio molitor*, MW).⁶ The golden apple snail (*Pomacea canaliculata*, GAS) was introduced to Asia from the Philippines in early 1980 for commercial purposes as a source of protein food.⁷ Using insects and GAS meat (GASM) as animal feed and sustainable raw materials has many advantages over traditional animal protein, such as lower production costs and environmental friendliness.

Numerous studies have shown that using BSFL, MW, FLM, and GASM protein meal can replace part of dietary fish meal in various aquatic animals, or can be directly used for feeding aquatic animals, without any adverse effects on the growth performance and weight gain rate.⁷⁻¹¹ In previous studies, the use of MW meal as a substitute for fish

† Joint first authors

a Corresponding author. Wenxiang Yao, email: 2642066807@qq.com

meal in the feed of species such as Nile tilapia (*Oreochromis niloticus*),¹² silver carp (*Cyprinus rubrofasciatus*),¹³ and mirror carp (*Cyprinus carpio* var. *specularis*)¹⁴ was found to increase the content of certain amino acids in the muscle, while having no significant effect on the content of free amino acids (FAAs) in the muscle. Yang et al.¹⁵ conducted an experiment by replacing part of the dietary fish meal of largemouth bass (*Micropterus salmoides*) with BSFL meal. They found that a 10%-30% substitution rate did not affect the growth performance and had no adverse effect on the fatty acid composition of the fish bodies. Liu et al.¹⁶ conducted an experiment by replacing part of the dietary fish meal with BSFL meal on hybrid croakers (*Siniperca chuatsi* ♀ × *Siniperca scherzeri* ♂). They found that a 20% substitution rate could significantly improve the growth performance, without any adverse effects on the muscle quality. In addition, replacing dietary fish meal with 10% GASM meal of catfish (*Pangasius* sp.) resulted in no negative impact on the growth and feed utilization.⁵ While fed *E. sinensis* with GASM, the results showed significant improvements in growth and nutritional quality.¹⁷ Substituting part of the dietary fish meal with FLM meal does not affect the growth performance of mirror carp,¹⁸ tilapia,¹⁹ Chinese soft-shelled turtle (*Pelodiscus sinensis*),²⁰ and effectively improves the weight gain rate and protein content of the farmed animals.

At present, most experiments have focused on the substitution of dietary fish meal with alternative protein sources. There has been no study on the substitution of TF with insects or GASM on *E. sinensis*. Therefore, this study aims to investigate the nutritional levels of MW, BSFL, GASM, FLM, and TF, as well as the effects of replacing TF with these four diets on the edible quality and flavor compounds of *E. sinensis*. It is expected to provide certain theoretical basis and practical reference for the application of MW, BSFL, FLM, and GASM in *E. sinensis* farming.

2. MATERIALS AND METHODS

2.1. EXPERIMENTAL CRAB AND FEEDING MANAGEMENT

The juvenile *E. sinensis* were provided by Jiangsu Haoran Bio-Industrial Group Co., Ltd. Crabs were initially reared in canvas pools, with polyvinyl chloride (PVC) pipes serving as shelters. During the rearing period, commercial feed (from Jiangsu Haoran Bio-Industrial Group Co., Ltd., with a crude protein content ≥ 40%) was provided. Feeding was stopped 24 hours before the formal experiment, and 400 juvenile crabs with intact appendages, good vitality, in the molting period, and an initial body weight of 4.15 ± 0.10 g were selected for the feeding trial. The 400 crabs were randomly distributed into a circulation water system consisting of 20 PVC tanks (1.0 m × 1.0 m × 0.5 m), with 20 crabs per tank. Crab nests were placed in tanks to serve as shelters. The experiment was divided into 5 groups, with 4 replicates for each group. The five diet types were TF, MW, BSFL, GASM, and FLM. The proximate composition of the diets (Table 1), as well as the composition of amino acids (Table 2) and fatty acids (Table 3), was determined. During the breeding

period, all crabs were fed twice a day (at 7:00 and 17:00) to apparent satiation. The feces at the bottom of the tanks were removed by siphoning once a day. The system water was replenished promptly after siphoning, and the water source was the filtered river water. The experiment lasted for 56 days. The water quality parameters were tested by ProQuatro/1020 (YSI, American), the water temperature, dissolved oxygen, pH, ammonia nitrogen, and nitrite were kept at 24–29°C, ≥ 5.8 mgL⁻¹, 7.0–8.5, ≤ 0.2 mgL⁻¹, and ≤ 0.05 mgL⁻¹, respectively. All 20 PVC tanks are within a single circulating water system, and the water quality of each parallel group remains consistent.

2.2. SAMPLING

After the feeding trial was completed, crabs in each tank were separately collected. Four crabs from each replicate were randomly selected, placed in a steamer, and steamed for 15 minutes. The steaming treatment of samples was performed to simulate the cooking process, aiming to analyze the flavor compound composition of crabs in an edible state. After steaming, the crab shells were opened, and the steamed hepatopancreas were collected and placed in a 10 ml centrifuge tube for the determination of FAAs, fatty acids, and flavor nucleotides. The crab leg and body muscles were collected and placed in 10 ml centrifuge tubes for the determination of FAAs and flavor nucleotides. Tissue samples from multiple crabs within the same tank were analyzed and pooled as a single sample.

2.3. DIETS COMPOSITION

Crude lipid, crude protein, ash, and moisture of experiment diets were measured following the method of AOAC.²¹ The moisture and ash content were analyzed by drying the samples at 105°C to constant weight and incinerating the samples at 550°C for 6 h, respectively. Crude protein was determined using an Auto Kjeldahl System (2300-Auto-analyzer, Foss Tecator, Sweden), and the crude lipid content was analyzed by the chloroform-methanol method.

2.4. DIETS HYDROLYZED AMINO ACIDS, MUSCLE AND HEPATOPANCREAS FAAS

2.4.1. PRE-TREATMENT OPERATIONS

Hydrolyzed amino acids: Approximately 1.0 g of the sample was weighed and 50 mL of 0.1% phenol in 6 mol/L hydrochloric acid was added. The mixture was ground into a paste and placed in an oven at 110°C for hydrolysis for approximately 20 h. After hydrolysis, the sample was removed and allowed to cool. A 1 mL aliquot of the hydrolysate was collected and evaporated to near dryness using a nitrogen blower. Subsequently, 1 mL of 0.1 M hydrochloric acid solution was added to dissolve the residue, and the solution was filtered through a membrane prior to derivatization.

Free amino acids (FAAs): Approximately 1.0 g of the sample was weighed and mixed with 10 mL of water. The mixture was ground into a paste, ultrasonicated for 1 h, and

Table 1. Proximate composition of the experimental baits (% , fresh tissue).

Item	Groups				
	TF	MW	BSFL	GASM	FLM
Moisture	73.51	65.34	71.01	76.35	73.52
Crude protein	17.63	17.51	14.96	16.20	17.33
Crude lipid	4.73	9.46	10.10	3.40	6.70
Ash	3.58	6.87	3.68	3.24	1.80

TF, Trash fish, MW, mealworm, BSFL, black soldier fly larvae, GASM, golden apple snail meat, FLM, fly maggot.

Table 2. Amino acid composition of the experimental baits (% , fresh tissue).

Item	Groups				
	TF	MW	BSFL	GASM	FLM
Histidine	0.29	0.47	0.34	0.22	0.35
Arginine	0.86	0.92	0.66	0.97	0.69
Threonine	0.62	0.65	0.45	0.63	0.50
Valine	0.62	0.87	0.58	0.63	0.47
Methionine	0.41	0.14	0.24	0.23	0.27
Isoleucine	0.60	0.65	0.45	0.57	0.40
Leucine	1.08	1.12	0.76	1.03	0.72
Phenylalanine	0.53	0.53	0.47	0.53	0.66
Lysine	1.67	1.08	0.94	0.71	1.08
EAA	6.68	6.44	4.88	5.52	5.14
Aspartic acid	1.66	1.46	0.91	1.35	1.40
Glutamic acid	2.32	2.04	1.15	2.20	1.63
Serine	0.62	0.82	0.50	0.65	0.55
Glycine	0.58	0.81	0.53	0.92	0.46
Alanine	0.85	1.21	0.68	0.76	0.73
Proline	0.42	1.01	0.53	0.58	0.48
Tyrosine	0.46	1.08	0.74	0.40	0.68
NEAA	6.91	8.44	5.04	6.86	5.93
TAA	13.59	14.88	9.92	12.38	11.06

TF, Trash fish, MW, mealworm, BSFL, black soldier fly larvae, GASM, golden apple snail meat, FLM, fly maggot. EAA, essential amino acids; NEAA, non-essential amino acid; TAA, total amino acids.

centrifuged to obtain the supernatant. The resulting supernatant was collected and prepared for derivatization.

2.4.2. DERIVATIZATION OF AMINO ACIDS

A total of 200 μ L of the clear liquid sample and 200 μ L of the amino acid standard solution were transferred separately into 2 mL EP tubes. Subsequently, 20 μ L of the positive leucine internal standard solution was accurately added to each tube. Then, 100 μ L of triethylamine–acetonitrile solution (pH > 7) and 100 μ L of phenyl isothiocyanate–acetonitrile solution were sequentially added to each EP tube. The mixtures were vortexed thoroughly and incubated at 25°C for 1 hour for derivatization. Following incubation, 1 mL of n-hexane was added to each tube, and the mixtures were shaken and allowed to stand for 10 minutes. The upper organic layer was collected and diluted

fivefold with water. The diluted solution was then filtered through a 0.22 μ m syringe filter prior to analysis.

2.4.3. LIQUID CHROMATOGRAPHY ANALYSIS CONDITIONS

An Agilent 1100 high-performance liquid chromatograph equipped with an ultraviolet detector set at 254 nm was used for the analysis. Separation was performed on a Cussons Amethyst C18-H chromatographic column (250 mm $\times$ 4.6 mm, 5 μ m). The column temperature was maintained at 40 °C, the flow rate was set at 1 mL/min, and the injection volume was 10 μ L. Mobile phase A was prepared by weighing 7.6 g of anhydrous sodium acetate, adding it to 925 mL of water, and dissolving it completely. The pH was then adjusted to 6.5 with acetic acid, followed by the addition of 70 mL of acetonitrile. The solution was mixed thoroughly and

Table 3. Fatty acids composition of the experimental baits (% total identified fatty acids).

Item	Groups				
	TF	MW	BSFL	GASM	FLM
C6:0	2.33	0.15	0.11	4.88	0.44
C8:0	3.00	0.17	0.27	2.93	0.61
C10:0	0.24	0.03	0.35	0.37	0.06
C12:0	0.69	0.10	14.64	1	0.15
C14:0	0.86	1.50	3.63	1.78	2.33
C15:0	7.24	0.77	0.83	5.73	1.69
C16:0	23.49	19.71	20.79	19.52	25.21
C17:0	0.28	0.21	0.12	1.07	0.22
C18:0	10.37	4.40	3.01	6.65	4.04
C20:0	0.24	0.17	0.10	0.38	0.19
C16:1	1.33	1.19	1.71	0.73	6.60
C18:1	10.76	35.56	30.26	30.51	28.30
C20:1	0.67	0.13	0.06	0.28	0.13
C22:1	0.12	0.01	0.02	0.2	0.04
C20:2	0.85	0.10	0.02	2.19	0.06
C18:2n6	19.39	35.59	23.35	8.51	27.99
C20:3n6	0.49	0.00	0.02	0.96	0.09
C18:3n6	0.10	0.00	0.02	0.07	0.13
C20:4n6 ARA	1.43	0.00	0.33	8.1	0.69
C18:3n3	1.70	0.17	0.12	1.14	0.30
C20:3n3	0.33	0.01	0.01	0.18	0.03
C20:5n3 EPA	1.48	0.01	0.20	0.65	0.62
C22:6n3 DHA	12.62	0.01	0.03	4.36	0.08
SFA	48.74	27.21	43.85	44.31	34.94
MUFA	12.88	36.89	32.05	31.72	35.06
n-6 PUFAs	21.41	35.60	23.71	17.64	28.91
n-3 PUFAs	16.12	0.20	0.36	6.33	1.03
n-6/n-3 PUFAs	1.33	178.00	65.86	2.79	28.07

ARA, arachidonic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

filtered through a 0.45 µm membrane filter. Mobile phase B consisted of an 80% aqueous acetonitrile solution.

2.5 MUSCLE AND THE HEPATOPANCREAS NUCLEOTIDES

2.5.1. PRE-TREATMENT OPERATION

Approximately 0.5 g of the sample was weighed and mixed with 1.0 mL of 6% perchloric acid aqueous solution. The mixture was ground into a paste and transferred into an EP tube. Ultrasonic extraction was performed for 20 minutes, followed by centrifugation. Subsequently, 0.5 mL of the supernatant was collected, and the pH was adjusted to 6.5 using sodium hydroxide solution. The volume was then brought up to 1 mL with water, filtered through a needle-type filter, and prepared for analysis.

2.5.2. LIQUID CHROMATOGRAPHY ANALYSIS CONDITIONS

An Agilent 1100 high-performance liquid chromatograph equipped with an ultraviolet detector was used, and the detection wavelength was set at 245 nm. Separation was performed using a Compass C18 (2) reversed-phase chromatographic column (250 mm × 4.6 mm, 5 µm). The column temperature was maintained at 30°C. The flow rate was 0.8 mL/min, and the injection volume was 10 µL. The mobile phase consisted of 0.05 mol/L KH₂PO₄.

2.5.3. STANDARD CURVE DETERMINATION

Precisely weighed each nucleotide standard, dissolved it in water, and prepared 5–6 standard solutions with different concentrations. The peak areas of each standard solution were determined under the chromatographic conditions described above. Standard curves for each nucleotide were constructed by plotting peak area against concentra-

tion, and the linear range and correlation coefficient were subsequently calculated.

2.6. DIETS AND HEPATOPANCREAS FATTY ACIDS

2.6.1. PRE-TREATMENT OPERATION

A 0.2 g sample was weighed into a 15 mL centrifuge tube. One milliliter of methanol was added, followed by 2 mL of hydrochloric acid solution (8.3 mol/L). The mixture was thoroughly mixed and placed in an 80°C water bath for hydrolysis for 40 minutes. After hydrolysis, the sample was cooled to room temperature, and 2 mL of methanol was added and mixed well. Subsequently, 2 mL of petroleum ether-ethyl ether (1:1, v/v) was added for extraction. The extraction procedure was repeated three times, and the extracts were combined and dried under a stream of nitrogen to obtain the fat extract.

To the centrifuge tube containing the fat extract, 500 µL of n-hexane was added, followed by 2 mL of 2.5% sulfuric acid-methanol solution. The mixture was reacted in an 80°C water bath for 1 hour. After cooling, 1 mL of n-hexane was added and mixed thoroughly, followed by the addition of 1 mL of saturated sodium chloride solution. The mixture was shaken well, and the upper n-hexane layer was transferred to an EP tube. The extraction was repeated three additional times, and the n-hexane phases were combined. The solvent was evaporated completely under a stream of nitrogen, and the residue was reconstituted to a final volume of 0.5 mL with n-hexane. The solution was vortexed to ensure complete dissolution, and an appropriate aliquot was filtered into a sample vial fitted with an inner liner for analysis. Samples containing higher concentrations of certain analytes were further diluted 10-fold and 100-fold prior to detection.

2.6.3. CHROMATOGRAPHIC ANALYSIS CONDITIONS

Chromatograph: Agilent 6890N gas chromatograph. Chromatographic column: WM-CN100 (100 m * 0.25 mm * 0.2 µm)

Detector (FID) temperature: 260 °C. Programmed temperature rise: 0-51 min; 140 °C - 240 °C. Split ratio: 10:1.

2.6.4. STANDARD CURVE DETERMINATION

37 fatty acid methyl ester standard substances were accurately weighed and dissolved in n-hexane. Five to six standard solutions with different mass concentrations were prepared. Under the above chromatographic conditions, the peak areas of the 37 fatty acid methyl esters in each standard solution were determined sequentially. The peak area was used as the ordinate and the concentration as the abscissa to construct standard curves for each fatty acid methyl ester. The linear range and correlation coefficient for each fatty acid methyl ester were then determined.

2.7. STATISTICAL ANALYSIS

The experimental data were presented as mean ± standard deviation (n = 4). All data were analyzed using SPSS 22.0 statistical software. A one-way analysis of variance (ANOVA) and Turkey's multiple range tests were used to determine the statistical significance among groups. Statistical significance was determined at $P < 0.05$.

3. RESULT

3.1. MUSCLE FAAS COMPOSITION

Several muscle FAAs with relatively high contents were glutamic acid, glycine, arginine, and proline, while several muscle FAAs with relatively low contents were serine, histidine, tyrosine, and phenylalanine (Table 4). Muscle-free flavor amino acids (FFAAs) in the BSFL and GASM groups reached the same level as that of the TF group ($P > 0.05$). Among the FFAAs (aspartic acid, glutamic acid, glycine and alanine), muscle free aspartic acid content in the MW group was significantly higher than other groups ($P < 0.05$). Muscle free glutamic acid content in the TF group was significantly higher than other groups ($P < 0.05$). Muscle free glycine content of the BSFL and GASM groups reached the same level as that of the TF group ($P > 0.05$). Muscle free alanine content of the GASM group was significantly higher than the other groups ($P < 0.05$). Muscle total FAAs (TFAAs) content in the MW group shows no significant difference with that of the TF group ($P > 0.05$), while the other groups were significantly lower than the TF group ($P < 0.05$).

3.2. HEPATOPANCREAS FAAS COMPOSITION

Hepatopancreas FAAs with relatively high contents in each group were leucine, arginine and lysine, while hepatopancreas FAAs with relatively low contents were serine, histidine and aspartic acid (Table 5). The hepatopancreas FAAs and FFAAs in the GASM group show no significant difference with those of the TF group ($P > 0.05$), while the other three insect diet groups were significantly lower than the TF group ($P < 0.05$). Among the FFAAs, the GASM group hepatopancreas free aspartic acid and alanine contents reached the same levels as those of the TF group ($P > 0.05$), and the free glycine content was significantly higher than that of the TF group ($P < 0.05$). In other insect diet groups, only the FLM showed the free glutamic acid content reached the same level as that of the TF group ($P > 0.05$).

3.3. THE MUSCLE AND HEPATOPANCREAS FLAVOR NUCLEOTIDES CONTENT

In muscle, the GASM group 5'-GMP content shows no significant difference with that of the TF group ($P > 0.05$) (Table 6). The GASM and MW group 5'-AMP content reached the same level as that of the TF group ($P > 0.05$). In hepatopancreas, the GASM and BSFL group 5'-GMP content shows no significant difference with that of the TF group ($P > 0.05$); The GASM group 5'-IMP and 5'-AMP content reached the same level as that of the TF group ($P > 0.05$).

Table 4. Muscle FAAs composition of *E. sinensis* fed with different baits (mg/100 g fresh tissue)

Item	Groups				
	TF	MW	BSFL	GASM	FLM
Aspartic acid	23.21±0.94 ^b	29.37±0.74 ^a	24.42±0.92 ^b	22.43±0.50 ^b	24.31±0.55 ^b
Glutamic acid	114.90±3.99 ^a	87.51±2.25 ^b	67.61±2.31 ^c	66.36±5.39 ^c	85.35±5.00 ^b
Histidine	21.44±0.91 ^b	28.17±1.37 ^a	21.22±1.27 ^b	30.61±1.88 ^a	19.45±0.83 ^b
Glycine	276.30±7.01 ^a	224.43±6.87 ^b	245.45±8.94 ^{ab}	267.78±12.69 ^a	234.18±18.55 ^b
Histidine	11.16±0.77 ^c	19.62±0.13 ^a	12.74±0.59 ^b	10.14±0.49 ^c	10.94±0.31 ^c
Arginine	320.70±8.51 ^{bc}	314.12±14.33 ^c	344.25±7.30 ^b	371.65±7.67 ^a	376.32±10.13 ^a
Tyrosine	31.43±1.12 ^a	33.44±1.14 ^a	15.70±0.98 ^b	15.54±1.32 ^b	18.28±0.81 ^b
Aspartic acid	130.93±7.08 ^d	159.89±7.25 ^c	183.11±3.49 ^b	200.27±6.79 ^a	152.60±5.22 ^c
Proline	327.00±6.18 ^a	344.08±11.19 ^a	226.01±5.98 ^b	183.46±15.70 ^c	323.72±15.98 ^a
Tyrosine	11.88±0.49 ^b	17.78±1.31 ^a	8.51±0.76 ^c	7.02±0.55 ^c	8.04±0.63 ^c
Valine	27.52±0.72 ^c	42.48±2.06 ^a	23.93±1.48 ^c	16.01±1.49 ^d	33.8±1.71 ^b
Methionine	98.71±5.19 ^a	9.73±0.37 ^d	19.76±0.99 ^c	34.30±1.52 ^b	24.53±0.94 ^c
Isoleucine	18.39±0.90 ^a	18.01±0.48 ^a	8.89±0.41 ^c	8.18±0.31 ^c	11.07±0.55 ^b
Leucine	28.42±1.31 ^a	29.39±0.73 ^a	13.69±1.07 ^c	14.52±0.74 ^c	17.89±0.93 ^b
Phenylalanine	11.56±0.93 ^a	8.91±0.38 ^b	4.86±0.34 ^c	7.46±0.51 ^b	5.07±0.28 ^c
Lysine	53.35±4.72 ^a	42.65±3.88 ^b	32.62±3.02 ^c	30.81±1.95 ^c	37.07±1.94 ^{bc}
TFAAs	1506.9±43.8 ^a	1409.6±38.5 ^{ab}	1252.8±12.7 ^d	1278.2±44.2 ^{cd}	1382.6±50.9 ^{bc}
FFAAs	545.33±12.40 ^a	501.20±10.48 ^b	520.59±10.57 ^{ab}	548.51±15.97 ^a	496.44±25.11 ^b

Note: In the same row, values with different superscripts mean significant difference ($P < 0.05$).

TFAAs: total free amino acids. FFAAs: free flavor amino acids.

Table 5. Hepatopancreas FAAs composition of *E. sinensis* fed with different baits (mg/100 g fresh tissue).

Item	Groups				
	TF	MW	BSFL	GASM	FLM
Aspartic acid	20.48±1.18 ^a	8.49±0.86 ^c	15.71±1.32 ^b	19.33±0.93 ^a	14.49±0.89 ^b
Glutamic acid	70.55±6.18 ^a	47.39±3.71 ^c	50.42±4.27 ^c	55.60±5.18 ^{bc}	66.06±4.22 ^{ab}
Serine	32.55±2.63 ^a	14.98±1.80 ^b	29.43±1.86 ^a	32.56±3.05 ^a	17.78±1.12 ^b
Glycine	41.42±3.09 ^b	22.95±2.54 ^d	33.39±3.08 ^c	56.58±3.37 ^a	31.66±2.75 ^c
Histidine	26.90±2.29 ^a	18.37±0.82 ^b	21.06±1.44 ^b	30.43±2.09 ^a	18.10±0.80 ^b
Arginine	311.06±15.41 ^b	233.21±12.22 ^c	227.84±10.14 ^c	305.73±7.64 ^a	192.83±10.71 ^d
Threonine	32.54±2.36 ^a	15.50±1.53 ^c	26.98±1.25 ^b	33.40±2.37 ^a	17.74±1.43 ^c
Alanine	105.90±6.47 ^a	78.58±6.63 ^b	59.45±4.16 ^c	99.35±8.41 ^a	63.81±4.75 ^{bc}
Proline	95.32±7.79 ^a	70.19±3.95 ^b	57.48±4.95 ^b	31.92±3.45 ^c	61.86±4.97 ^b
Tryptophan	77.93±6.89 ^{ab}	42.36±4.08 ^c	63.57±5.78 ^b	82.19±6.95 ^a	47.26±3.09 ^c
Valine	50.82±3.56 ^{ab}	25.07±2.57 ^c	41.90±3.84 ^b	51.65±4.94 ^a	27.35±2.22 ^c
Methionine	43.03±3.50 ^a	17.19±2.00 ^d	28.41±1.44 ^c	36.52±2.56 ^b	19.67±0.94 ^d
Isoleucine	40.77±3.15 ^a	22.53±1.91 ^b	37.20±1.93 ^a	42.69±2.63 ^a	21.20±1.57 ^b
Leucine	116.93±9.13 ^a	67.91±4.72 ^c	96.00±5.40 ^b	129.15±8.71 ^a	71.59±3.33 ^c
Phenylalanine	73.20±4.87 ^b	40.83±2.33 ^d	58.85±5.40 ^c	91.36±6.82 ^a	48.15±2.21 ^{cd}
Lysine	193.43±10.32 ^b	153.72±3.18 ^c	182.16±6.52 ^b	222.73±10.63 ^a	153.87±10.58 ^c
TFAAs	1332.8±80.3 ^a	879.3±42.6 ^c	1029.9±41.8 ^b	1321.2±95.1 ^a	873.4±41.1 ^c
FFAAs	238.35±15.92 ^a	157.41±9.24 ^b	158.98±9.32 ^b	230.86±17.86 ^a	176.01±11.90 ^b

Note: In the same row, values with different superscripts mean significant difference ($P < 0.05$).

TFAAs: total free amino acids. FFAAs: free flavor amino acids.

Table 6. Muscle and hepatopancreas flavor nucleotide content of *E. sinensis* fed with different baits (fresh tissue, mg/100 g).

Item	Groups				
	TF	MW	BSFL	GASM	FLM
Muscle					
5'-GMP	31.99±1.73 ^a	26.87±1.41 ^{bc}	21.72±2.32 ^d	31.18±1.52 ^{ab}	22.24±2.32 ^{cd}
5'-IMP	108.01±8.39 ^a	80.80±4.93 ^b	63.37±6.04 ^c	83.26±6.07 ^b	67.36±6.27 ^{bc}
5'-AMP	96.03±5.66 ^a	86.70±5.84 ^a	66.07±4.41 ^b	94.90±4.82 ^a	67.71±4.04 ^b
Hepatopancreas					
5'-GMP	29.13±2.35 ^a	15.23±1.30 ^b	25.20±1.62 ^a	28.91±1.71 ^a	15.94±1.18 ^b
5'-IMP	79.42±1.84 ^a	62.00±3.50 ^b	59.20±2.93 ^b	83.86±3.73 ^a	62.51±2.55 ^b
5'-AMP	42.39±2.60 ^a	21.13±2.35 ^c	20.65±1.92 ^c	42.59±2.57 ^a	33.74±3.68 ^b

Note: In the same row, values with different superscripts mean significant difference ($P < 0.05$).

In the same row, values with different superscripts mean significant difference ($P < 0.05$).

GMP, guanylic acid sodium salt; IMP, sodium Inosinate; AMP, sodium adenosine triphosphate.

3.4. HEPATOPANCREAS FATTY ACIDS COMPOSITION

The BSFL group had a significantly higher SFA proportion in the hepatopancreas than the other groups ($P < 0.05$) (Table 7). The MW and FLM group hepatopancreas MUFA proportion were significantly higher than that of the other groups ($P < 0.05$). The TF group n-3 PUFAs proportion was significantly higher than that of the other groups ($P < 0.05$). The GASM group n-3 PUFAs proportion was significantly higher than that of the MW, BSFL, and FLM groups ($P < 0.05$).

4. DISCUSSION

4.1. FACTORS AFFECTING THE EDIBLE QUALITY AND FLAVOR

The umami and sweetness of the muscle and hepatopancreas in *E. sinensis* are highly favored by consumers, mainly due to the presence of a large amount of FAAs, flavor nucleotides, and fatty acids.²² The content of FAAs is a key factor influencing the flavor of meat. For instance, serine, glycine, and alanine have a sweet taste, while aspartic acid and glutamic acid have an inherent sour taste on their own, and this sourness manifests as umami when sodium salt is present.²³ Meanwhile, glycine, lysine, phenylalanine, and threonine can undergo Maillard reactions with glucose to produce various aromas.²⁴ Additionally, acidic amino acids and various neutral amino acids can enhance the flavor through the interaction with IMP taste receptors.²⁵ The main components of FAAs in the muscle of *E. sinensis* are glutamic acid, glycine, arginine, and Proline. Studies on crucian carp (*Carassius Auratus*)²⁶ and Senegal sole (*Solea Senegalensis*)²⁷ have shown that an increase in the levels of glutamic acid and alanine can significantly enhance the umami flavor of the meat. Moreover, it has been demonstrated that glycine plays a significant role in presenting sweetness in snow crab (*Chionoecetes opilio*),²⁸ clams,²⁹ and scallops.³⁰ Among the flavor nucleotides, Wang et al.³¹ reported that the contents of AMP, IMP, and GMP are important flavor substances that affect the edible quality of *E.*

sinensis, with AMP mainly increasing sweetness, and IMP and GMP mainly enhancing umami flavor.

Turchini et al.³² mentioned in their study that the change in the fatty acid composition of fish fillets would affect the total volatile compounds, thereby affecting the flavor. n-3PUFAs are healthy lipids that improve the absorption, digestion, and transport of nutrients and are very important for growth performance. It can enhance the nutritional value of crabs and may also generate volatile flavor substances through lipid oxidation, making the crab meat aroma more intense. Experts from the Food and Agriculture Organization of the United Nations (FAO) proposed that the ratio of n-6/n-3 PUFAs in food should be between 5:1 and 10:1. Fillmore et al.³³ and El-Ansary et al.³⁴ suggested that it is beneficial to human health when the ratio of n-6/n-3 PUFAs in the human body is 1:1. Currently, as human fat intake continues to increase, the intake of n-3 PUFAs has significantly decreased, while the intake of n-6 PUFAs has continuously increased. The ratio of n-6/n-3 PUFAs has reached as high as 30:1.³⁵ This severe imbalance ratio will eventually cause lipid metabolism disorders, thereby triggering a series of metabolic diseases such as obesity and diabetes.³⁶ Therefore, the appropriate ratio of n-6/n-3 PUFAs in the fatty acid composition is of great significance for flavor and nutritional quality. An appropriate n-6/n-3 ratio helps maintain lipid metabolism balance, prevents excessive oxidation that can generate unpleasant odors, and simultaneously enhances the freshness, aroma, and harmony of the crab meat's taste.

4.2. THE INFLUENCE OF MW ON THE EDIBLE QUALITY AND FLAVOR

In recent years, many studies have conducted experiments on replacing dietary fish meal with MW. Xu et al.³⁷ pointed out that the nutritional components of defatted mealworm meal are similar to those of fish meal and have a strong fishy smell, which has a certain feeding-enticing effect and a relatively small impact on feeding volume. In this experiment, it was also found that the feeding volume of *E. sinensis* in the MW group was comparable to that in the

Table 7. Hepatopancreas fatty acid composition of *E. sinensis* fed with different diets (% total identified fatty acids).

item	Groups				
	TF	MW	BSFL	GASM	FLM
C6:0	0.03±0.01 ^{bc}	0.05±0.01 ^b	0.02±0.01 ^c	0.19±0.02 ^a	0.04±0.01 ^{bc}
C8:0	0.14±0.02 ^b	0.13±0.01 ^b	0.10±0.01 ^c	0.34±0.02 ^a	0.16±0.01 ^b
C10:0	0.01±0.01 ^c	0.01±0.01 ^c	0.18±0.01 ^a	0.05±0.01 ^b	0.01±0.01 ^c
C12:0	0.05±0.01 ^b	0.11±0.01 ^b	16.62±0.53 ^a	0.16±0.02 ^b	0.11±0.01 ^b
C14:0	1.35±0.07 ^c	1.39±0.05 ^c	4.96±0.09 ^a	2.47±0.15 ^b	1.25±0.12 ^c
C15:0	0.47±0.09 ^{cd}	0.81±0.05 ^b	0.45±0.09 ^d	2.64±0.06 ^a	0.65±0.07 ^{bc}
C16:0	20.63±1.03 ^b	15.58±0.80 ^c	16.39±1.06 ^c	24.29±0.82 ^a	15.71±0.88 ^c
C17:0	0.13±0.01 ^{ab}	0.16±0.02 ^{ab}	0.09±0.01 ^b	0.69±0.50 ^a	0.12±0.01 ^{ab}
C18:0	2.53±0.14 ^{bc}	2.83±0.07 ^b	2.25±0.10 ^{cd}	6.24±0.26 ^a	2.03±0.14 ^d
C20:0	0.01±0.01 ^c	0.13±0.02 ^{ab}	0.01±0.01 ^c	0.15±0.01 ^a	0.11±0.01 ^b
C14:1	0.10±0.01 ^c	0.07±0.01 ^c	0.51±0.04 ^a	0.30±0.02 ^b	0.07±0.01 ^c
C16:1	5.70±0.29 ^c	4.26±0.33 ^d	6.73±0.14 ^b	9.70±0.16 ^a	6.29±0.24 ^{bc}
C17:1	0.19±0.01 ^c	0.25±0.02 ^b	0.26±0.01 ^b	0.79±0.03 ^a	0.23±0.03 ^{bc}
C18:1n9	29.88±1.37 ^b	41.87±1.02 ^a	28.54±1.04 ^b	19.80±1.12 ^c	39.83±1.92 ^a
C20:1	0.92±0.03 ^a	0.31±0.02 ^c	0.11±0.02 ^d	0.45±0.03 ^b	0.38±0.03 ^b
C20:2	1.48±0.04 ^b	1.13±0.06 ^c	0.36±0.03 ^e	3.12±0.20 ^a	0.78±0.03 ^d
C18:2n6	25.63±1.30 ^b	29.82±1.36 ^a	20.78±1.41 ^c	11.44±0.88 ^d	29.84±1.76 ^a
C18:3n6	0.09±0.01 ^a	0.01±0.01 ^c	0.03±0.01 ^b	0.03±0.01 ^{bc}	0.04±0.01 ^b
C20:3n6	0.30±0.01 ^b	0.05±0.01 ^c	0.05±0.01 ^c	1.18±0.03 ^a	0.07±0.01 ^c
C20:4n6 ARA	0.30±0.01 ^b	0.05±0.01 ^b	0.05±0.01 ^b	1.18±0.03 ^a	0.07±0.01 ^b
C18:3n3	0.18±0.03 ^b	0.15±0.01 ^b	0.17±0.01 ^b	0.26±0.02 ^a	0.25±0.01 ^a
C20:3n3	0.41±0.02 ^a	0.12±0.01 ^d	0.10±0.01 ^d	0.29±0.02 ^b	0.17±0.01 ^c
C20:5n3 EPA	1.22±0.07 ^b	0.57±0.04 ^d	0.64±0.07 ^d	2.45±0.07 ^a	1.03±0.06 ^c
C22:6n3 DHA	8.02±0.10 ^a	0.58±0.06 ^c	0.33±0.03 ^d	2.74±0.06 ^b	0.38±0.07 ^d
SFA	25.36±1.39 ^c	21.21±0.92 ^d	41.07±1.71 ^a	37.23±0.87 ^b	20.19±1.23 ^d
MUFA	38.27±1.17 ^b	47.89±1.43 ^a	36.51±1.25 ^b	34.16±1.51 ^b	47.59±2.26 ^a
n-6 PUFAs	26.52±1.35 ^{bc}	30.36±1.41 ^{ab}	21.60±1.47 ^d	23.55±1.27 ^{cd}	30.85±1.81 ^a
n-3 PUFAs	9.83±0.20 ^a	1.42±0.09 ^d	1.24±0.12 ^d	5.75±0.15 ^b	1.83±0.15 ^c
n-6/n-3 PUFAs	2.70±0.09 ^d	21.41±0.35 ^a	17.42±0.45 ^b	4.09±0.11 ^c	16.90±0.37 ^b

Note: In the same row, values with different superscripts mean significant difference ($P < 0.05$). ARA, arachidonic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

TF group. Regarding the composition of the feed, the crude protein content of MW (17.51%) was consistent with that of TF (17.63%), while the crude fat (9.46%) and ash (6.87%) contents were higher than those of TF (4.73%, 3.58%), which was consistent with the research results of Christos et al.³⁸ Therefore, MW can provide sufficient protein, fat and mineral sources for *E. sinensis*.

In this experiment, the muscle TFAAs content in the MW group reached the same level of the TF group, while the FFAAs content was significantly lower than that of the TF group (Table 4), which is consistent with the experimental results of Zhang et al.³⁹ The hepatopancreas TFAAs and FFAAs contents in the MW group were significantly lower than those in the TF group. This result is consistent with the experimental results of Iaconisi et al.,⁴⁰ who replaced 50% of the dietary fish meal with MW meal for *Sparus aurata* L., resulting in a decrease in muscle FFAA content.

In terms of the diet amino acid composition, these flavor amino acids in MW have no significant difference from those in TF, and the content of alanine (1.21) and glycine (0.81) in MW is higher than that in TF (0.85, 0.58). The reason for the decrease in the muscle and hepatopancreas FFAAs content may lie in the differences in the absorption and metabolism of diet components by the *E. sinensis*, further research is needed. In the MW group, except for the muscle 5'-AMP content, which reached the same level as that of the TF group, the contents of other umami nucleotides in the hepatopancreas and muscle were significantly lower than those in the TF group, which may also affect the flavor performance of the crabs.

The hepatopancreas SFA and n-3 PUFA content in the MW group was significantly lower than in the TF group, whereas MUFA and n-6 PUFA content were significantly higher in the MW group. Studies on large yellow croaker

(*Larimichthys crocea*),⁴¹ European sea bass (*Dicentrarchus labrax* L.),⁴² common catfish (*Ameiurus melas* Raf.),⁴³ rainbow trout,⁴⁴ tilapia,⁴⁵ and blackspot sea bream (*Pagellus bogaraveo*),⁴⁶ it was found that as the proportion of dietary fish meal replaced by the MW meal increased, the n-3 PUFAs and the ratio of n-3/n-6 PUFAs in the experimental animals showed a downward trend, while the content of linoleic acid and n-6 PUFAs significantly increased. Mastoraki et al.⁴² reported that the MW linoleic acid content was much higher, consistent with the results of this experiment. Sánchez-Muros et al.⁴⁷ documented that this is mainly because most terrestrial insects typically rely on plant-based substances as their main food source and lack direct sources of n-3 PUFAs. As a result, they are significantly deficient in EPA and DHA. This phenomenon is consistent with the results in this experiment (Table 3), and is in agreement with the difference in the proportion of fatty acids in the crab hepatopancreas in the MW group. However, EPA and DHA have significant biological functions in aquatic organisms. After replacing TF with MW for feeding, the crabs' fatty acid nutritional requirements could not be met. The specific impacts resulting from this and the corresponding improvement plans still need to be further explored.

4.3. THE INFLUENCE OF BSFL ON THE EDIBLE QUALITY AND FLAVOR

Studies have shown that the protein content of BSFL is comparable to that of other insect and plant protein sources.⁴⁸ Although BSFL is in the middle to lower range among insects, the crude fat content of BSFL meal is higher than that of most insect meals, even higher than fish meal and soybean meal. After de-fatting, the crude protein content of defatted BSFL meal can be significantly increased.^{47, 48} In the present study, the BSFL fat content was higher than that of the other four diets, which is consistent with previous studies.

In this experiment, the muscle TFAAs content of the BSFL group was significantly lower than that of the TF group, while the muscle FFAAs content reached the same level as that of the TF group (Table 4). The total hepatopancreas TFAAs and FFAAs contents of the BSFL group were significantly lower than those of the TF group (Table 5). This might be due to the BSFL total amino acid content (9.92%) and the essential amino acid content (4.88%) being significantly lower than those of the TF (13.59% and 6.68%), resulting in insufficient supply, or it might be related to the protein synthesis mechanism of the crabs and their utilization efficiency of the protein in the diet. However, Qiu et al.⁴⁹ found in their study that feeding male *E. sinensis* with BSFL resulted in a significant increase in the content of FFAAs. Contrary to the results of this experiment, this might be due to the tissue-specific absorption differences between male and female crabs, and further research on the correlation is needed. In terms of nucleotide content, the contents of 5'-GMP, 5'-IMP, and 5'-AMP in the muscle of the BSFL group, as well as the contents of 5'-IMP and 5'-AMP in the hepatopancreas, were significantly lower

than those in the TF group. This may affect the overall synergistic effect of flavor.

In this experiment, the hepatopancreas SFA content in the BSFL group was significantly higher than in the TF group, whereas the n-6 and n-3 PUFAs content was significantly lower than in the TF group (Table 7). Study by Belforti et al.⁵⁰ also indicated that as the increasing proportion of dietary fish meal was replaced by BSFL meal, the proportion of EPA and DHA in trout fillets significantly decreased, which was consistent with the results of this experiment. This was also demonstrated in feeding experiments conducted on rainbow trout^{51,52} and largemouth bass.⁵³ The fundamental reason is that the content of n-3 PUFAs in BSFL (0.36%) is significantly lower than that in TF (16.12%), leading to insufficient accumulation of n-3 PUFAs. Therefore, although BSFL has certain characteristics in terms of certain amino acids and fatty acids components, feeding them to crabs has a significant negative impact on the content of crab FFAAs and n-3 PUFAs, which may affect the flavor and nutritional value of the crabs.

4.4. THE INFLUENCE OF FLM ON THE EDIBLE QUALITY AND FLAVOR

FLM is classified as animal feed, and numerous studies have reported that it has great potential for development.^{54,55} The detection results show that the ash content of FLM (1.80%) is lower than that of TF (3.58%), while the fat content (6.70) is higher than that of TF (4.73). The difference in ash content between the two is consistent with the results of Ogunji et al.⁵⁶ and Jabir et al.,⁵⁷ where the ash content of fish decreased as the increase in dietary fish meal was replaced by FLM meal. The report by Weatherup et al.⁵⁸ also noted that replacing dietary fish meal with FLM meal increased fish lipid levels and decreased ash content. In Chinese mud crabs (*Scylla paramamosain*),⁵⁹ Pacific white shrimp (*Litopenaeus vannamei*),^{60,61} Chinese soft shelled turtles,⁶² and tilapia,⁶³ dietary fish meal replaced by FLM meal resulted in a significant increase in body fat content as the amount of FLM meal increased, while protein content remained basically unchanged, which is consistent with the MW nutritional composition results in this study.

In this experiment, the muscle and hepatopancreas TFAAs and FFAAs in the FLM group were significantly lower than those in the TF group (Table 4, Table 5). Shi et al.⁶³ pointed out in their report that the content of Met and lysine in FLM meal was much lower than that in fish meal, which is consistent with the results of this experimental study (Table 2). It indicated that the deficiency of essential amino acids in FLM will affect the growth and metabolic performance of *E. sinensis*, thereby influencing the edible quality of *E. sinensis*. Regarding the content of flavor nucleotides, the 5'-GMP, 5'-IMP, and 5'-AMP contents in the muscle and hepatopancreas of the FLM group were significantly lower than those in the TF group. This may have led to a reduction in the flavor of the *E. sinensis*.

In this experiment, the proportions of SFA and n-3 PUFA in the crab fed with FLM were significantly lower than those in the TF group, while the proportions of MUFA and n-6 PUFAs were significantly higher than those in the TF group

(Table 7). This is consistent with the fatty acid composition of TF compared to FLM. Turchini et al.⁶⁴ and Borgogno et al.⁶⁵ have reported that differences in fatty acid composition may affect the sensory characteristics of aquatic products at the aroma and flavor levels. Direct feeding of FLM to crabs is bound to have a negative impact on the crabs' edible quality. FLM, like BSFL and MW, are all terrestrial insects, which usually rely on plant-based substances as their main food source and lack direct sources of n-3 PUFAs. Their nutritional composition is significantly deficient in EPA and DHA. The fatty acids in aquatic animals are usually accumulated through digestion and absorption from their food, so directly feeding them terrestrial insects is likely to cause a deficiency of highly unsaturated fatty acids in their bodies, thereby affecting the edible quality.

4.5. THE INFLUENCE OF GASM ON THE EDIBLE QUALITY AND FLAVOR

In recent years, the rice-calamus symbiotic system, which involves raising *E. sinensis* in rice fields to prey on pests such as GAS, has become increasingly common. This system not only protects rice and increases yields, but also breeding *E. Sinensis* as a by-product to generate economic benefits, creating a virtuous cycle,⁶⁶ demonstrating the potential of GAS as a food source for *E. sinensis*. Currently, studies on aquatic animals such as pasupati catfish (*Pangasius* sp.),⁵ striped catfish (*Pangasianodon hypophthalmus*),⁶⁷,⁶⁸ tiger shrimp (*Penaeus monodon*),⁶⁹ and tilapia⁷⁰ have shown that dietary fish meal can be part replaced by the GASM meal has no negative impact on the growth performance of the farmed animals. As aquatic organisms, the growth environment and physiological metabolism of the GAS have its own uniqueness, and there is also a certain similarity with TF.⁷ The crude protein content of GASM is 16.20%, which is similar to that of TF (17.63%), indicating that GASM can provide relatively abundant protein to meet the basic requirements of the growth and development of *E. sinensis*. Its crude fat content is 3.40%, lower than that of other diet. This may help reduce excessive fat accumulation, which could affect the crab's taste and flavor. In addition, the ash content of GASM is 3.24%, similar to that of TF (3.58%), indicating that it can meet the physiological needs such as the development of the exoskeleton of *E. sinensis*.

It is rare to find reports on the influence of GASM as a diet or feed ingredient on the flavor and quality of aquatic animals. The content of FFAAs in the hepatopancreas and muscle of crabs in the GASM group reached the same level as that of the TF group (Tables 4 and 5). The muscle-free alanine and the hepatopancreas-free glycine were even significantly higher than those in the TF group (Tables 4 and 5). This suggests that the crabs in the GASM group exhibited flavor profiles comparable to those in the TF group. Meanwhile, compared with the TF group, the crabs fed with GASM had a relatively minor impact on the composition of flavor nucleotides. Apart from the 5'-IMP content in the muscle being lower than that of the TF group, there were no significant differences in the contents of other taste nucleotides in the muscle and hepatopancreas between the two groups. Nucleotides are synergistic enhancers of

umami,²⁵ indicating that the crabs fed with GASM can effectively retain the umami substances, supporting their flavor quality.

In the present study, the proportion of SFA in the hepatopancreas of crabs fed with GASM was significantly higher than that in the TF group, while the proportion of n-3 PUFAs was significantly lower than that in the TF group. Wang et al.¹⁷ also documented that feeding *E. sinensis* with GASM could significantly increase the proportion of SFA and reduce the proportion of n-3 PUFAs in the hepatopancreas. Although the proportion of n-3 PUFAs in the hepatopancreas (5.75) was significantly lower than that in the TF group (9.83), it was still significantly higher than that in the MW (1.42), BSFL (1.24), and FLM (1.83) groups. At the same time, Bombeo-Tuburan et al.⁶⁹ showed that GASM is a good source of EPA. Therefore, from the perspective of fatty acid composition, the GASM group has a significant substitution advantage over the three types of insect diets and has greater potential as an alternative to the *E. sinensis* diet. Regarding the flavor substance content in the muscle and hepatopancreas of *E. sinensis*, GASM also has the potential to replace TF.

5. CONCLUSION

In this experiment, three insect diets have a significant negative impact on the edible quality and flavor of the crabs. The GASM diet showed almost no effect on the muscle and hepatopancreas FFAAs and nucleotides. The proportion of hepatopancreas n-3 PUFAs in the GASM group was significantly lower to the TF group, but it was still significantly higher than those of the three insect groups. In conclusion, based on the measured biochemical indicators, among the four types of diet on the edible quality and flavor, GASM has the greatest potential to replace TF as a diet for *E. sinensis*.

ACKNOWLEDGMENTS

This work was financially supported by Jiangsu Agri-animal Husbandry Vocational College school level research project (NSF2025ZR08) and Jiangsu Haorun Biological Industry Group Co., Ltd. (S20240619).

AUTHORS' CONTRIBUTIONS

Conceptualization: Wenxiang Yao (Equal), Chunyan Zhang (Equal). Methodology: Wenxiang Yao (Equal), Chunyan Zhang (Equal). Investigation: Wenxiang Yao (Equal), Chunyan Zhang (Equal). Writing – review & editing: Wenxiang Yao (Equal), Chunyan Zhang (Equal). Project administration: Wenxiang Yao (Equal), Xinze Li (Equal), Xiaoya Wu (Equal), Guoan Hua (Equal), Sizhe Zhao (Equal), Chunyan Zhang (Equal). Funding acquisition: Wenxiang Yao (Equal), Xinze Li (Equal), Xiaoya Wu (Equal), Chunyan Zhang (Equal). Formal Analysis: Ningyang Sun (Equal), Guoan Hua (Equal), Sizhe Zhao (Equal). Writing – original draft: Ningyang Sun (Lead).

ETHICS STATEMENT

All animal care and use procedures were approved by the Institutional Animal Care and Use Committee of Jiangsu Agri-animal Husbandry Vocational College (permit number: jsahvc-2024-25), and all authors clearly indicated that such guidelines have been followed.

DATA AVAILABILITY

All data generated or analyzed during this study are included in this article.

Submitted: June 22, 2026 CDT. Accepted: July 08, 2026 CDT.
Published: August 05, 2026 CDT.

CONFLICTS OF INTEREST

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.



This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY-4.0). View this license's legal deed at <http://creativecommons.org/licenses/by/4.0> and legal code at <http://creativecommons.org/licenses/by/4.0/legalcode> for more information.

REFERENCES

1. China Fishery Statistical Yearbook. China Agriculture Press; 2024.
2. Yang Y, Sun LS. Effects of different diets on the edible quality of Chinese mitten crab during the fattening period (*Eriocheir sinensis*). *Journal of Shanghai Ocean University*. 2022;30:123-130. doi:[10.27441/d.cnki.gyzdu.2022.000627](https://doi.org/10.27441/d.cnki.gyzdu.2022.000627)
3. Jia E, Zheng XC, Cheng HH, et al. Dietary fructooligosaccharide can mitigate the negative effects of immunity on Chinese mitten crab fed a high level of plant protein diet. *Fish and Shellfish Immunology*. 2019;84:100-107. doi:[10.1016/j.fsi.2018.09.074](https://doi.org/10.1016/j.fsi.2018.09.074)
4. Wang Y, Xu X, Yan Q, Xiong H, Deng F, Ma Y. Bacterial composition in feed mash of fresh frozen trash fish for large yellow croaker (*Larimichthys crocea*). *South China Fisheries Science*. 2014;10:45-52. doi:[10.3969/j.issn.2095-0780.2014.03.008](https://doi.org/10.3969/j.issn.2095-0780.2014.03.008)
5. Pertiwi MP, Saputri DD. Golden apple snail (*Pomacea canaliculata*) as an alternative protein source in Pasupati catfish (*Pangasius sp.*) fish feed. *Nusantara Bioscience*. 2020;12:162-167. doi:[10.13057/nusbiosci/n120212](https://doi.org/10.13057/nusbiosci/n120212)
6. Sogari G, Amato M, Biasato I, Chiesa S, Gasco L. The potential role of insects as feed: a multi-perspective review. *Animals*. 2019;9:119. doi:[10.3390/ani9040119](https://doi.org/10.3390/ani9040119)
7. Nusantara S, Natsir MH, Sjoefjan O. Nutritive value of golden apple snail (*Pomacea canaliculata*) as animal and aquaculture feed. *Reviews in Agricultural Science*. 2024;12:147-164. doi:[10.7831/ras.12.0_147](https://doi.org/10.7831/ras.12.0_147)
8. Ardra M, Pradhan C, Das S, Pillai D. The effect of fishmeal replacement with organic acid fermented black soldier fly (*Hermetia illucens*) larvae meal on growth, nutrient utilization, metabolic enzyme activity, antioxidant status and immunity in *Pangasius* (*Pangasianodon hypophthalmus*). *Aquaculture*. 2024;591:741114. doi:[10.1016/j.aquaculture.2024.741114](https://doi.org/10.1016/j.aquaculture.2024.741114)
9. Song Z, Wang L, Huang H, Jin W, Tian Z. Rapid determination of amino acid content of *Tenebrio molitor* by high performance liquid chromatography. *China Feed*. 2008;05:39-43. doi:[10.15906/j.cnki.cn11-2975/s.2008.05.009](https://doi.org/10.15906/j.cnki.cn11-2975/s.2008.05.009)
10. Li KQ. The application of *Pomacea canaliculata* in aquaculture and poultry farming and the prevention of its harm to crops. *Fishery Guide to be Rich*. 2003;21:29.
11. Inaoka T, Okubo G, Yokota M, Takemasa M. Nutritive value of house fly larvae and pupae fed on chicken feces as food source for poultry. *Journal of Poultry Science*. 1999;36:174-180. doi:[10.2141/jpsa.36.174](https://doi.org/10.2141/jpsa.36.174)
12. Zhang L, Wu HX, Li WJ, et al. Partial replacement of soybean meal by yellow mealworm (*Tenebrio molitor*) meal influences the flesh quality of Nile tilapia (*Oreochromis niloticus*). *Animal Nutrition*. 2023;12:108-115. doi:[10.1016/j.aninu.2022.09.007](https://doi.org/10.1016/j.aninu.2022.09.007)
13. Sankian Z, Khosravi S, Kim YO, Lee SM. Effects of dietary inclusion of yellow mealworm (*Tenebrio molitor*) meal on growth performance, feed utilization, body composition, plasma biochemical indices, selected immune parameters and antioxidant enzyme activities of mandarin fish (*Siniperca scherzeri*) juveniles. *Aquaculture*. 2018;496:79-87. doi:[10.1016/j.aquaculture.2018.07.012](https://doi.org/10.1016/j.aquaculture.2018.07.012)
14. Li H, Hu Z, Liu S, Sun J, Ji H. Influence of dietary soybean meal replacement with yellow mealworm (*Tenebrio molitor*) on growth performance, antioxidant capacity, skin color, and flesh quality of mirror carp (*Cyprinus carpio* var. *specularis*). *Aquaculture*. 2022;561:738686. doi:[10.1016/j.aquaculture.2022.738686](https://doi.org/10.1016/j.aquaculture.2022.738686)
15. Yang W, Kuang Y, Ye Y, Wu P, Xiao X, Wang J. Black gadfly meal partially replaces fishmeal in *Micropterus salmoides* diets and affects fish fatty acid composition. *Feed Industry*. Published online 2024. <https://link.cnki.net/urlid/21.1169.s.20241030.1602.004>
16. Liu ZJ, Li JZ, Ou YC. The influence of black soldier fly larvae powder as a substitute for fish meal on the growth performance, physiological metabolism and muscle quality of hybrid croakers. *Journal of Shanghai Ocean University*. Published online 2024:1-16. <http://kns.cnki.net/kcms/detail/31.2024.S.20250414.1309.004.html>
17. Wang J, Zhang YX, Lv H, et al. Effectiveness of juvenile *Eriocheir sinensis* in controlling *Pomacea canaliculata* and their growth and nutritional response to feeding on the snail. *Animals*. 2025;15:85. doi:[10.3390/ANI15010085](https://doi.org/10.3390/ANI15010085)
18. Feng Y, Yan Y, Xiao Z, Qiao H, Li J, Wang X. Effect of fish meal replacement by fly maggot meal on growth performance, body composition and serum biochemical indices of German mirror carp. *Feed Research*. 2023;46:51-54. doi:[10.13557/j.cnki.issn1002-2813.2023.04.011](https://doi.org/10.13557/j.cnki.issn1002-2813.2023.04.011)

19. Fashina-Bombata HA, Balogun O. The effect of partial or total replacement of fish meal with maggot meal in the diet of tilapia (*Oreochromis niloticus*) fry. *Journal of Prospects in Science*. 1997;1:178-181.
20. Liang QR, Zheng TL, Chen XM, et al. Effects of feeding with maggot protein added dietaries on immune and metabolic responses in liver and serum of soft-shelled turtles *Pelodiscus sinensis*. *Acta Agriculturae Zhejiangensis*. 2022;34:2172-2181. doi:[10.3969/j.issn.1004-1524.2022.10.11](https://doi.org/10.3969/j.issn.1004-1524.2022.10.11)
21. AOAC (Association of Official Analytical Chemists). *Official Methods of Official Analytical Chemists International*. 16th ed. Association of Official Analytical Chemists; 2005.
22. Shao L, Wang C, He J, Wu X, Cheng Y. Hepatopancreas and gonad quality of Chinese mitten crabs fattened with natural and formulated diets. *Journal of Food Quality*. 2013;36:217-227. doi:[10.1111/jfq.12030](https://doi.org/10.1111/jfq.12030)
23. Yamaguchi S, Yoshikawa T, Ikeda S, Ninomiya T. Measurement of the relative taste intensity of some α -amino acid and 5'-nucleotides. *Journal of Food Science*. 1971;36:846-849. doi:[10.1111/j.1365-2621.1971.tb15541.x](https://doi.org/10.1111/j.1365-2621.1971.tb15541.x)
24. Wong KH, Abdul Aziz S, Mohamed S. Sensory aroma from Maillard reaction of individual and combinations of amino acids with glucose in acidic conditions. *International Journal of Food Science and Technology*. 2008;43:1512-1519. doi:[10.1111/j.1365-2621.2006.01445.x](https://doi.org/10.1111/j.1365-2621.2006.01445.x)
25. Kawai M, Okiyama A, Ueda Y. Taste enhancements between various amino acids and IMP. *Chemical Senses*. 2002;27:739-745. doi:[10.1093/chemse/27.8.739](https://doi.org/10.1093/chemse/27.8.739)
26. Costas B, Aragão C, Mancera JM, Dinis MT, Conceição LE. High stocking density induces crowding stress and affects amino acid metabolism in Senegalese sole *Solea senegalensis* (Kaup 1858) juveniles. *Aquaculture Research*. 2008;39:1-9. doi:[10.1111/j.1365-2109.2007.01845.x](https://doi.org/10.1111/j.1365-2109.2007.01845.x)
27. Dong B, Wu L, Wang Y, et al. Glutamate improves flesh quality and muscle growth of triploid crucian carp. *Aquaculture Reports*. 2023;33:101832. doi:[10.1016/j.aqrep.2023.101832](https://doi.org/10.1016/j.aqrep.2023.101832)
28. Fuke S, Konosu S. Taste-active components in some foods: a review of Japanese research. *Physiology and Behavior*. 1991;49:863-868. doi:[10.1016/0031-9384\(91\)90195-T](https://doi.org/10.1016/0031-9384(91)90195-T)
29. Spurvey S, Pan BS, Shahidi F. Flavour of shellfish. In: Shahidi F, ed. *Flavor of Meat, Meat Products and Seafoods*. 2nd ed. Blackie Academic & Professional; 1998:159-196.
30. Wu HC, Shiau CY. Proximate composition, free amino acids and peptides contents in commercial chicken and other meat essences. *Journal of Food and Drug Analysis*. 2002;10:170-177.
31. Wang X, He Y, Wang YY, et al. Comparison of flavour qualities of three sourced *Eriocheir sinensis*. *Food Chemistry*. 2016;200:24-31. doi:[10.1016/j.foodchem.2015.12.093](https://doi.org/10.1016/j.foodchem.2015.12.093)
32. Turchini GM, Hermon K, Moretti VM, et al. Seven fish oil substitutes over a rainbow trout grow-out cycle: II) effects on final eating quality and a tentative estimation of feed-related production costs. *Aquaculture Nutrition*. 2013;19:95-109. doi:[10.1111/anu.12045](https://doi.org/10.1111/anu.12045)
33. Fillmore N, Huqi A, Jaswal JS, et al. Effect of fatty acids on human bone marrow mesenchymal stem cell energy metabolism and survival. *PLOS ONE*. 2015;10:e0120257. doi:[10.1371/journal.pone.0120257](https://doi.org/10.1371/journal.pone.0120257)
34. El-Ansary A, Al-Ayadhi L. Relative abundance of short chain and polyunsaturated fatty acids in propionic acid-induced autistic features in rat pups as potential markers in autism. *Lipids in Health and Disease*. 2014;13:140. doi:[10.1186/1476-511X-13-140](https://doi.org/10.1186/1476-511X-13-140)
35. Cecile CV, Federico FD, Arnaud AM, et al. Adipose tissue mitochondrial dysfunction triggers a lipodystrophic syndrome with insulin resistance, hepatosteatosis and cardiovascular complications. *FASEB Journal*. 2014;28:4408-4419. doi:[10.1096/fj.14-253971](https://doi.org/10.1096/fj.14-253971)
36. Samuel BS, Hansen EE, Manchester JK, et al. Genomic and metabolic adaptations of *Methanobrevibacter smithii* to the human gut. *Proceedings of the National Academy of Sciences*. 2007;104:10643-10648. doi:[10.1073/pnas.0704189104](https://doi.org/10.1073/pnas.0704189104)
37. Xu R, Wang GQ, Wu BC, Liu CX. Effect of defatted *Tenebrio molitor* on nursery pig's production performance and serum biochemical indexes. *Chinese Feed*. 2019;09:41-44. doi:[10.15906/j.cnki.cn11-2975/s.20190908](https://doi.org/10.15906/j.cnki.cn11-2975/s.20190908)
38. Christos IR, Ioannis TK, Eleni M, Christos GA. The lesser mealworm *Alphitobius diaperinus*: a noxious pest or a promising nutrient source. *Reviews in Aquaculture*. 2019;11(4):1418-1437. doi:[10.1111/raq.12300](https://doi.org/10.1111/raq.12300)

39. Zhang ZY, Yuan J, Tian SJ, et al. Effects of dietary vitamin E supplementation on growth, feed utilization and flesh quality of large yellow croaker *Larimichthys crocea* fed with different levels of dietary yellow mealworm *Tenebrio molitor* meal. *Aquaculture*. 2022;551:737954. doi:[10.1016/j.aquaculture.2022.737954](https://doi.org/10.1016/j.aquaculture.2022.737954)
40. Iaconisi V, Secci G, Sabatino G, et al. Effect of mealworm (*Tenebrio molitor* L.) larvae meal on amino acid composition of gilthead sea bream (*Sparus aurata* L.) and rainbow trout (*Oncorhynchus mykiss* W.) filets. *Aquaculture*. 2019;513:734403. doi:[10.1016/j.aquaculture.2019.734403](https://doi.org/10.1016/j.aquaculture.2019.734403)
41. Yuan J, Wu Y, Zhang ZY, et al. Replacement of fishmeal by yellow mealworm meal on the growth performance, feed utilisation and quality of large yellow croaker. *Journal of Insects as Food and Feed*. 2022;8:1311-1332. doi:[10.3920/JIFF2021.0144](https://doi.org/10.3920/JIFF2021.0144)
42. Mastoraki M, Mollá Ferrándiz P, Vardali SC, et al. A comparative study on the effect of fish meal substitution with three different insect meals on growth, body composition and metabolism of European sea bass (*Dicentrarchus labrax* L.). *Aquaculture*. 2020;528:735511. doi:[10.1016/j.aquaculture.2020.735511](https://doi.org/10.1016/j.aquaculture.2020.735511)
43. Roncarati A, Gasco L, Parisi G, Terova G. Growth performance of common catfish (*Ameiurus melas* Raf.) fingerlings fed mealworm (*Tenebrio molitor*) diet. *Journal of Insects as Food and Feed*. 2015;1:233-240. doi:[10.3920/jiff2014.0006](https://doi.org/10.3920/jiff2014.0006)
44. Belforti M, Gai F, Lussiana C, et al. Tenebrio molitor meal in rainbow trout (*Oncorhynchus mykiss*) diets: effects on animal performance, nutrient digestibility and chemical composition of filets. *Italian Journal of Animal Science*. 2015;14:670-676. doi:[10.4081/ijas.2015.4170](https://doi.org/10.4081/ijas.2015.4170)
45. Sánchez-Muros MJ, Haro C, Sanz A, Trenzado CE, Villareces S, Barroso FG. Nutritional evaluation of *Tenebrio molitor* meal as fishmeal substitute for tilapia (*Oreochromis niloticus*) diet. *Aquaculture Nutrition*. 2016;22:943-955. doi:[10.1111/anu.12313](https://doi.org/10.1111/anu.12313)
46. Iaconisi V, Marono S, Parisi G, et al. Dietary inclusion of *Tenebrio molitor* larvae meal: effects on growth performance and final quality traits of blackspot sea bream (*Pagellus bogaraveo*). *Aquaculture*. 2017;476:49-58. doi:[10.1016/j.aquaculture.2017.04.007](https://doi.org/10.1016/j.aquaculture.2017.04.007)
47. Sánchez-Muros MJ, Barroso FG, Manzano-Agugliaro F. Insect meal as renewable source of food for animal feeding: a review. *Journal of Cleaner Production*. 2014;65:16-27. doi:[10.1016/j.jclepro.2013.11.068](https://doi.org/10.1016/j.jclepro.2013.11.068)
48. Spranghers T, Ottoboni M, Klootwijk C, et al. Nutritional composition of black soldier fly (*Hermetia illucens*) prepupae reared on different organic waste substrates. *Journal of the Science of Food and Agriculture*. 2017;97:2594-2600. doi:[10.1002/jsfa.8081](https://doi.org/10.1002/jsfa.8081)
49. Qiu JF, Luo C, Ren LH, et al. Black soldier fly larvae replace traditional iced trash fish diet to enhance the delicious flavor of Chinese mitten crab (*Eriocheir sinensis*). *Frontiers in Marine Science*. Published online 2023. doi:[10.3389/fmars.2022.1089421](https://doi.org/10.3389/fmars.2022.1089421)
50. Belforti M, Gai F, Lussiana C, et al. *Tenebrio molitor* meal in rainbow trout (*Oncorhynchus mykiss*) diets: effects on animal performance, nutrient digestibility and chemical composition of filets. *Italian Journal of Animal Science*. 2015;14:4170. doi:[10.4081/ijas.2015.4170](https://doi.org/10.4081/ijas.2015.4170)
51. Renna M, Schiavone A, Gai F, et al. Evaluation of the suitability of a partially defatted black soldier fly (*Hermetia illucens* L.) larvae meal as ingredient for rainbow trout (*Oncorhynchus mykiss* Walbaum) diets. *Journal of Animal Science and Biotechnology*. 2017;8:57. doi:[10.1186/s40104-017-0191-3](https://doi.org/10.1186/s40104-017-0191-3)
52. Bolton CM, Muller N, Hyland J, et al. Black soldier fly larval meal with exogenous protease in diets for rainbow trout (*Oncorhynchus mykiss*) production meeting consumer quality. *Journal of Agriculture and Food Research*. 2021;6:100232. doi:[10.1016/j.jafr.2021.100232](https://doi.org/10.1016/j.jafr.2021.100232)
53. Weng XZ, Shao X, Ye JQ, Wu YB, Wang XJ, Wang J. Effects of replacing fish meal with defatted black soldier fly larvae meal on growth performance and muscle quality of largemouth bass (*Micropterus salmoides*). *Feed Research*. 2024;47:70-74. doi:[10.13557/j.cnki.issn1002-2813.2024.24.014](https://doi.org/10.13557/j.cnki.issn1002-2813.2024.24.014)
54. Fasakin EA, Balogun AM, Ajayi OO. Evaluation of full-fat and defatted maggot meals in the feeding of clariid catfish *Clarias gariepinus* fingerlings. *Aquaculture Research*. 2003;34:733-738. doi:[10.1046/j.1365-2109.2003.00876.x](https://doi.org/10.1046/j.1365-2109.2003.00876.x)
55. Ogunji J, Kloas W, Wirth M, Schulz C, Rennert B. Housefly maggot meal (maggot meal) as an emerging substitute of fishmeal in tilapia diets. In: *Conference on International Agricultural Research for Development, Tropentag*. ; 2006.
56. Ogunji J, Summan RUA, Schulz C, Kloas W. Growth performance and nutrient utilization of Nile tilapia *Oreochromis niloticus* fed housefly maggot meal (maggot meal) diets. *Turkish Journal of Fisheries and Aquatic Sciences*. 2008;8:141-147.

57. Jabir MAR, Jabir SAR, Vikineswary S. Nutritive potential and utilization of super worm (*Zophobas morio*) meal in the diet of Nile tilapia (*Oreochromis niloticus*) juvenile. *African Journal of Biotechnology*. 2014;11:6592-6598. doi:[10.4314/ajb.v11i24](https://doi.org/10.4314/ajb.v11i24)
58. Weatherup RN, McCracken KJ. Changes in rainbow trout, *Oncorhynchus mykiss* (Walbaum), body composition with weight. *Aquaculture Research*. 1999;30:305-314. doi:[10.1046/j.1365-2109.1999.00320.x](https://doi.org/10.1046/j.1365-2109.1999.00320.x)
59. Sun LH, Zhang HQ, Huang AX, Li Q, Jiang RX, Lin F. The effects of adding silkworm peptide powder or fly maggot powder to the feed on the growth, body composition and digestive enzyme activity of juvenile Chinese mud crabs. *Journal of Shanghai Fisheries University*. 2022;31:906-914. doi:[10.12024/jsou.20210403393](https://doi.org/10.12024/jsou.20210403393)
60. Chen XM, Chen ZT, Yan ZB, Zhao PY, Wang FH, Li GH. The effects of fly maggot protein on the growth, immunity and muscle composition of *Penaeus vannamei* shrimp. *Fisheries Science*. 2018;37:324-329. doi:[10.16378/j.cnki.1003-1111.2018.03.006](https://doi.org/10.16378/j.cnki.1003-1111.2018.03.006)
61. Yan J, Cao JM, Wang RX, et al. The influence of fly maggot meal as a substitute for fish meal on the nutritional components, amino acids and inosinic acid content of penaeid shrimp muscle. *Journal of Fishery Sciences of China*. 2012;19:265-274. doi:[10.3724/SP.J.1118.2012.00265](https://doi.org/10.3724/SP.J.1118.2012.00265)
62. Chen XM, Huang QC, Wang FH, Li GH. The effects of fly maggots protein on the growth performance and nutritional quality of Chinese soft shelled turtles. *Aquatic Sciences*. 2018;37:51-58. doi:[10.16378/j.cnki.1003-1111.2018.01.008](https://doi.org/10.16378/j.cnki.1003-1111.2018.01.008)
63. Shi DJ, Liang YJ, Sun YS, Zhu ZY. The effects of maggot meal replacing fish meal on the growth, muscle composition and non-specific immune indicators of tilapia. *Freshwater Fisheries*. 2015;42(6):319-323. doi:[10.16446/j.cnki.1001-1994.2015.06.006](https://doi.org/10.16446/j.cnki.1001-1994.2015.06.006)
64. Turchini GM, Mentasti T, Caprino F, Panseri S, Moretti V, Valfrè F. Effects of dietary lipid sources on flavour volatile compounds of brown trout (*Salmo trutta* L.) fillet. *Journal of Applied Ichthyology*. 2004;20:71-75. doi:[10.1046/j.0175-8659.2003.00522.x](https://doi.org/10.1046/j.0175-8659.2003.00522.x)
65. Borgogno M, Dinnella C, Iaconisi V, et al. Inclusion of *Hermetia illucens* larvae meal on rainbow trout (*Oncorhynchus mykiss*) feed: effect on sensory profile according to static and dynamic evaluations. *Journal of the Science of Food and Agriculture*. 2017;97:3402-3411. doi:[10.1002/jsfa.8191](https://doi.org/10.1002/jsfa.8191)
66. Li WJ, Wang HY, Pan JT, et al. Research progress on the impact of rice-crab symbiosis on rice growth and paddy field ecology. *Transactions of Oceanology and Limnology*. 2024;46:203-210. doi:[10.13984/j.cnki.cn37-1141.2024.06.026](https://doi.org/10.13984/j.cnki.cn37-1141.2024.06.026)
67. Da CT, Lundh T, Lindberg JE. Evaluation of local feed resources as alternatives to fish meal in terms of growth performance, feed utilisation and biological indices of striped catfish (*Pangasianodon hypophthalmus*) fingerlings. *Aquaculture*. 2012;364-365:150-156. doi:[10.1016/j.aquaculture.2012.08.010](https://doi.org/10.1016/j.aquaculture.2012.08.010)
68. Da CT, Lundh T, Lindberg JE. Digestibility of dietary components and amino acids in animal and plant protein feed ingredients in striped catfish (*Pangasianodon hypophthalmus*) fingerlings. *Aquaculture Nutrition*. 2013;19:741-750. doi:[10.1111/anu.12021](https://doi.org/10.1111/anu.12021)
69. Bombeo-Tuburan I, Fukumoto S, Rodriguez EM. Use of the golden apple snail, cassava, and maize as feeds for the tiger shrimp, *Penaeus monodon*, in ponds. *Aquaculture*. 1995;131:91-100. doi:[10.1016/0044-8486\(94\)00329-M](https://doi.org/10.1016/0044-8486(94)00329-M)
70. Catalma MT, Capili DT, Antalan RA, Serra AB, Barroga AJ, Orden E. Golden snail (*Pomacea* sp.) use in animal feeds. *International Rice Research Institute Newsletter*. 1991;16:26-27.