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Research Article

A Comparative Study on the Quality of Large Yellow Croaker (*Larimichthys crocea*) of Different Sizes Cultured in Different Cage Systems

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This study analyzed the quality of large yellow croaker (*Larimichthys crocea*) of different sizes cultured in farmed floating sea-cage (common cage, CC) or deep-water cage (DWC) models. The quality was assessed based on several factors: condition factors, ventral color, texture, protein and lipid content, and fatty acid composition. In addition, we analyzed and identified taste characteristics and volatile substances. The results showed that large yellow croaker cultured in DWC had a better body shape than CC with lower condition factors and higher body length-to-height ratio. The DWC cultured fish were yellower with lower lipid content than the CC cultured fish. The springiness of the flesh from fishes cultured in DWC was significantly higher than those cultured in CC. The level of immobilized water and n-3 polyunsaturated fatty acid was higher in DWC. The DWC culture model contributed to the sweetness, saltiness, and umami of the flesh. The flesh from DWC had a higher content of aldehydes, such as pentanal, heptanal, and hexanal. The results demonstrated that the DWC culture model is a better choice to improve the quality of large yellow croaker in terms of organoleptic properties, nutritional value, and taste.

1. Introduction

The large yellow croaker (*Larimichthys crocea*) is mainly found in coastal waters of continental East Asia. It is a large endemic species in China, inhabiting the southern Yellow Sea, East China Sea, and northern South Sea [1]. It has become a popular seafood in China due to its high nutritional value and special flavor. The protein content of the large yellow croaker is about 18% and it contains high levels of minerals and microelements [2]. Owing to the breakthrough of artificial propagation technology in the 1990s, the breeding of large yellow croaker has developed rapidly. In 2021, the production of large yellow croaker was 254,224 tons, making it the most produced species in marine aquaculture.

Fish nutrition can be affected by different factors, such as diet, size, and environmental conditions [3–6]. In the wild, the large yellow croaker lives typically inhabit deeper waters, often reaching depths of up to 60 m, significantly deeper than the conditions in artificial cultivation [7]. These fish move seasonally and prefer low-velocity environments [8]. The use of net cages in the large yellow croaker breeding industry significantly limited fish movement and led to various issues, such as increased susceptibility, whiter skin, lower flesh quality, and higher lipid content [9]. To satisfy the demands for high-quality large yellow croaker, several farming models have been explored: traditional pond farming, farmed floating sea-cage (common cage, CC) and deep-water cage (DWC). Compared to CC, DWC is much bigger and the water of DWC is deeper. The DWC system offers an expanding culture area and a higher water exchange rate, resulting in a suitable growth environment and improvement of the fish quality [10, 11]. However, the quality of large yellow croaker

with different sizes cultured in CC or DWC still needs to be investigated.

Fish quality comprises both organoleptic properties and nutritional value [12]. The organoleptic properties include color, texture, and flavor. The nutritional value of the fish is determined by the fats, proteins, and carbohydrates in the flesh [13]. Chromameter is widely used to compare the color of fish without any destruction. The value of b^* measured by a chromameter is always used to identify the degree of yellow pigmentation in large yellow croaker [14–16]. Texture profile analysis (TPA) was developed to characterize the texture profile of the flesh just using a block of flesh [17, 18]. Using TPA, the texture characteristics of the flesh can be quantified by hardness, springiness, cohesiveness, chewiness, and so forth. Flavor is determined by the taste and odor of the food. Taste is reflected by the binding of water-soluble taste-presenting substances to human taste receptors [19]. The unique electrical signals generated by these compounds enable us to discern different tastes. Based on the biological mechanism of taste perception, the electronic tongue is designed to characterize slight differences in taste and is widely used to evaluate the characteristics of foods [20, 21]. The odor of the flesh is determined by the volatile components, such as alkane, olefin, ketone, alcohol, and aromatic compounds. Compared to current analytical techniques such as gas chromatography (GC) and GC-mass spectrometry, gas chromatography-ion mobility spectrometry (GC-IMS) requires no complex pretreatment and is sensitive and fast [22]. GC-IMS is widely used to identify the differences in flavor volatile components in large yellow croaker [23, 24].

The rapid development of nondestructive technologies in food quality assessment has significantly enhanced our understanding of the quality of large yellow croaker. However, the quality of large yellow croaker cultured in improved farming model still needs further investigation. This study analyzed the differences in color, texture, nutrition, and taste of large yellow croaker with different sizes cultured in CC or DWC. Furthermore, the attribution of farming models and fish sizes on the quality of large yellow croaker was investigated. The data presented in this paper will contribute to the distinction of flesh quality of large yellow croaker in different sizes and farming models, as well as enhance our understanding of improving quality by farming model.

2. Materials and Methods

2.1. Animals and Sample Preparation. The large yellow croaker used in this study was obtained from a commercial farm in August 2022. The fish were cultured in the marine culture area of Sanduao, Ningde City, Fujian Province. The fish were cultured in two models: farmed floating sea-cage (CC) and DWC. The dimensions of the cage in CC are $3 \times 3 \times 3$ m, while the cage in DWC has a diameter of 15 m and a depth of 10 m. For the DWC culture model, juvenile fish were cultured in CC, and transferred to DWC after reaching a weight of 150 g. Twenty-five fish were collected from each model: five in large size (L, with an average weight of 996 g), ten in medium size (M, with an average weight of 553 g), and ten in small size (S, with an average weight of 276 g). Fish of large size were cultured for 3 years, while fish of medium and small sizes were cultured for only 2 years. All the fish were caught at night and kept in an ice foam box. The samples were transported to the lab within 8 hr. After arriving at the lab, the body weight, length, height, caudal peduncle length, height, color, and texture of the fish were measured as soon as possible. To reduce the impact of muscle location variations, epaxial muscles from both sides of the fish were selected for the present study. The muscle was mixed and stored at −80°C before further analyses.

2.2. Morphology Analysis. The body weight (W) and weight without viscera (W_0) of fish were measured. Body length (L) is measured from the snout to the last vertebra. Body height (H) is defined as the vertical distance between the ventral and dorsal edges of fish. The caudal peduncle length ($L1$) and height ($H1$) represent the length from the end of the anal fin to the last vertebra and the minimum caudal peduncle height. The condition factor (K) was calculated as $K = W_0/L^3 \times 100$.

2.3. Ventral Color Analysis. The ventral color was measured using a chroma meter (CR400, Konica Minolta, Japan). The value of b^* was obtained according to the CIE standard. The measurement and illumination area were 8 and 11 mm, respectively. Three values of b^* were measured from each fish, two at the base of the ventral fin and the anal fin. The third site was located at the midpoint of ventral and anal fin. The average of three values was used to characterize the color of the fish.

2.4. Texture Analysis. Epaxial muscle was used for the texture analysis referred to the methods described by Wang et al. [25]. Once the fresh fishes arrive at the lab, the epaxial muscle will be separated from the fish. After removing the skin, the epaxial muscle was diced into $1 \times 1 \times 1$ cm. A texture analyzer (TMS Pro, Food Technology Corporation, USA) with a test probe of P/5 was used to analyze the texture. The TPA method characterized the texture by cohesiveness, springiness, adhesiveness, and chewiness. The detection speed was 50 mm/min. The strain was set to 50% and the travel distance to 25 mm.

2.5. Low-Field Nuclear Magnetic Resonance Analysis. Low-field nuclear magnetic resonance (LF NMR, Niumag Analytical Instrument Corporation, China) with a magnetic field of 0.5 T was used to analyze the water distribution of the flesh [26]. Epaxial muscle was cut into $1 \times 1 \times 1$ cm. The samples were placed in a test cylindrical glass tube. The transverse relaxation time ($T2$) was measured using the Carr–Purcell–Meiboom–Gill pulse sequence. Each sample was scanned 16 times, with a 3-s interval between each scan, resulting in a total of 2,500 echoes.

2.6. Proximate Composition Measurement. Frozen samples were kept at room temperature. After thawing, the samples in one group were homogenized. Three replicates were conducted to measure the moisture, protein, and lipid contents. Moisture analyzer (HE53, METTLER TOLEDO, USA) was used to measure the moisture. About 1 g homogenized sample was placed on a plate and was dried to constant

Table 1: Morphological characteristics of *Larimichthys crocea* cultured in DWC or CC systems.

	W (g)	K (g/cm^3)	L/H	$L1/H1$	b *
DWC-L	1,029 ± 89	1.31 ± 0.07^a	4.19 ± 0.13^b	4.47 ± 0.58^b	66.18 ± 2.44^d
DWC-M	576 ± 38	1.41 ± 0.09^a	4.04 ± 0.20^b	4.00 ± 0.28^{ab}	70.13 ± 4.69^d
DWC-S	307 ± 21	1.36 ± 0.10^a	4.11 ± 0.14^b	4.22 ± 0.21^{ab}	60.16 ± 6.86^c
CC-L	963 ± 23	1.92 ± 0.14^c	3.37 ± 0.16^a	3.76 ± 0.44^a	54.28 ± 6.08^{bc}
CC-M	529 ± 10	1.73 ± 0.14^b	3.52 ± 0.16^a	3.78 ± 0.19^a	49.66 ± 5.19^{ab}
CC-S	244 ± 12	1.70 ± 0.12^b	3.54 ± 0.19^a	4.19 ± 0.28^{ab}	44.59 ± 5.46^a

Note: All data were expressed as means ± standard deviations. Mean values within the same column with different superscripts are significantly different ($P < 0.05$).

weight. Moisture was determined based on the rate of weight change. Total protein was determined by measuring nitrogen using the Kjeldahl method (GB 5009.5-2016). Petroleum ether was used to extract the lipid. The content of ash was measured by combustion at 550°C for 4 hr. For both protein, lipid, and ash, three replicates were performed.

2.7. Fatty Acid Composition Measurement. Crude lipid was extracted using chloroform–methanol (2 : 1, v/v). Methanol was removed after delamination by adding sodium chloride. The water in the chloroform phase was removed by filtrating through anhydrous sodium sulfate. Then the chloroform was evaporated under a rotary evaporator. The lipid was kept at −80°C for further use. The lipid was saponified using a saponification reagent (2 g sodium hydroxide in 100 mL methanol) at 100°C. The fatty acid methyl ester was conducted by transesterification with 14% BF_3-methanol for 5 min. Then the n-hexane was added to stop the reaction. Upon addition of saturated sodium chloride solution, the mixture underwent delamination. The upper layer was collected and filtered through a 0.22 μm syringe filter. All the samples were conducted in triplicate.

Chromatographic analysis was performed using a GC (GC7820, Agilent, USA). The injector and detector were maintained at temperatures of 250 and 280°C, respectively. The temperature program was as follows: an initial temperature of 45°C was set, followed by a ramp up to 105°C at 25°C/min, maintaining this temperature for 2 min. The temperature was then ramped up to 200°C at a rate of 15°C/min and held for 10 min. Subsequently, the temperature was increased to 210°C at 1°C/min and maintained for 10 min before increasing to 220°C at 2°C/min and holding for a further 10 min. The quantification of fatty acids was analyzed using OpenLab CDS (Agilent, USA). The relative proportion of each fatty acid was expressed as a percentage of the total fatty acid.

2.8. Electronic Tongue Analysis. Taste Sensing System (SA402B, Insent, Japan) was used for taste-sensing analysis. Sample preparation followed the previously reported method [27]. The thawed sample (50 ± 0.001 g) was weighed and homogenized with 200 mL ultrapure water at 40°C. Then the samples were centrifuged at 3,000 rpm for 10 min, and kept at room temperature until delamination. The supernatant was filtered by filter paper and subsequently collected for further use. A total of six detecting sensors were used in this study: CT0 specific for saltiness, AAE for umami and richness, CA0 for sourness, C00 for bitterness and aftertaste-B, AE1 for astringency and aftertaste-A, and GL1 for sweetness. Each sample was measured five times, and only the last three values were used to determine taste. Origin Pro (OriginLab, USA) was employed to conduct the radar chart ordering and principal component analysis (PCA) for the taste-sensing analysis.

2.9. Volatile Compound Analysis. FlavourSpec® Sensitive Analyser (GAS, Germany) was used to analyze the volatile compounds of the flesh, according to Wang et al. [28]. Frozen samples were thawed at room temperature. The thawed sample (3 ± 0.001 g) was weighed and transferred into a 20 mL headspace glass vial, which was then sealed and incubated at 60°C for 15 min. The headspace injector automatically injected headspace gas in split flow mode at 85°C. The volume of the injection was 500 μL, and the cleaning time was 30 s. The MXT-WAX chromatographic column (30 m × 0.53 mm, df 1 μm) separated the volatile compounds at 60°C for 30 min. The carrier and drift gas were nitrogen (99.999%). The flow rate was programmed as follows: 2 mL/min for the first 2 min, which was then ramped up to 10 mL/min over 8 min and further increased to 100 mL/min over 10 min. Subsequently, the flow rate was maintained at 100 mL/min for 10 min, and the analysis lasted 30 min. Data from GC-IMS was identified and quantified by VOCal software using NIST and IMS databases.

2.10. Statistical Analysis. All data in this study were presented as means ± standard deviations. Statistical significance was evaluated using one-way analysis of variance combined with Duncan's multiple range test using SPSS Statistics 22 (IBM, USA), and $P < 0.05$ was considered to be a statistically significant change. Graphs in this study were generated using GraphPad Prism 9 (GraphPad, USA) and Origin Pro (OriginLab, USA).

3. Results

3.1. Appearance Indicators. We analyzed the condition factor, body length-to-height ratio, caudal peduncle length-to-height ratio, and ventral color of large yellow croaker cultured in CC or DWC (Table 1). The condition factors in DWC were significantly lower than those in CC, while the ratios of body length and height were significantly increased in DWC ($P < 0.05$). Fishes with different sizes cultured in DWC had the same condition factor and body length/height ($P > 0.05$). As the increased in size, the

Table 2: Flesh texture of *Larimichthys crocea* cultured in DWC or CC systems.

	Cohesiveness	Springiness (mm)	Adhesiveness (N)	Chewiness (mj)
DWC-L	0.39 ± 0.06^{bc}	2.48 ± 0.20^{b}	19.49 ± 1.44^{c}	48.61 ± 5.86^{c}
DWC-M	0.44 ± 0.03^{cd}	2.41 ± 0.08^{b}	12.79 ± 1.19^{b}	30.80 ± 3.57^{b}
DWC-S	0.49 ± 0.05^{d}	1.96 ± 0.06^{a}	9.66 ± 1.09^{a}	19.00 ± 2.42^{a}
CC-L	0.36 ± 0.02^{ab}	1.88 ± 0.15^{a}	9.44 ± 1.95^{a}	18.05 ± 5.01^{a}
CC-M	0.42 ± 0.10^{bc}	1.89 ± 0.19^{a}	8.58 ± 1.45^{a}	16.58 ± 3.78^{a}
CC-S	0.33 ± 0.03^{a}	1.86 ± 0.15^{a}	8.03 ± 1.55^{a}	15.24 ± 3.75^{a}

Note: All data were expressed as means ± standard deviations. Mean values within the same column with different superscripts are significantly different ($P < 0.05$).

Table 3: Proximate composition of flesh from *Larimichthys crocea* cultured in DWC or CC systems (% of wet weight).

	Moisture	Lipid	Protein	Ash
DWC-L	72.72 ± 0.70^{a}	3.79 ± 0.11^{a}	18.75 ± 0.60^{ab}	1.29 ± 0.08^{ab}
DWC-M	72.05 ± 0.45^{a}	5.30 ± 0.05^{c}	19.03 ± 0.30^{b}	1.16 ± 0.06^{a}
DWC-S	73.98 ± 0.37^{b}	4.64 ± 0.25^{b}	18.66 ± 0.18^{ab}	1.36 ± 0.11^{b}
CC-L	71.90 ± 1.20^{a}	8.56 ± 0.19^{d}	19.22 ± 0.29^{b}	1.14 ± 0.13^{a}
CC-M	72.05 ± 0.55^{a}	13.54 ± 0.19^{e}	17.89 ± 0.49^{a}	1.06 ± 0.06^{a}
CC-S	71.43 ± 0.62^{a}	8.52 ± 0.03^{d}	17.91 ± 0.63^{a}	1.34 ± 0.09^{b}

Note: All data were expressed as means ± standard deviations. Mean values within the same column with different superscripts are significantly different ($P < 0.05$).

condition factor of fishes cultured in CC was increased, with significant change found in the larger size (CC-L) ($P < 0.05$). Although the body length/height was reduced, no statistically significant difference was found ($P > 0.05$). No significant differences were observed in the caudal peduncle length-to-height ratio among fish of different sizes cultured in either CC or DWC ($P > 0.05$). However, DWC-L had significantly higher caudal peduncle length/height than CC-L and CC-M ($P < 0.05$). Fish in DWC was yellower than those in CC, and fishes with larger sizes had higher b^* than small ones ($P < 0.05$).

3.2. Texture. The cohesiveness, springiness, adhesiveness, and chewiness of the fishes cultured in DWC or CC are shown in Table 2. The study findings revealed that the variations in culture models significantly affected the springiness, adhesiveness, and chewiness of the sample. Compared with the fishes cultured in CC, the muscle of fishes cultured in DWC had higher springiness, adhesiveness, and chewiness with significant changes in large and medium sizes ($P < 0.05$). No change was observed in cohesiveness among fish of different sizes cultured in DWC or CC ($P > 0.05$). A significant change was only found between the small size ($P < 0.05$).

3.3. Proximate Composition. The proximate composition of the flesh was shown in Table 3, the moisture content among the fishes was similar in the absence of DWC-S ($P > 0.05$). However, in the presence of DWC-S, the moisture content was significantly higher than in the other fishes ($P < 0.05$). Minor changes were found in protein levels with higher levels in DWC-M and CC-L than CC-M and CC-S ($P < 0.05$). Lipid was significantly affected by the culture models. Fishes cultured in DWC had lower content of lipids ($P < 0.05$). The highest lipid content was found in CC-M ($P < 0.05$). Medium fishes had the highest lipid for each culture model than other sizes ($P < 0.05$). The contents of the ash between DWC and CC were similar. A significantly higher content of ash was found in small fish ($P < 0.05$).

3.4. Fatty Acid Composition. Lipid nutritional value is related to the fatty acid composition. The fatty acid compositions of fishes cultured in different models were analyzed and presented in Table 4. Although lipid content in DWC was significantly lower than in CC ($P < 0.05$), the categories of fatty acids were the same in both DWC and CC. The results revealed that C16:0, C18:1n-9, and DHA were the main fatty acids in large yellow croaker. Saturated fatty acid (SFA) in the DWC culture model was slightly lower than the CC model ($P > 0.05$). The polyunsaturated fatty acid (PUFA) in DWC was higher than CC, with significantly higher levels in medium and small sizes ($P < 0.05$). The highest levels of n-3 PUFA and the n-3/n-6 ratio were found in DWC-S.

3.5. Water Distribution. As demonstrated in Figure 1, three types of water were identified in the flesh of large yellow croak, including protein-associated water or bound water (T_{2b}, 0–10 ms), immobilized water (T_{21}, 10–100 ms), and free water (T_{22}, 100–1,000 ms). The proportions of each type of water were calculated by the peak area and represented as P_{2b}, P_{21}, and P_{22}. No significant differences were observed in the ratio of bound water among fishes cultured in DWC and CC ($P > 0.05$). Immobilized water is the main type of water in the flesh, which could be converted to free water. A higher level of immobilized water was identified in DWC, leading to a corresponding decrease in free water ($P < 0.05$).

3.6. Taste Characteristics. The outline of the sensory taste value was shown in Figure 2(a). As shown, the outline of different tastes was similar among different culture models.

Table 4: Fatty acid composition of flesh from *Larimichthys crocea* cultured in DWC or CC systems (%).

	DWC-L	DWC-M	DWC-S	CC-L	CC-M	CC-S
C14:0	3.50 ± 0.06^{a}	3.37 ± 0.05^{a}	3.61 ± 0.27^{a}	3.43 ± 0.02^{a}	4.29 ± 0.21^{b}	4.28 ± 0.11^{b}
C15:0	0.66 ± 0.00^{a}	0.63 ± 0.01^{a}	0.68 ± 0.05^{a}	0.52 ± 0.00^{b}	0.79 ± 0.04^{c}	0.79 ± 0.02^{c}
C16:0	36.90 ± 0.22^{ab}	36.54 ± 0.58^{ab}	34.31 ± 3.88^{a}	38.79 ± 0.13^{bc}	41.76 ± 2.04^{c}	37.32 ± 1.04^{ab}
C17:0	0.98 ± 0.03^{a}	0.95 ± 0.02^{a}	1.02 ± 0.08^{ac}	0.81 ± 0.01^{b}	1.08 ± 0.05^{cd}	1.14 ± 0.03^{d}
C18:0	6.15 ± 0.04^{a}	7.23 ± 0.11^{a}	7.52 ± 0.60^{a}	4.96 ± 2.36^{a}	3.70 ± 2.64^{a}	5.10 ± 2.76^{a}
C20:0	0.09 ± 0.00^{a}	0.09 ± 0.00^{a}	0.09 ± 0.01^{a}	0.10 ± 0.00^{a}	0.12 ± 0.01^{b}	0.12 ± 0.01^{b}
C21:0	0.32 ± 0.00^{ab}	0.30 ± 0.00^{ab}	0.26 ± 0.07^{b}	0.39 ± 0.00^{ab}	0.41 ± 0.02^{a}	0.35 ± 0.12^{ab}
C22:0	0.20 ± 0.00^{a}	0.19 ± 0.00^{a}	0.20 ± 0.01^{a}	0.19 ± 0.00^{a}	0.19 ± 0.01^{a}	0.20 ± 0.01^{a}
∑SFA	48.79 ± 0.25^{a}	49.30 ± 0.78^{a}	47.68 ± 2.82^{a}	49.18 ± 2.21^{a}	52.36 ± 4.73^{a}	49.31 ± 3.26^{a}
C16:1	0.68 ± 0.00^{a}	0.59 ± 0.01^{ab}	0.52 ± 0.06^{ab}	0.43 ± 0.11^{b}	0.68 ± 0.04^{a}	0.53 ± 0.20^{ab}
C17:1	0.92 ± 0.02^{a}	0.86 ± 0.01^{a}	0.86 ± 0.07^{a}	0.85 ± 0.00^{a}	0.94 ± 0.05^{a}	0.86 ± 0.05^{a}
C18:1	32.14 ± 0.20^{a}	26.92 ± 1.58^{b}	31.88 ± 1.67^{ab}	35.40 ± 1.86^{a}	30.26 ± 2.83^{ab}	30.75 ± 3.37^{ab}
C22:1	0.15 ± 0.01^{ab}	0.13 ± 0.03^{a}	0.15 ± 0.01^{ab}	0.18 ± 0.02^{b}	0.19 ± 0.01^{b}	0.17 ± 0.03^{ab}
C24:1	0.22 ± 0.02^{a}	0.17 ± 0.01^{ab}	0.16 ± 0.04^{b}	0.13 ± 0.01^{b}	0.14 ± 0.01^{b}	0.14 ± 0.04^{b}
∑MUFA	34.11 ± 0.19^{a}	28.67 ± 1.59^{b}	33.57 ± 1.71^{ab}	36.99 ± 1.93^{a}	32.21 ± 2.76^{ab}	32.45 ± 3.15^{ab}
C18:2n6	2.79 ± 0.02^{a}	6.30 ± 1.93^{b}	2.35 ± 0.35^{a}	2.89 ± 0.02^{a}	2.82 ± 0.13^{a}	2.31 ± 0.50^{a}
C18:3n3	2.24 ± 0.01^{a}	1.60 ± 0.23^{b}	1.57 ± 0.24^{b}	2.04 ± 0.01^{a}	2.60 ± 0.12^{c}	2.78 ± 0.08^{c}
C20:2n6	0.03 ± 0.01^{ab}	0.03 ± 0.00^{ab}	0.02 ± 0.01^{a}	0.05 ± 0.00^{bc}	0.09 ± 0.01^{d}	0.07 ± 0.03^{cd}
C20:3n6	1.89 ± 0.01^{a}	2.03 ± 0.04^{ab}	2.13 ± 0.16^{b}	1.68 ± 0.01^{c}	1.88 ± 0.09^{a}	1.86 ± 0.07^{a}
C20:3n3	0.28 ± 0.10^{a}	0.27 ± 0.02^{a}	0.44 ± 0.28^{ab}	0.28 ± 0.10^{a}	0.73 ± 0.20^{b}	0.35 ± 0.18^{ab}
C20:4n6	0.54 ± 0.02^{abd}	0.32 ± 0.03^{abc}	0.15 ± 0.11^{c}	0.20 ± 0.04^{ac}	0.59 ± 0.11^{bd}	0.85 ± 0.33^{d}
C20:5n3	0.91 ± 0.01^{a}	0.88 ± 0.26^{a}	0.40 ± 0.18^{b}	0.47 ± 0.18^{b}	0.76 ± 0.11^{ab}	0.72 ± 0.16^{ab}
C22:6n3	8.42 ± 0.40^{ab}	10.61 ± 0.36^{bc}	11.68 ± 0.77^{c}	6.22 ± 0.07^{a}	5.97 ± 2.71^{a}	9.29 ± 0.46^{bc}
∑PUFA	18.62 ± 0.45^{a}	25.36 ± 2.04^{b}	23.01 ± 1.59^{b}	15.16 ± 2.30^{a}	14.31 ± 2.13^{a}	18.20 ± 2.57^{a}
∑PUFA (n-3)	11.86 ± 0.46^{ab}	13.37 ± 0.41^{b}	14.09 ± 0.68^{b}	9.01 ± 0.26^{c}	10.06 ± 2.81^{ac}	13.14 ± 0.67^{b}
∑PUFA (n-6)	5.24 ± 0.04^{a}	8.67 ± 1.88^{b}	4.65 ± 0.45^{a}	4.82 ± 0.06^{a}	5.38 ± 0.27^{a}	5.10 ± 0.65^{a}
(n-3)/(n-6)	2.26 ± 0.10^{b}	1.61 ± 0.31^{a}	3.04 ± 0.15^{c}	1.87 ± 0.05^{a}	1.90 ± 0.63^{ab}	2.63 ± 0.42^{bc}

Note: All data were expressed as means ± standard deviations. Mean values within the same column with different superscripts are significantly different ($P < 0.05$). SFA, saturated fatty acid; MUFA, mono-unsaturated fatty acid; PUFA, polyunsaturated fatty acid.

For the large yellow croaker, umami and richness are the most prominent taste, followed by saltiness. Fishes cultured in different models had slight changes in saltiness, sourness, and richness. The taste differences were classified using PCA, which reduced the dimension to two principal components. As shown in Figure 2(b), PC1 and PC2 accounted for 76.3% of the variables. The fish taste in DWC and CC had a significant separation trend in PC1. Specifically, the taste of DWC fish was located on the negative side of PC1, while the taste of CC fish was on the positive side. For the component of PC1, umami, saltiness, and sweetness negatively attributed to PC1, evident positive attributions existed in astringency, sourness, aftertaste-B, and bitterness. The taste scores were quantified and visualized using a heatmap (Figure 2(c)). DWC exhibited a higher score of richness, sweetness, and saltiness, and a lower score of aftertaste-B, bitterness, astringency, and sourness, indicating a superior taste profile. DWC-M and DWC-S had similar taste patterns with higher richness, sweetness, and saltiness and lower scores of aftertaste-B, bitterness, astringency, and sourness. Opposite results were found in CC-L and CC-M.

3.7. Volatile Substances. The volatile compounds were identified using NIST and IMS databases to compare the specific substances among different groups. Out of a total of 47 compounds detected, only 34 were identifiable. Therefore, the 34 identified compounds were selected for fingerprint comparison. As shown in Figure 3, the 34 compounds could be divided into six groups, including seven ketones, one aromatic, six esters, one hydrocarbon, ten alcohols, and nine aldehydes. The alcohols, aldehydes, and ketones exhibited significant differences among different culture models. For ketones, 3-hydroxy-2-butanone was higher in CC, while DWC had a higher level of 2-pentanone. DWC-S had a higher level of 4-methyl-3-penten-2-one than other fish. Alcohols, such as 1-propanol, 3-methyl-1-butanol, 3-methyl-1-propanol, 1-butanol, and ethanol were similar in different groups without CC-S, which was higher than other groups. Opposite results were found in aldehydes. CC-S had the lowest level of aldehydes. And the aldehydes in CC were lower than in DWC.

Peak intensity was used to quantitate the volatile compounds. The changes in volatile compounds between different groups are shown in Figure 4. The content of different compounds could be divided into 5 clusters, comprising 9, 7, 7, 6, and 4 compounds, respectively. For the compounds in cluster 1, muscle from DWC had a higher level than CC. In the same culture model, the level of these compounds

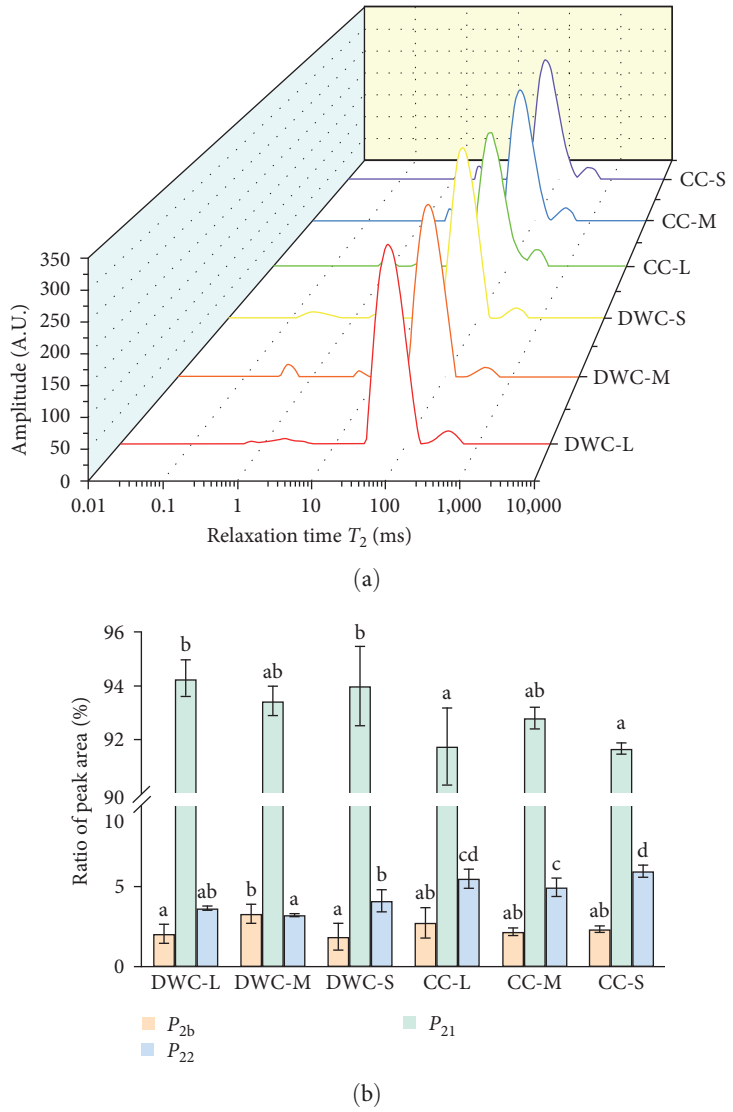

FIGURE 1: Water distribution of flesh from *Larimichthys crocea* cultured in DWC or CC systems. (a) Distribution of *T*2 relaxation times and (b) ratio of relaxation time peak area.

increased with weight gain. Cluster 1 was mainly composed of aldehydes, including 2-methyl butanal (monomer, M), pentanal, heptanal, butanal, and hexanal. Among the compounds in cluster 2, the highest concentrations were observed in DWC-L, while no specific trends were found in the other groups. Cluster 2 comprised acetone, isobutyraldehyde, 1-penten-3-ol, propyl butanoate, hexyl acetate, and 1-pentanol. Clusters 3 and 4 had similar trends among different groups with higher levels of CC, while no trend was found in cluster 5. In cluster 3, the level of CC-S was the highest among the compounds and decreased with an increase in weight. In cluster 4, the lowest content of the compounds was found in DWC-L, and increased as weight decreased.

4. Discussion

Organoleptic characteristics, including color, taste, flavor, and nutritional value, are important factors contributing to the quality of fish [29]. The quality of fish has been proven to be affected by the environment [6]. Therefore, various culture models have been developed to improve fish quality [30]. For large yellow croaker, DWC was developed to improve the quality of the fish as it can provide a suitable environment by increasing the flow of water [31]. This study evaluated the nutritional quality and flavor compounds in fish cultured in DWC or CC.

The appearance of large yellow croaker, including its shape and color, can directly indicate its quality. Consumer acceptance and price of large yellow croaker are higher for fish with a slender body and yellower skin color [14]. It has been found that most wild fish have a slimmer body than farmed fish [9, 32]. Compared with wild fish, farmed fish have easily available food and limited activity space, which resulting in higher energy intake and less physical activity [9, 33]. The condition factor is a useful indicator for assessing the overall health of fish, which can be influenced by a variety

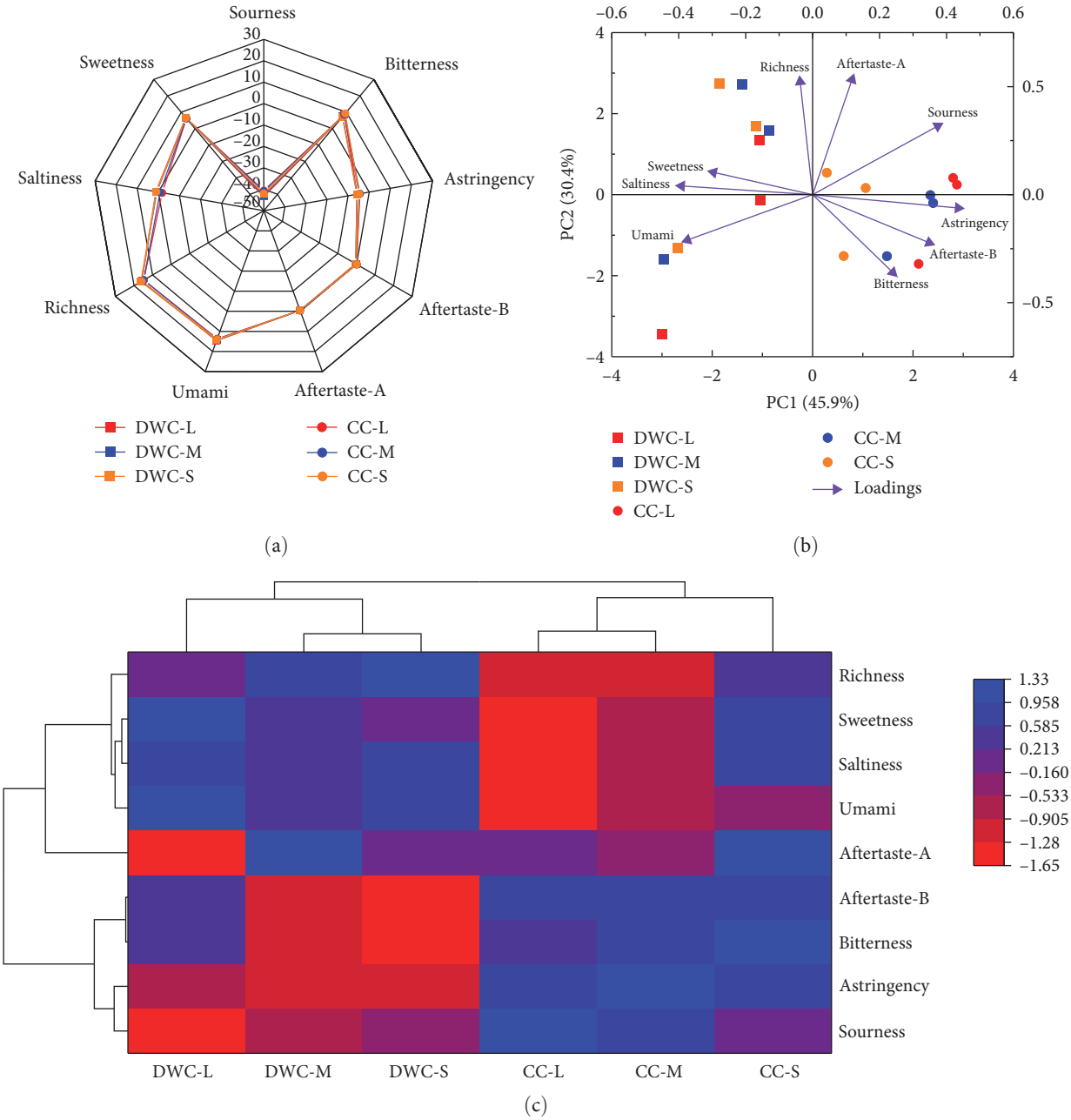

FIGURE 2: Taste-sensing analysis of flesh from *Larimichthys crocea* cultured in DWC or CC systems. (a) Radar map, (b) PCA plot, and (c) heatmap and cluster analysis.

of factors, including diet and environmental conditions [34]. Farm systems also had effects on the condition factor of fish. The condition factor of *Micropterus salmoides* cultured in in-pond raceway system was significantly lower than of fish cultured in usual-pond system [35]. In this study, DWC has more space than CC, and fish in DWC exercise more. The increased length and height ratio of the caudal peduncle in DWC also indicated a greater swimming ability. The slender body can be reflected by higher body length/height. The results from the present study indicated that DWC was an efficient model for improving the shape of large yellow croaker.

Ventral color is an indicator not only of the health of fish, but also of customer acceptance [36]. Fish are incapable of synthesizing carotenoids de novo. These pigments are primarily obtained through diet [37]. Fish can consume carotenoids from their diets, leading to an enhancement in their ventral color [14, 38]. Although fed with the same diets, large yellow croaker cultured in enclosures were yellower than cages [39]. Similarly, in our study, the large yellow croaker in DWC was yellower than CC. Fish cultured in enclosures and DWC had the potential chances to catch more living food to obtain carotenoids. In addition, light intensity has been identified as a contributing factor to the variation in fish skin pigment. On a white background, the numbers of melanophores in *Danio rerio* were significantly decreased due to the apoptosis of melanophores. On a black background, the

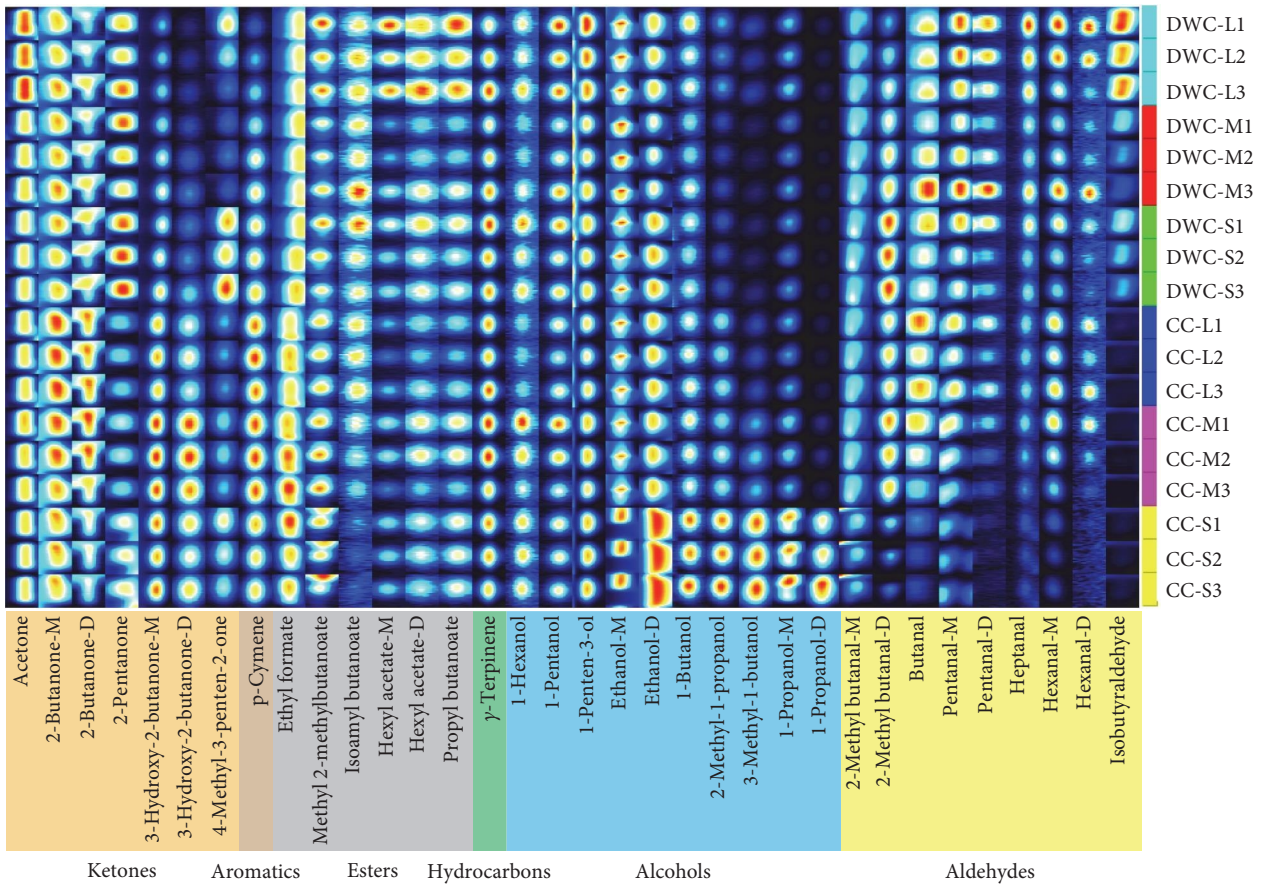

FIGURE 3: Gallery plot of the identified volatile compounds of the flesh from *Larimichthys crocea* cultured in DWC or CC systems.

number of melanophores increased [40]. Low light intensity significantly increased skin lightness of red porgy [41]. In the present study, water in DWC (10 m) was much deeper than CC (3 m). As water depth increases, there is a significant decrease in light intensity. We hypothesized that the enhanced ventral coloration in DWC was primarily attributable to the greater water depth.

The texture of flesh is determined by various factors, such as muscle fibers and lipids [13]. In this study, DWC significantly improved the springiness and chewiness of the flesh. We hypothesized that the enhanced texture could be attributed to the increased swimming activity of fish in DWC, as it had been reported that sustained swimming exercises could improve the texture by increasing the density of fibers [42, 43]. Similar results had also been found in gilthead sea bream and bighead carp [30, 44]. Larger surface areas provide a greater space for fish movement and exercise, thus increasing muscle fiber density and the textural characteristics of the flesh.

Moisture, protein, and lipid are important indicators in the nutritional quality of fish flesh [45], which are used to characterize the flesh quality of large yellow croaker cultured in DWC or CC. The proximate composition of large yellow croaker was analyzed under different conditions: including different diets and culture models [6, 9, 46]. Similar to the present study, the moisture content did not differ significantly among fish fed with different diets. However, wild fish have higher moisture than farmed fish. Compared with moisture, the lipid and protein content could be easily changed by diet [47]. Under the same condition of diet, the crude lipid of large yellow croaker cultured in enclosure was significantly lower than cage culture [39]. In our study, different culture models also had a significant impact on the lipid. Similar results were found in *M. salmoides*, wherein recycling water significantly reduced the lipid level [48]. In the DWC and recycling water system, fishes have more space for exercise, which requires more energy. Lipids can be used to produce energy following glycogen depletion as a substrate for energy [35]. Moreover, the effects of different sizes were analyzed in each model. Our findings indicated that the highest lipid levels were observed in medium sizes. The relationship between lipid content and fish size has yet to be sufficiently studied. As a seasonally migratory species, we hypothesize that higher lipid in medium size was attributed to the high requirement of energy in this stage [49].

Our results revealed that palmitic acid (C16:0), oleic acid (C18:1n-9), and docosahexaenoic acid (DHA) were the main fatty acids in large yellow croaker, which was similar to other studies [2, 11]. For the different fatty acids, SFAs are usually used for energy [50]. In the present study, SFA in the DWC culture model was slightly lower than the CC model, suggesting that fish in DWC require more SFA for energy [51, 52].

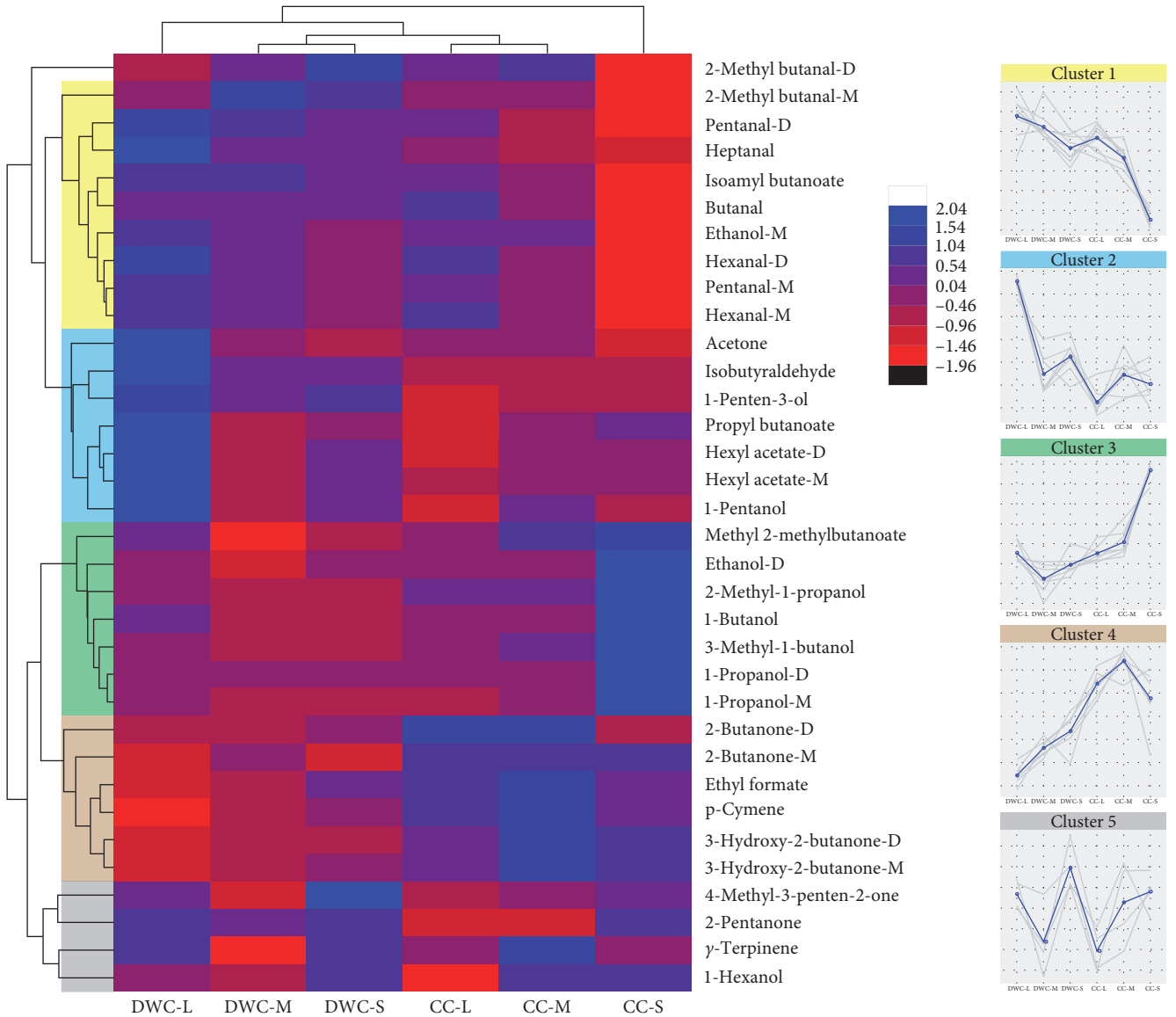

FIGURE 4: Qualitative results and cluster analysis of gas phase ion mobility spectra of flesh from *Larimichthys crocea* cultured in DWC or CC systems.

Unsaturated fatty acids in fish are essential for human health, especially PUFAs such as eicosapentaenoic acid and DHA [53, 54]. The large yellow croak has a limited ability to synthesize PUFA and needs to obtain PUFA from the diet [55]. We hypothesized that fish in DWC had more opportunities to catch living food with a high content of PUFA due to its higher water exchange rate [56]. For humans, consuming foods rich in n-3 PUFA has been linked with reduced risk of cancer [57], and favorable effects on metabolic and inflammatory profiles [58]. The highest levels of n-3 PUFA and the n-3/n-6 ratio were found in DWC-S, suggesting that DWC-S has a better fatty acid composition.

Water distribution in the flesh is closely related to its quality, including juiciness and tenderness [59]. LF NMR is an efficient and convenient tool to analyze the water distribution of water in the flesh [60]. The proportion of immobilized and free water can indicate the water-holding capacity [61]. Higher P_{21} in DWC suggests that flesh in DWC has a higher water-holding capacity and is more tender. Compared to DWC, flesh in CC has a higher proportion of free water, which suggests the possibility of potential drip in CC [59]. In summary, flesh in DWC has higher water-holding capacity and juiciness due to the higher level of immobilized water.

Fish is renowned for its umami flavor derived from its high concentration of free amino acids [62, 63]. The taste flavor of the meat can be quantified using a bionic sensor, namely an electronic tongue [64]. In our study, the taste characteristics could be used to distinguish fishes cultured in DWC and CC. DWC was better than CC in richness, sweetness, and umami. Therefore, utilizing DWC may be a better option for enhancing the flavor profile of large yellow croaker.

Odor is a crucial factor contributing to the quality of fish. The volatiles of fish muscle could be affected by diet

composition and cultivating conditions [65, 66]. Fillets obtained from outdoor ponds (with lower temperature) had less 2-methylisoborneol and (E)-2-hexenal, while 2-butanone was less in indoor ponds (with higher temperature) [65]. In our study, cluster 1 was mainly composed of aldehydes, including 2-methyl butanal (monomer, M), pentanal, heptanal, butanal, and hexanal. Compared to other compounds, aldehydes have a lower odor threshold and contribute more to the overall odor [67]. Pentanal, heptanal, and hexanal can produce an intense, green, fatty, and fishy aroma [68, 69]. Based on the results, we can conclude that the DWC culture model promotes the aroma of pungent, green, fatty, and fishy in large yellow croaker, and the pungent, green, fatty, and fishy aromas increase with the growth of the fish. 1-Pentanol and 1-penten-3-ol in cluster 2 were common volatile compounds in fish [68], contributing to the "mushroom, earthy" and "plastic, green" odor, respectively [70]. Despite being present in higher levels in DWC-L, their contribution to the odor is limited due to their relatively high odor thresholds [67, 71]. Propyl butanoate, hexyl acetate, and isobutyraldehyde were high in DWC-L, but their contributions to the odor were less reported. These compounds in cluster 4 were mainly ketones and alcohols, such as 2-butanon, 3-hydroxy-2-butanone, which had higher odor thresholds [67].

5. Conclusions

In summary, this study analyzed the quality of large yellow croaker of different sizes cultured in DWC and CC. Culture model contributed more to the quality of flesh. Fish in DWC had a slender body, better body color, lower lipid content, and higher n-3 PUFA. The texture of flesh in DWC was improved, including springiness and chewiness. The greater immobilized water indicates a higher water holding capacity and juiciness in DWC. DWC culture model contributed to the sweetness, saltiness, and umami of the flesh. The flesh obtained from DWC had a higher content of aldehydes, such as pentanal, heptanal, and hexanal. These characteristics in DWC suggested better quality and taste in DWC model, which could be a better choice in the aquaculture of large yellow croaker.

Data Availability

All data are presented in the article and are available from the corresponding author on request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Authors' Contributions

Banghong Wei and Shengyang Zheng contributed equally to this work.

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References

[1] S. X. Chen, Y. Q. Su, and W. S. Hong, "Aquaculture of the large yellow croaker," in *Aquaculture in China: Success Stories and Modern Trends*, J. F. Gui, Q. S. Tang, Z. J. Li, J. S. Liu, and S. S. De Silva, Eds., Willey Blackwell, USA, 2018.

[2] A. H. Zhong, Z. J. Chu, L. Y. Dai, and X. J. Wang, "Evaluation of nutrient components and nutritive quality of *Larimichthys crocea* (big yellow croaker) in different aquaculture models," *Animal Husbandry and Feed Science*, vol. 6, no. 6, pp. 296–299, 318, 2014.

[3] H. G. Tang, T. X. Wu, Z. Y. Zhao, and X. D. Pan, "Biochemical composition of large yellow croaker (*Pseudosciaena crocea*) cultured in China," *Journal of Food Quality*, vol. 31, no. 3, pp. 382–393, 2008.

[4] K. Grigorakis, "Effects of nutrition and aquaculture practices on fish quality," in *Handbook of Seafood Quality, Safety and Health Applications*, C. Alasalvar, F. Shahidi, K. Miyashita, and U. Wanasundara, Eds., Wiley-Blackwell, Chichester, 2010.

[5] J. E. Breck, "Body composition in fishes: body size matters," *Aquaculture*, vol. 433, pp. 40–49, 2014.

[6] Q. Y. Guo, T. Truonghuynh, C. J. Jiang, L. M. Wang, B. G. Li, and X. L. Xing, "Quality differences of large yellow croaker (*Pseudosciaena crocea*) cultured in deep-water sea cages of two China," *Journal of Aquaculture Research & Development*, vol. 9, no. 9, Article ID 100547, 2018.

[7] M. Liu and Y. S. de Mitcheson, "Profile of a fishery collapse: why mariculture failed to save the large yellow croaker," *Fish and Fisheries*, vol. 9, no. 3, pp. 219–242, 2008.

[8] R. Chai, H. Yin, R. Huo et al., "Fatigue metabolites of large yellow croaker and construction of swimming model," *BioRxiv*, 2021.

[9] R. Ma, Y. Meng, W. Zhang, and K. Mai, "Comparative study on the organoleptic quality of wild and farmed large yellow croaker *Larimichthys crocea*," *Journal of Oceanology and Limnology*, vol. 38, no. 1, pp. 260–274, 2020.

[10] H. Lü, J. Xu, and G. Vander Haegen, "Supplementing marine capture fisheries in the East China Sea: sea ranching of prawn *Penaeus orientalis*, restocking of large yellow croaker *Pseudosciaena crocea*, and cage culture," *Reviews in Fisheries Science*, vol. 16, no. 1–3, pp. 366–376, 2008.

[11] Y. Gong, J. Lu, L. Gao, X. Wang, and H. Huang, "Nutrient compositional differentiation in the muscle of wild, inshore and offshore cage-cultured large yellow croaker (*Pseudosciaena crocea*)," *Iranian Journal of Fisheries Sciences*, vol. 18, no. 3, pp. 497–506, 2019.

[12] K. Grigorakis, "Compositional and organoleptic quality of farmed and wild gilthead sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) and factors affecting it: a review," *Aquaculture*, vol. 272, no. 1–4, pp. 55–75, 2007.

[13] A. Listrat, B. Lebret, I. Louveau et al., "How muscle structure and composition influence meat and flesh quality," *The Scientific World Journal*, vol. 2016, Article ID 3182746, 14 pages, 2016.

[14] X. Yi, W. Xu, H. Zhou et al., "Effects of dietary astaxanthin and xanthophylls on the growth and skin pigmentation of large yellow croaker *Larimichthys croceus*," *Aquaculture*, vol. 433, pp. 377–383, 2014.
[15] X. Yi, F. Zhang, W. Xu, J. Li, W. Zhang, and K. Mai, "Effects of dietary lipid content on growth, body composition and pigmentation of large yellow croaker *Larimichthys croceus*," *Aquaculture*, vol. 434, pp. 355–361, 2014.
[16] X. Yi, J. Li, W. Xu, W. Zhang, and K. Mai, "Effects of dietary lutein/canthaxanthin ratio on the growth and pigmentation of large yellow croaker *Larimichthys croceus*," *Aquaculture Nutrition*, vol. 22, no. 3, pp. 683–690, 2016.
[17] M. A. Brandt, E. Z. Skinner, and J. A. Coleman, "Texture profile method," *Journal of Food Science*, vol. 28, no. 4, pp. 404–409, 1963.
[18] A. S. Szczesniak, "Classification of textural characteristics," *Journal of Food Science*, vol. 28, no. 4, pp. 385–389, 1963.
[19] Y. Wang, S. Nie, C. Li et al., "Application of untargeted metabolomics to reveal the taste-related metabolite profiles during mandarin fish (*Siniperca chuatsi*) fermentation," *Foods*, vol. 11, no. 7, Article ID 944, 2022.
[20] J. Z. Tan and J. Xu, "Applications of electronic nose (e-nose) and electronic tongue (e-tongue) in food quality-related properties determination: a review," *Artificial Intelligence in Agriculture*, vol. 4, pp. 104–115, 2020.
[21] B. H. Gao, X. B. Hu, R. L. Li, Y. Zhao, Y. G. Tu, and Y. Zhao, "Screening of characteristic umami substances in preserved egg yolk based on the electronic tongue and UHPLC-MS/MS," *LWT*, vol. 152, no. 2, Article ID 112396, 2021.
[22] S. Wang, H. Chen, and B. Sun, "Recent progress in food flavor analysis using gas chromatography-ion mobility spectrometry (GC-IMS)," *Food Chemistry*, vol. 315, Article ID 126158, 2020.
[23] T. Zhao, S. Benjakul, C. Sanmartin et al., "Changes of volatile flavor compounds in large yellow croaker (*Larimichthys crocea*) during storage, as evaluated by headspace gas chromatography-ion mobility spectrometry and principal component analysis," *Foods*, vol. 10, no. 12, Article ID 2917, 2021.
[24] T. Zhao, Z. Cao, J. Yu et al., "Gas-phase ion migration spectrum analysis of the volatile flavors of large yellow croaker oil after different storage periods," *Current Research in Food Science*, vol. 5, pp. 813–822, 2022.
[25] X. Wang, X. Xie, T. Zhang, Y. Zheng, and Q. Guo, "Effect of edible coating on the whole large yellow croaker (*Pseudosciaena crocea*) after a 3-day storage at −18°C: with emphasis on the correlation between water status and classical quality indices," *LWT*, vol. 163, Article ID 113514, 2022.
[26] Y. Shi, Y. Zheng, B. Li, X. Yang, Q. Guo, and A. Liu, "Prevention of quality characteristic decline in freeze-thawed cultured large yellow croaker (*Larimichthys crocea*) using flammulina velutipes polysaccharide," *Food Science & Nutrition*, vol. 11, no. 1, pp. 181–190, 2023.
[27] H. Z. Du, Q. Chen, Q. Liu, Y. Wang, and B. H. Kong, "Evaluation of flavor characteristics of bacon smoked with different woodchips by HS-SPME-GC-MS combined with an electronic tongue and electronic nose," *Meat Science*, vol. 182, Article ID 108626, 2021.
[28] D. Wang, J. Zhang, Z. Zhu, Y. Lei, S. Huang, and M. Huang, "Effect of ageing time on the flavour compounds in Nanjing water-boiled salted duck detected by HS-GC-IMS," *LWT*, vol. 155, Article ID 112870, 2022.
[29] J. Freitas, P. Vaz-Pires, and J. S. Câmara, "From aquaculture production to consumption: freshness, safety, traceability and authentication, the four pillars of quality," *Aquaculture*, vol. 518, Article ID 734857, 2020.
[30] B. Hu, J. Zhou, H. Qiu et al., "Comparison of nutritional quality and volatile flavor compounds among bighead carp from three aquaculture systems," *Saudi Journal of Biological Sciences*, vol. 28, no. 8, pp. 4291–4299, 2021.
[31] H. N. Duy, G. J. Coman, M. Wille et al., "Effect of water exchange, salinity regime, stocking density and diets on growth and survival of domesticated black tiger shrimp *Penaeus monodon* (Fabricius, 1798) reared in sand-based recirculating systems," *Aquaculture*, vol. 338–341, pp. 253–259, 2012.
[32] I. A. Johnston, X. J. Li, V. L. A. Vieira et al., "Muscle and flesh quality traits in wild and farmed *Atlantic salmon*," *Aquaculture*, vol. 256, no. 1–4, pp. 323–336, 2006.
[33] P. Arechavala-Lopez, P. Sanchez-Jerez, J. T. Bayle-Sempere, D. G. Sfakianakis, and S. Somarakis, "Morphological differences between wild and farmed Mediterranean fish," *Hydrobiologia*, vol. 679, no. 1, pp. 217–231, 2012.
[34] M. Aminisarteshnizi and N. A. G. Moyo, "Condition factor and length-weight relationship of *Scardinius erythrophthalmus* (Linnaeus, 1758) in Anzali Lagoon," *Pakistan Journal of Biological Sciences*, vol. 25, no. 10, pp. 899–904, 2022.
[35] J. Yuan, M. Ni, M. Liu et al., "Analysis of the growth performances, muscle quality, blood biochemistry and antioxidant status of *Micropterus salmoides* farmed in in-pond raceway systems versus usual-pond systems," *Aquaculture*, vol. 511, Article ID 734241, 2019.
[36] E. Leclercq, J. F. Taylor, and H. Migaud, "Morphological skin colour changes in teleosts," *Fish and Fisheries*, vol. 11, no. 2, pp. 159–193, 2010.
[37] A. L. F. C. Ho, N. M. O. Bertran, and L. J. Da, "Dietary esterified astaxanthin concentration effect on dermal coloration and chromatophore physiology in *Spinecheek anemonefish*, *Premnas biaculeatus*," *Journal of the World Aquaculture Society*, vol. 44, no. 1, pp. 76–85, 2013.
[38] X. Yi, H. Shen, J. Li et al., "Effects of dietary vitamin E and astaxanthin on growth, skin colour and antioxidative capacity of large yellow croaker *Larimichthys crocea*," *Aquaculture Nutrition*, vol. 24, no. 1, pp. 472–480, 2018.
[39] X. Li, B. Li, N. Chen, X. Huang, X. Hua, and X. Leng, "A comparison study on flesh quality of large yellow croaker (*Larimichthys croceus*) cultured with three different modes," *Journal of Ocean University of China*, vol. 16, no. 6, pp. 1187–1194, 2017.
[40] M. Sugimoto, M. Yuki, T. Miyakoshi, and K. Maruko, "The influence of long-term chromatic adaptation on pigment cells and striped pigment patterns in the skin of the zebrafish, *Danio rerio*," *Journal of Experimental Zoology Part A: Comparative Experimental Biology*, vol. 303A, no. 6, pp. 430–440, 2005.
[41] M. Pavlidis, M. Karkana, E. Fanouraki, and N. Papandroulakis, "Environmental control of skin color in the red porgy, *Pagrus pagrus*," *Aquaculture Research*, vol. 39, no. 8, pp. 837–849, 2008.
[42] X.-M. Li, J.-M. Yuan, S.-J. Fu, and Y.-G. Zhang, "The effect of sustained swimming exercise on the growth performance, muscle cellularity and flesh quality of juvenile qingbo (*Spinibarbus sinensis*)," *Aquaculture*, vol. 465, pp. 287–295, 2016.

[43] Y. Harimana, X. Tang, P. Xu et al., "Effect of long-term moderate exercise on muscle cellularity and texture, antioxidant activities, tissue composition, freshness indicators and flavor characteristics in largemouth bass (*Micropterus salmoides*)," *Aquaculture*, vol. 510, pp. 100–108, 2019.

[44] L. M. P. Valente, J. Cornet, C. Donnay-Moreno et al., "Quality differences of gilthead sea bream from distinct production systems in Southern Europe: intensive, integrated, semi-intensive or extensive systems," *Food Control*, vol. 22, no. 5, pp. 708–717, 2011.

[45] T. Gjedrem, "Flesh quality improvement in fish through breeding," *Aquaculture International*, vol. 5, no. 3, pp. 197–206, 1997.

[46] X. Li, Q. Chen, Q. Li et al., "Effects of high levels of dietary linseed oil on the growth performance, antioxidant capacity, hepatic lipid metabolism, and expression of inflammatory genes in large yellow croaker (*Larimichthys crocea*)," *Frontiers in Physiology*, vol. 12, Article ID 631850, 2021.

[47] Z. Wei, K. Deng, W. Zhang, and K. Mai, "Interactions of dietary vitamin C and proline on growth performance, anti-oxidative capacity and muscle quality of large yellow croaker *Larimichthys crocea*," *Aquaculture*, vol. 528, Article ID 735558, 2020.

[48] S.-P. Jia, L. Wang, J.-M. Zhang et al., "Comparative study on the morphological characteristics and nutritional quality of largemouth bass (*Micropterus salmoides*) cultured in an aquaculture system using land-based container with recycling water and a traditional pond system," *Aquaculture*, vol. 549, Article ID 737721, 2022.

[49] R. Company, A. Astola, C. Pendón, M. M. Valdivia, and J. Pérez-Sánchez, "Somatotropic regulation of fish growth and adiposity: growth hormone (GH) and somatolactin (SL) relationship," *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*, vol. 130, no. 4, pp. 435–445, 2001.

[50] J. Trushenski, B. Mulligan, D. Jirsa, and M. Drawbridge, "Sparing fish oil with soybean oil in feeds for White seabass: effects of inclusion rate and soybean oil composition," *North American Journal of Aquaculture*, vol. 75, no. 2, pp. 305–315, 2013.

[51] A. Kiessling, J. Pickova, J. G. Eales, B. Dosanjh, and D. Higgs, "Age, ration level, and exercise affect the fatty acid profile of chinook salmon (*Oncorhynchus tshawytscha*) muscle differently," *Aquaculture*, vol. 243, no. 1–4, pp. 345–356, 2005.

[52] A. P. Palstra and J. V. Planas, "Fish under exercise," *Fish Physiology and Biochemistry*, vol. 37, no. 2, pp. 259–272, 2011.

[53] J. X. Kang, "The importance of omega-6/omega-3 fatty acid ratio in cell function," *World Review of Nutrition & Dietetics*, vol. 92, pp. 23–36, 2003.

[54] S. I. Rapoport, J. S. Rao, and M. Igarashi, "Brain metabolism of nutritionally essential polyunsaturated fatty acids depends on both the diet and the liver," *Prostaglandins, Leukotrienes and Essential Fatty Acids*, vol. 77, no. 5-6, pp. 251–261, 2007.

[55] L. F. C. Castro, D. R. Tocher, and O. Monroig, "Long-chain polyunsaturated fatty acid biosynthesis in chordates: insights into the evolution of Fads and Elovl gene repertoire," *Progress in Lipid Research*, vol. 62, pp. 25–40, 2016.

[56] D. R. Tocher, "Fatty acid requirements in ontogeny of marine and freshwater fish," *Aquaculture Research*, vol. 41, no. 5, pp. 717–732, 2010.

[57] Y. Kim and J. Kim, "Intake or blood levels of n-3 polyunsaturated fatty acids and risk of colorectal cancer: a systematic review and meta-analysis of prospective studies," *Cancer Epidemiology Biomarkers & Prevention*, vol. 29, no. 2, pp. 288–299, 2020.

[58] F. Guebre-Egziabher, R. Rabasa-Lhoret, F. Bonnet et al., "Nutritional intervention to reduce the n-6/n-3 fatty acid ratio increases adiponectin concentration and fatty acid oxidation in healthy subjects," *European Journal of Clinical Nutrition*, vol. 62, no. 11, pp. 1287–1293, 2008.

[59] K. L. Pearce, K. Rosenvold, H. J. Andersen, and D. L. Hopkins, "Water distribution and mobility in meat during the conversion of muscle to meat and ageing and the impacts on fresh meat quality attributes—a review," *Meat Science*, vol. 89, no. 2, pp. 111–124, 2011.

[60] R. Cao, X. Liu, Y. Liu et al., "Applications of nuclear magnetic resonance spectroscopy to the evaluation of complex food constituents," *Food Chemistry*, vol. 342, Article ID 128258, 2021.

[61] H. C. Bertram, P. P. Purslow, and H. J. Andersen, "Relationship between meat structure, water mobility, and distribution: a low-field nuclear magnetic resonance study," *Journal of Agricultural and Food Chemistry*, vol. 50, no. 4, pp. 824–829, 2002.

[62] W. Wang, X. Zhou, and Y. Liu, "Characterization and evaluation of umami taste: a review," *TrAC Trends in Analytical Chemistry*, vol. 127, Article ID 115876, 2020.

[63] D. Yang, C. Li, L. Li, S. Chen, X. Hu, and H. Xiang, "Taste mechanism of umami peptides from Chinese traditional fermented fish (*Chouguiyu*) based on molecular docking using umami receptor T1R1/T1R3," *Food Chemistry*, vol. 389, Article ID 133019, 2022.

[64] Í. M. G. Marx, N. Rodrigues, L. G. Dias et al., "Quantification of table olives' acid, bitter and salty tastes using potentiometric electronic tongue fingerprints," *LWT—Food Science and Technology*, vol. 79, pp. 394–401, 2017.

[65] A. Hallier, C. Prost, and T. Serot, "Influence of rearing conditions on the volatile compounds of cooked fillets of *Silurus glanis* (European catfish)," *Journal of Agricultural and Food Chemistry*, vol. 53, no. 18, pp. 7204–7211, 2005.

[66] H. Mu, Z. Wei, L. Yi et al., "Dietary fishmeal levels affect the volatile compounds in cooked muscle of farmed large yellow croaker *Larimichthys crocea*," *Aquaculture Research*, vol. 48, no. 12, pp. 5821–5834, 2017.

[67] X. Zhou, Y. Chong, Y. Ding, S. Gu, and L. Liu, "Determination of the effects of different washing processes on aroma characteristics in silver carp mince by MMSE-GC-MS, e-nose and sensory evaluation," *Food Chemistry*, vol. 207, pp. 205–213, 2016.

[68] H. Mu, Z. Wei, L. Yi, J. Shentu, W. Zhang, and K. Mai, "Effects of low dietary fish meal on the volatile compounds in muscle of large yellow croaker *Larimichthys crocea*," *Aquaculture Research*, vol. 48, no. 9, pp. 5179–5191, 2017.

[69] R. Ma, X. Liu, H. Tian et al., "Odor-active volatile compounds profile of triploid rainbow trout with different marketable sizes," *Aquaculture Reports*, vol. 17, Article ID 100312, 2020.

[70] D. Frank, S. Poole, S. Kirchhoff, and C. Forde, "Investigation of sensory and volatile characteristics of farmed and wild barramundi (*Lates calcarifer*) using gas chromatography-olfactometry mass spectrometry and descriptive sensory analysis," *Journal of Agricultural and Food Chemistry*, vol. 57, no. 21, pp. 10302–10312, 2009.

[71] H. Wang, J. Zhang, Y. Zhu, X. Wang, and W. Shi, "Volatile components present in different parts of grass carp," *Journal of Food Biochemistry*, vol. 42, no. 6, Article ID e12668, 2018.