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Morphological Trait Correlations and Nutrient Compositions of the Japanese Moon Scallop *Ylistrum japonicum* in China

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Abstract: The *Ylistrum japonicum* is a scallop of commercial significance, renowned for its capacity to undertake long-distance swimming. A total of 150 individuals were collected to explore the connections between morphological traits and quality traits and to determine the nutritional components of the adductor muscle. The results showed a robust positive correlation between morphological traits and quality traits, with certain variations in the intensity of the correlation depending on gender. For both female and male individuals, the most significant factor directly influencing the quality traits was shell width, and shell length had the greatest indirect influence on the individual quality traits. The nutritional results of the adductor muscle of *Y. japonicum* showed that the moisture content was 80.17%, the ash content was 1.43%, the protein content was 16.93%, the fat content was 0.67%, and the carbohydrate content was 0.80%. Furthermore, a total of 17 amino acids and a total of 23 fatty acids were detected. The study's findings contribute to the understanding of the quality traits and nutritional value of *Y. japonicum*, laying a basis for the development of selective breeding strategies aimed at boosting the species' aquaculture potential.

Keywords: morphological traits; nutritional composition; amino acids; fatty acids

Key Contribution: The correlations between quality traits and body measurements of *Y. japonicum* were analyzed. The nutrient composition of the adductor muscle in *Y. japonicum* was determined.

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1. Introduction

The *Ylistrum japonicum* is a scallop species belonging to the phylum Mollusca, class Bivalvia, order Pterioida, and family Pectinidae, possessing significant ornamental and edible value [1,2]. It is primarily distributed in Hokkaido, Japan, and Jeju Island, South Korea [3]. Additionally, considerable populations have been reported in the coastal regions of Guangdong and Fujian, China [4–6]. Nevertheless, due to overfishing in the past, the population of *Y. japonicum* has significantly declined in recent years, resulting in a current scarcity of fishery resources [1,2]. Therefore, there is an urgent need to assess its germplasm resources and advance artificial breeding techniques. The reproductive biology of *Y. japonicum* has been the subject of several studies: Pal-Won et al. studied the annual reproductive cycle [7], the relationship between age and growth [8], and the first sexual maturity and sex ratio [3] of *Y. japonicum*. In China, the available research is also limited; Ye and Liang conducted a preliminary observation on the ecology of *Y. japonicum* [2] and undertook a preliminary exploration of its larval development [1].

Both body measurements and quality traits serve as important references in the genetic breeding of shellfish, and their interrelation enables the non-destructive preliminary selection of broodstock [9–12]. Therefore, multiple regression analysis and path analysis can better correlate quality traits with body measurements to achieve selective breeding objectives. In recent years, multiple regression analysis and path analysis have been extensively applied in the selective breeding of scallops, including *Chlamys farreri*, *Mizuhopecten yessoensis*, *Argopecten irradians*, and *Placopecten magellanicus* [13–18]. In addition, the nutritional components of a species are of vital importance because of their relationship to economic value. This study employs multiple regression and path analyses to examine the body measurements and quality traits of *Y. japonicum* and determines its nutritional composition. It establishes the foundation for the selective breeding of superior varieties, the exploration of germplasm resources, and the development of related industries for *Y. japonicum*.

2. Materials and Methods

2.1. Sample Collection

A total of 150 *Y. japonicum* individuals were collected in April 2024 from the sea areas of Hailing Island, Yangjiang City, Guangdong Province (21.61° N, 111.93° E) (Figure 1). The collected specimens were transported to the Key Laboratory of Mariculture and Stock Enhancement at the Ministry of Agriculture of the North China Sea, Dalian, China. All the specimens were kept in a circulating seawater tank (100 L) under natural light and allowed to acclimate to standard laboratory conditions (temperature: 22.45 ± 0.12 °C; pH: 7.83 ± 0.3; salinity: 32.97 ± 0.15 practical salinity units, PSU). The specimens were collected for the exclusive purpose of commercial use, and no ethical issues were involved in the handling of the animals, as the collection was carried out in accordance with standard fishing practices.

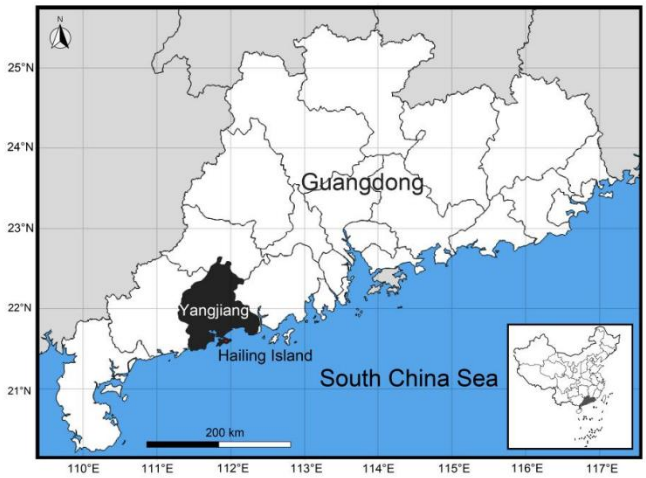


Figure 1. Collection location of *Y. japonicum*.

2.2. Measurement of Quality Traits and Body Measurements

A total of 150 *Y. japonicum* individuals were selected. The shell length (SL), shell width (SW), and shell height (SH) were determined using a vernier caliper (0.01 mm) (Figure 2C). Before measuring the wet weight, the surface moisture of the shells was carefully absorbed using a tissue to minimize the potential error caused by remaining moisture. The wet weight (WW), soft body weight (FW), gonad weight (GW), and adductor muscle weight (AW) of each individual were measured by an electronic balance (0.01 g). During the dissection and measurement process, the sex of each individual was recorded. Notably, the gonadal color served as a differentiating feature, with females showing an orange-red gonadal color and males presenting a milky white gonadal appearance (Figure 2A,B).

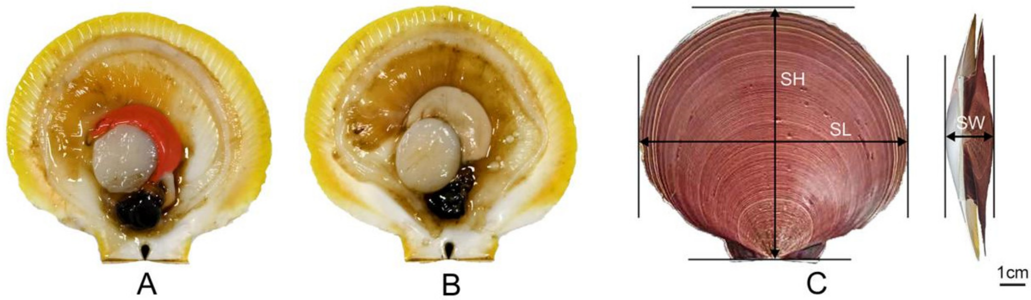


Figure 2. Schematic representations of *Y. japonicum*. (**A**) Female individual with orange-red gonadal color. (**B**) Male individual with milky white gonadal color. (**C**) Schematic illustration of morphological trait measurements.

2.3. Detection of Nutritional Components of Adductor Muscle

The adductor muscle samples of *Y. japonicum* were randomly apportioned into three parallel groups and it was ensured that the weight of each adductor muscle group exceeded 100 g. The determination of the nutritional indicators followed the national standards of China (GB). The moisture content was determined in accordance with GB5009.3-2016, employing the direct drying method at 101 °C to 105 °C. The ash content was determined according to the GB5009.4-2010 protocol, utilizing the muffle furnace at a high temperature of 550 °C for ashing. The fat content was determined according to GB5009.6-2016 using the Soxhlet extraction method [19]. The protein content was determined based on GB5009.5-2016 using the Kjeldahl method [20]. The fatty acid content was determined based on GB5009.168-2016 using the gas chromatography normalization method [21]. Amino acid content was determined according to GB5009.124-2016 using the amino acid automatic analyzer method [22].

2.4. Data Analysis

The traits of the samples were organized in Excel 2022, and the mean value, standard deviation, and coefficient of variation of the traits were calculated. SPSS 22.0 software was used to analyze the correlation, path coefficient, and indirect path coefficient between each trait. The determination coefficient of morphological traits to quality traits was calculated by the path coefficient of each morphological trait to quality traits and the correlation coefficient between morphological traits [23,24]. The SL, SW, and SH were taken as independent variables, while WW, FW, GW, and AW were taken as dependent variables. Multiple linear regression analysis and partial regression coefficient tests were carried out. After stepwise regression analysis, the collinear independent variables with insignificant regression were eliminated, and the optimal multiple linear regression equation of morphological traits and quality traits was constructed [25,26]. The significance level was set at $p < 0.05$, and the extremely significant level was set at $p < 0.01$. The specific calculation formula is as follows:

$$\text{Indirect path coefficient: } P_{ij} = r_{ij}P_j \quad (1)$$

$$\text{Coefficient of determination: } d_i = P_i{}^2 \quad (2)$$

$$\text{Co-determination coefficient: } d_{ij} = 2r_{ij}P_iP_j \quad (3)$$

where r_{ij} is the correlation coefficient between i and j; P_i is the path coefficient of i; and P_j is the path coefficient of j.

According to the FAO/WHO amino acid scoring standard model and the amino acid model of whole egg protein, the amino acid score (AAS) and chemical score (CS) were calculated according to the following formula [27]:

$$\text{AAS} = \text{certain amino acid content in the sample to be tested/certain amino acid content in the FAO scoring model} \quad (4)$$

$$\text{CS} = \text{an amino acid content in the sample to be tested/an amino acid content in the egg} \quad (5)$$

$$\text{Amino acid content (mg/gN)} = \text{amino acid content in fresh sample (\%)/crude protein content in fresh sample (\%)} \times 6.25 \times 1000 \quad (6)$$

3. Results

3.1. Summary Statistics of Measured Traits

The average values for SL, SW, and SH of *Y. japonicum* were 100.6 ± 4.42 mm, 20.57 ± 1.09 mm, and 97.37 ± 3.95 mm, respectively. The average values for WW, FW, GW, and AW were 79.63 ± 18.08 g, 27.68 ± 6.62 g, 1.83 ± 0.60 g, and 10.56 ± 2.42 g, respectively. In 150 samples, 66 individuals were female, and 84 individuals were male. The ratio of males to females was 1:1.27. In female individuals, the average values of all traits, except shell height, were higher than those of male individuals. For WW, FW, and GW, the values in female individuals were significantly higher than those in male individuals ($p < 0.05$). No statistically significant differences were found in the remaining indicators ($p > 0.05$). Furthermore, among all individuals, the coefficient of variation for quality traits exceeded that for morphological traits, with the maximum coefficient of variation being GW. Additionally, the results of the Kolmogorov–Smirnov (K-S) normality test indicated that all the data were normally distributed ($p > 0.05$). Therefore, subsequent correlation analysis and path analysis can be conducted (Table 1).

Table 1. Statistical analysis of various traits of *Y. japonicum*.

Individual	Parameter	SL/mm	SW/mm	SH/mm	WW/g	FW/g	GW/g	AW/g
All individuals	Mean	100.60	20.57	97.37	79.63	27.68	1.83	10.56
	SD	4.42	1.09	3.95	18.08	6.62	0.60	2.42
	CV/%	4.39	5.29	4.05	22.70	23.90	32.78	22.92
	P (K-S)	0.51	0.41	0.54	0.44	0.42	0.12	0.35
Female individuals	Mean	101.04	20.74	97.16	80.87 *	28.53 *	2.00 *	10.75
	SD	4.51	1.12	4.00	18.40	6.82	0.61	2.58
	CV/%	4.46	5.40	4.12	22.80	23.90	30.50	24.00
	P (K-S)	0.47	0.42	0.61	0.41	0.49	0.14	0.41
Male individuals	Mean	100.21	20.42	97.56	78.49 *	26.91 *	1.67 *	10.38
	SD	4.41	1.08	3.96	18.04	6.52	0.59	2.30
	CV/%	4.40	5.29	4.06	22.98	24.23	35.33	22.16
	P (K-S)	0.46	0.37	0.64	0.51	0.47	0.11	0.34

SD: standard deviation; CV: coefficient of variation; SL: shell length; SW: shell width; SH: shell height; WW: wet weight; FW: soft body weight; GW: gonad weight; AW: adductor muscle weight. *: $p < 0.05$, male vs. female.

3.2. Correlation Analysis of Measured Traits

The correlation matrix for various traits of *Y. japonicum*, including shell width (SW), shell height (SH), wet weight (WW), soft body weight (FW), gonad weight (GW), and adductor muscle weight (AW), for all individuals, female individuals, and male individuals, is shown in Table 2. In the correlation analysis, a highly significant positive correlation ($p < 0.01$) was observed among all traits. This indicated a biological association between the selected traits, and the correlation analysis was statistically significant. In the entire population, the correlation between SL and SH, and between WW and FW, was the highest, with correlation coefficients of 0.987. The correlation between SL and GW was the lowest, with a correlation coefficient of 0.767. Among female individuals, the highest correlation was between SL and SH, with a correlation coefficient of 0.990. The correlation between SH and GW was the lowest, with a correlation coefficient of 0.823. In the male individuals, the correlation between WW and FW was the highest, with a correlation coefficient of 0.988. The correlation between AW and GW was the lowest, with a correlation coefficient of 0.731. These results indicated a strong positive correlation among the morphological and weight-related traits, with some variation in the strength of correlation depending on gender.

Table 2. Correlation matrix of *Y. japonicum* traits by gender.

Individual	Character	SW	SH	WW	FW	GW	AW
All individuals	SL	0.972 **	0.987 **	0.967 **	0.952 **	0.796 **	0.952 **
	SW	1	0.958 **	0.986 **	0.969 **	0.817 **	0.960 **
	SH		1	0.953 **	0.934 **	0.767 **	0.940 **
	WW			1	0.987 **	0.841 **	0.979 **
	FW				1	0.889 **	0.965 **
	GW					1	0.786 **
Female individuals	SL	0.970 **	0.990 **	0.962 **	0.956 **	0.823 **	0.938 **
	SW	1	0.968 **	0.984 **	0.978 **	0.853 **	0.955 **
	SH		1	0.956 **	0.957 **	0.823 **	0.941 **
	WW			1	0.988 **	0.852 **	0.981 **
	FW				1	0.880 **	0.976 **
	GW					1	0.848 **
Male individuals	SL	0.975 **	0.985 **	0.973 **	0.954 **	0.784 **	0.964 **
	SW	1	0.951 **	0.987 **	0.972 **	0.814 **	0.970 **
	SH		1	0.953 **	0.937 **	0.770 **	0.940 **
	WW			1	0.988 **	0.805 **	0.982 **
	FW				1	0.862 **	0.964 **
	GW					1	0.731 **

SL: shell length; SW: shell width; SH: shell height; WW: wet weight; FW: soft body weight; GW: gonad weight; AW: adductor muscle weight. **: $p < 0.01$.

3.3. Path Analysis and Decision Coefficient Analysis of Morphological Traits to Quality Traits

Path analysis was utilized to dissect the direct and indirect influences of morphological traits on quality traits. The results indicated that for both female and male individuals, the most significant factor directly influencing the quality traits (WW, FW, GW, and AW) was SW, while SL had the greatest indirect impact on individual quality traits (WW, FW, GW, and AW) through SW (Table 3).

The determination coefficient of the quality characteristics of *Y. japonicum* was determined by either a single morphological characteristic or the combination of two morphological characteristics. In male and female individuals, the determination coefficient of SW as a single parameter for WW and FW was higher than those of other morphological traits. The major determinants of GW in the entire population were jointly determined by SL and SW. However, in female and male individuals, the major determinant of gonad weight was SW. In female individuals, the coefficient of determination for AW was primarily determined by SW. In male individuals, the coefficient of determination for AW was jointly determined by SL and SW (Table 4).

Table 3. Path analysis of the relationship between morphological traits and quality traits in *Y. japonicum*.

Individuals	Qualitative Trait	Morphological Trait	Relative Coefficient	Direct Effect	Indirect Effect			
					SL	SW	SH	Σ
All individuals	WW	SL	0.967 **	0.164	——	0.808	−0.005	0.803
		SW	0.986 **	0.831	0.159	——	−0.005	0.154
		SH	0.953 **	−0.005	0.162	0.796	——	0.958
	FW	SL	0.952 **	0.356	——	0.773	−0.177	0.596
		SW	0.969 **	0.795	0.346	——	−0.171	0.175
		SH	0.934 **	−0.179	0.351	0.762	——	1.113
	SW	SL	0.796 **	0.705	——	0.794	−0.663	0.131
		SW	0.817 **	0.776	0.685	——	−0.644	0.621
		SH	0.767 **	−0.672	0.696	0.743	——	1.439
	AW	SL	0.952 **	0.296	——	0.612	0.043	0.655
		SW	0.960 **	0.630	0.288	——	0.042	0.330
		SH	0.940 **	0.044	0.292	0.604	——	0.896
Female individuals	WW	SL	0.962 **	0.254	——	0.868	−0.161	0.707
		SW	0.984 **	0.895	0.246	——	−0.158	0.088
		SH	0.956 **	−0.163	0.251	0.866	——	1.117
	FW	SL	0.956 **	0.006	——	0.834	0.114	0.948
		SW	0.978 **	0.860	0.006	——	0.111	0.117
		SH	0.957 **	0.115	0.006	0.832	——	0.838
	SW	SL	0.823 **	0.014	——	0.943	−0.135	0.808
		SW	0.853 **	0.972	0.014	——	−0.132	−0.118
		SH	0.823 **	−0.136	0.014	0.941	——	0.955
	AW	SL	0.922 **	−0.005	——	0.727	0.216	0.943
		SW	0.925 **	0.749	−0.005	——	0.211	0.206
		SH	0.897 **	0.218	−0.005	0.725	——	0.720
Male individuals	WW	SL	0.973 **	0.137	——	0.776	0.060	0.836
		SW	0.987 **	0.796	0.134	——	0.058	0.192
		SH	0.953 **	0.061	0.135	0.757	——	0.892
	FW	SL	0.954 **	−0.074	——	0.852	0.176	1.028
		SW	0.972 **	0.874	−0.072	——	0.170	0.098
		SH	0.937 **	0.179	−0.073	0.831	——	0.758
	SW	SL	0.784 **	−0.406	——	0.967	0.225	1.192
		SW	0.814 **	0.992	−0.396	——	0.217	−0.179
		SH	0.770 **	0.228	−0.400	0.943	——	0.543
	AW	SL	0.964 **	0.494	——	0.585	−0.115	0.470
		SW	0.970 **	0.600	0.482	——	−0.111	0.371
		SH	0.940 **	−0.117	0.487	0.571	——	1.058

SL: shell length; SW: shell width; SH: shell height; WW: wet weight; FW: soft body weight; GW: gonad weight; AW: adductor muscle weight. **: $p < 0.01$.

Table 4. Coefficient of determination for the influence of morphological traits on quality traits in *Y. japonicum*.

Individuals	Qualitative Trait	Morphological Trait	Coefficient of Determination			
			SL	SW	SH	In Total
All individuals	WW	SL	0.027	0.265	−0.002	0.974
		SW	——	0.691	−0.008	
		SH	——	——	0.001	
	FW	SL	0.127	0.550	−0.126	0.942
		SW	——	0.632	−0.273	
		SH	——	——	0.032	
	GW	SL	0.497	1.064	−0.935	0.681
		SW	——	0.602	−0.999	
		SH	——	——	0.452	
	AW	SL	0.088	0.363	0.026	0.929
		SW	——	0.397	0.053	
		SH	——	——	0.002	

Table 4. *Cont.*

Individuals	Qualitative Trait	Morphological Trait	Coefficient of Determination			
			SL	SW	SH	In Total
Female individuals	WW	SL	0.065	0.441	−0.082	0.969
		SW	——	0.801	−0.283	
		SH	——	——	0.027	
	FW	SL	0.000	0.010	0.001	0.955
		SW	——	0.740	0.191	
		SH	——	——	0.013	
	GW	SL	0.000	0.026	−0.004	0.729
		SW	——	0.945	−0.256	
		SH	——	——	0.018	
	AW	SL	0.000	−0.007	−0.002	0.915
		SW	——	0.561	0.316	
		SH	——	——	0.047	
Male individuals	WW	SL	0.019	0.213	0.016	0.978
		SW	——	0.634	0.092	
		SH	——	——	0.004	
	FW	SL	0.005	−0.126	−0.026	0.947
		SW	——	0.764	0.298	
		SH	——	——	0.032	
	GW	SL	0.165	−0.785	−0.182	0.664
		SW	——	0.984	0.430	
		SH	——	——	0.052	
	AW	SL	0.244	0.578	−0.114	0.948
		SW	——	0.360	−0.134	
		SH	——	——	0.014	

SL: shell length; SW: shell width; SH: shell height; WW: wet weight; FW: soft body weight; GW: gonad weight; AW: adductor muscle weight.

3.4. Establishment of the Multiple Linear Regression Equation

Set the quality traits as the dependent variable and the morphological traits as the independent variable to conduct regression analysis. Exclude insignificant morphological traits and obtain the optimal regression equation through stepwise analysis.

All individuals:

(1) WW = −94.659 + 0.336SL + 6.885SW (r^2 = 0.974);
(2) FW = −34.118 + 0.795SW-0.151SH (r^2 = 0.942);
(3) GW = −4.492 + 0.319SW (r^2 = 0.681);
(4) AW = −12.514 + 0.076SL + 0.687SW (r^2 = 0.929).

Female individuals:

(1) WW = −87.48 + 0.517SL + 7.350SW (r^2 = 0.969);
(2) FW = −34.255 + 2.568SW (r^2 = 0.955);
(3) GW = −4.972 + 0.398SW (r^2 = 0.729);
(4) AW = −13.356 + 0.065SL + 0.861SW (r^2 = 0.915).

Male individuals:

(1) WW = −99.078 + 0.280SL + 6.657SW (r2 = 0.978);
(2) FW = −35.811 + 2.637SW (r2 = 0.947);
(3) GW = −4.051 + 0.34SW (r2 = 0.664);
(4) AW = −12.37 + 0.129SL + 0.642SW (r2 = 0.948).

3.5. Nutrient Composition Analysis of Adductor Muscle

The water content of *Y. japonicum* was 80.17%, the ash content was 1.43%, the protein content was 16.93%, the fat content was 0.67%, and the carbohydrate content was 0.80% (Figure 3). Compared with the three major economic scallops in China (*Mizuhopecten* *yessoensis*, *Argopecten irradians*, and *Chlamys farreri*) [28], *Y. japonicum* had the highest protein content and the lowest fat content.

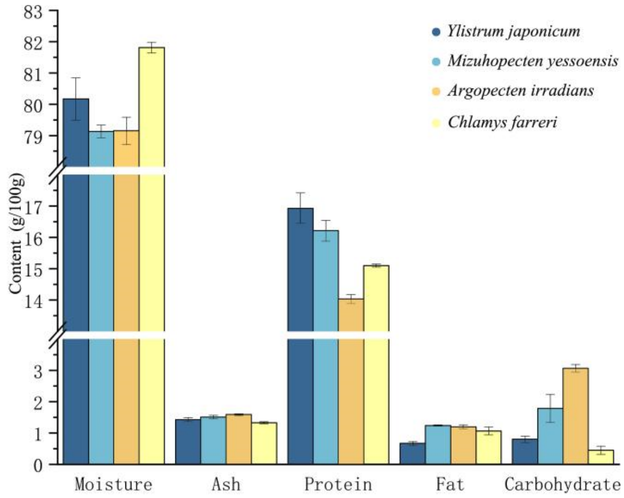
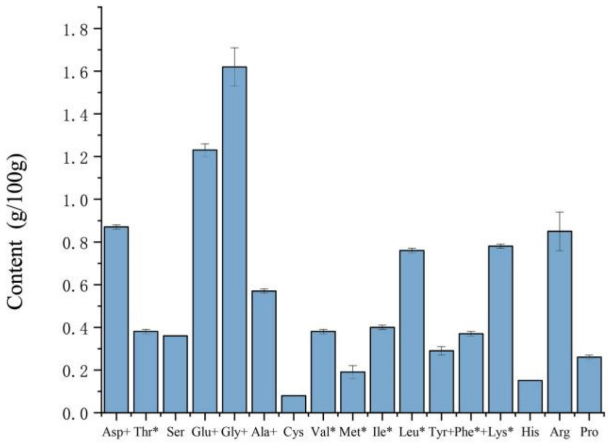


Figure 3. General nutritional composition of *Y. japonicum* and comparison with three other scallops.

The muscles of *Y. japonicum* contained a wide variety of amino acids. Except for tryptophan (Trp), which was completely destroyed during acid hydrolysis and could not be detected, a total of 17 amino acids were identified, including 7 essential amino acids, 10 non-essential amino acids, and 6 flavor amino acids. In the adductor muscle of *Y. japonicum*, the highest amino acid content was glycine (Gly) at 1.62 g/100 g, followed by glutamic acid (Glu) at 1.23 g/100 g and aspartic acid (Asp) at 0.87 g/100 g (Figure 4A), both of which belonged to flavor amino acids. The content of essential amino acids in the adductor muscle was 3.25 g/100 g, accounting for 34% of the total amino acids; the content of taste amino acids was 4.95 g/100 g, accounting for 52% of the total amino acids; the content of non-essential amino acids was 6.28 g/100 g, accounting for 66% of the total amino acids. Through the analysis of amino acid score (AAS) and chemical score (CS), it was found that the first limiting amino acid in *Y. japonicum* was methionine + cysteine (Met + Cys), and the second limiting amino acid was valine (Val) (Figure 4B). This characteristic was similar to that of *M. yessoensis*, *A. irradians*, and *C. farreri* [28].



A

Amino acid	AAS	CS
Thr	0.57	0.48
Val	0.45**	0.32**
Met + Cys	0.44*	0.25*
Ile	0.59	0.44
Leu	0.64	0.53
Phe + Tyr	0.64	0.43
Lys	0.84	0.65

B

Figure 4. Amino acid content of the adductor muscle of *Y. japonicum*. (**A**) The amino acid content is indicated, with * denoting essential amino acids and + indicating umami (savory) amino acids. (**B**) Amino acid score (AAS) and chemical score (CS) are presented. The first limiting amino acid is indicated by *, and the second limiting amino acid is indicated by **.

A total of 23 types of fatty acids were detected in the adductor muscle of *Y. japonicum*, including 10 saturated fatty acids (SFA), 3 monounsaturated fatty acids (MUFA), and 10 polyunsaturated fatty acids (PUFA). The total fatty acid content was 210 mg/100 g, with a saturated fatty acid (SFA) content of 74 mg/100 g, accounting for 36.31% of the total fatty acids. The monounsaturated fatty acid (MUFA) content was 5.5 mg/100 g, accounting for 2.68% of the total fatty acids. The polyunsaturated fatty acid (PUFA) content was 125 mg/100 g, accounting for 61.01% of the total fatty acids (Figure 5). It was observed that the fatty acids of *Y. japonicum* were mainly polyunsaturated fatty acids (PUFAs). Among all types of fatty acids, the four fatty acids with the highest content were C22:6n3 (61.50 mg/100 g), C16:0 (32.80 mg/100 g), C18:0 (25.70 mg/100 g), and C20:5n3 (21.80 mg/100 g).

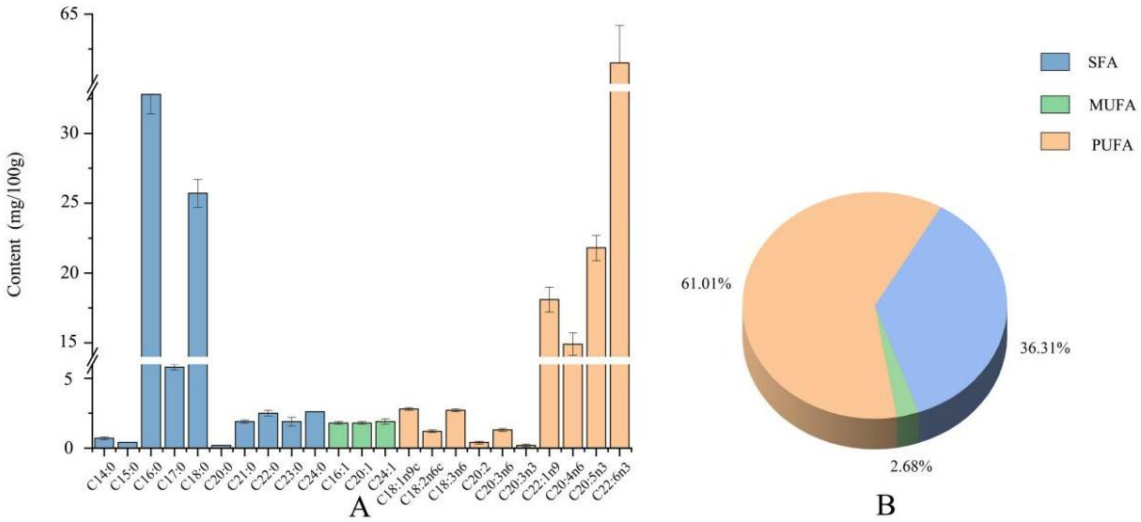


Figure 5. (**A**) Fatty acid content of the adductor muscle of *Y. japonicum*. (**B**) Proportions of different types of fatty acids. Contents of saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), and polyunsaturated fatty acid (PUFA).

4. Discussion

Morphological traits were significant determinants of quality traits and may be influenced by natural selection and gender differences [29–31]. In this study, it was discerned that female individuals of *Y. japonicum* exhibited higher mean values for all morphological traits except shell height, compared to male individuals.

In the correlation analysis, the results indicated that the correlation coefficients between the morphological traits and the mass traits for both male and female individuals were found to be highly significant ($p < 0.01$), aligning with the studies on diverse scallop species [15–17]. In *Y. japonicum*, the female individuals showed a more robust correlation between gonadal weight and morphological traits in comparison to the male individuals. In the path analysis, no gender-specific differences were observed between the morphological traits and quality traits in *Y. japonicum*. This finding was consistent with other bivalve species, such as *Chlamys farreri* [18] and *Mactra chinensis* [14].

The State of World Fisheries and Aquaculture report by the Food and Agriculture Organization (FAO) emphasized the significance of aquatic foods in sustaining nations, thereby reaffirming the connection between nutritional value and economic significance [32]. The protein and fat content are important criteria for assessing the nutritional value of scallops [33–35]. The adductor muscle of *Y. japonicum* exhibited a protein content of 16.93 g per 100 g, which was higher than that of other commercially significant scallop species, such as *M. yessoensis* (16.21 g/100 g), *A. irradians* (14.03 g/100 g), *C. farreri* (14.03 g/100 g), *M. crassicostata* (14.30 g/100 g), and *A. pleuronectes* (16.30 g/100 g) [28,36,37]. This elevated protein content endowed *Y. japonicum* with a high nutritional value. In contrast, the fat content of *Y. japonicum* was lower by 0.67 g/100 g, positioning it beneath the aforementioned scallop species in terms of fat content [28,36,37]. Consequently, *Y. japonicum* is characterized as a dietary source that is rich in protein and low in fat.

In terms of amino acid composition, the three amino acids with the highest content in *Y. japonicum* were glycine (Gly), glutamic acid (Glu), and aspartic acid (Asp). These are all flavor amino acids, and the deliciousness of seafood protein mainly depends on the composition and content of flavor amino acids [38]. Essential amino acids are amino acids that the human body cannot synthesize or synthesizes in insufficient quantities and must be provided by exogenous food. High-quality proteins are usually characterized by the presence of all essential amino acids (EAAs) in balanced proportions [33,35]. In the adductor muscle of *Y. japonicum*, the EAA content was 3.25 g/100 g, representing 34% of the total amino acid (TAA) content. This percentage was slightly higher or similar to that observed in other economic scallops such as *M. yessoensis* (33%), *A. irradians* (31%), *C. farreri* (34%), and *M. crassicostata* (34%) [28,37]. The FAO/WHO ideal protein model suggests that for a protein to be considered high quality, the EAA/TAA ratio should be approximately 40%. The EAA/TAA ratio of *Y. japonicum* was close to this benchmark, indicating a high-quality protein profile.

In the context of amino acid scoring (AAS), lysine exhibited the highest score in *Y. japonicum*. Lysine, a primary essential amino acid for human physiology, plays a pivotal role in metabolic processes and is frequently identified as the most limiting amino acid in human diets [39]. The elevated lysine content in *Y. japonicum* is significant as it has the potential to supplement the protein intake of individuals, particularly enhancing the nutritional value of proteins commonly consumed by humans. Furthermore, for individuals whose diets are primarily based on grains, which are often low in lysine, the consumption of *Y. japonicum* could help to offset this deficiency. By providing additional lysine, it could improve the overall protein utilization by the human body, thereby contributing to a more balanced amino acid profile in the diet [40].

In the context of fatty acid profiling, it was found that the adductor muscle of *Y. japonicum* contained a total of 23 distinct fatty acids, which represented a greater diversity compared to other scallops [28,37]. The distribution of fatty acid content within *Y. japonicum* adhered to the typical pattern observed in scallops, with polyunsaturated fatty acids (PUFAs) predominating over saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFAs) [41]. The four most abundant fatty acids in *Y. japonicum* were identified as C22:6n3 (docosahexaenoic acid, DHA) at 61.50 mg/100 g, C16:0 (palmitic acid) at 32.80 mg/100 g, C18:0 (stearic acid) at 25.70 mg/100 g, and C20:5n3 (eicosapentaenoic acid, EPA) at 21.80 mg/100 g. Notably, C22:6n3 (DHA) was the most abundant and also had high concentrations in other scallop species. Conversely, C20:5n3 (EPA), while less abundant in other scallops, was found in higher amounts in *Y. japonicum*. Extensive research supports the notion that EPA and DHA are significant PUFAs with key roles in various physiological processes. These include the inhibition of prostaglandin synthesis and platelet aggregation, reduction of neutral lipids in the bloodstream, anti-atherosclerotic effects, and enhancement of immune function [42–44]. Based on this comparative analysis with other shellfish, it can be concluded that the adductor muscle of *Y. japonicum* is a significant source of both DHA and EPA, making it a valuable component of diets for its nutritional benefits.

5. Conclusions

In conclusion, the adductor muscles of *Y. japonicum* are recognized for their high protein and low fat composition, coupled with a consistent amino acid profile and a diverse array of fatty acids. These characteristics make them not only highly nutritious but also economically valuable. Shell width emerged as the predominant criterion in the selection for both male and female scallops, with an accompanying emphasis on shell length to ensure the genetic quality and marketability of the offspring. By integrating these selection criteria, the breeding program aims to enhance the nutritional excellence and economic potential of *Y. japonicum*, thereby contributing to the sustainability and profitability of the aquaculture industry.

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