

Original Research Articles

Analysis of the influence of two kinds of shell characteristics on the total weight and soft tissue weight of the clam *Cyclina sinensis*

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To reveal the influence of shell traits between two shell colors on the body and soft tissue weight of the clam *Cyclina sinensis*, a total of 1000 individuals (500 with white shells and 500 with purple shells) were randomly selected to analyze the effects of shell length, shell height, shell width, ligament length, and shell weight on the body and soft tissue weight. The results indicated that the shell traits of the clam were significantly correlated with the total weight and the soft tissue weight at an extremely significant level ($P < 0.01$). Shell height was the main determinant of total body weight and soft tissue weight in the white shell group and the mixed group. Shell length is the main characteristic that determines the total weight and soft tissue weight of the purple shell. The optimal multiple regression equations with total weight and soft tissue weight as dependent variables and other characteristics as independent variables were established for the two shell color groups of *C. sinensis*. The results provided a theoretical basis for the breeding and production of the clam.

INTRODUCTION

Cyclina sinensis belongs to the family *Veneroida* and *Veneroidae*. It is widely distributed in the nearshore sandy intertidal zone¹ of China, Korea, and Japan. It is an important cultured marine shellfish in China. However, over recent years, the culture industry of the clam has faced a series of problems caused by the degradation of germplasm resources, such as slow growth, individual miniaturization, and a decline in disease resistance. Therefore, there is an urgent need to intensify research on the improvement of germplasm in clams.

The shape and quality of shellfish are key economic indicators in aquaculture production and breeding operations.² The quality directly reflects the growth index of shellfish. However, assessing soft tissue quality is challenging as it can lead to tissue damage and is difficult to obtain in production settings. In contrast, morphological traits are relatively stable, easier to analyze, and more readily accessible.³ Among them, shell color is an important phenotypic trait in morphological characteristics. Therefore, the directional selection of shell color is an important breeding direction in the genetic breeding of the clam.⁴ Using path analysis and multiple regression analysis, the direct influence of shell color on quality traits was obtained, and the relationship between shell color and quality traits was stud-

ied, which offered significant implications for the breeding of the clam.⁴

Path analysis has been widely used in the selection of excellent breeding in aquaculture, and there have been numerous reports on the correlation between morphological characteristics and quality characteristics of shellfish. In commercial shellfish, morphological traits often have a high correlation with body mass. Relevant studies have been conducted on *Placopecten magellanicus*,⁵⁻⁷ *Tegillarca granosa*,⁸ *Crassostrea sikamea*,^{4,9} *Ruditapes philippinarum*,¹⁰ *Pinctada martensii*^{11,12} and some other species. Zhang et al.² established optimal regression equations by analyzing the relationship between shell morphological traits and body weight in *Meretrix meretrix* and *C. sinensis*. Similarly, Huo et al.¹⁰ used path analysis to study the impact of Manila clam shell morphology on live weight, while Chen et al.¹³ and Luo et al.¹⁴ applied the same method to investigate the effects of shell traits on body weight in *Sinonovacula constricta* and interspecific hybrid abalone (*Haliotis discus hannai* and *Haliotis gigantea*), respectively. Whereas there is no report on the effect of different shell colors on the quality traits of the clam. In this study, the relationship between shell traits of purple shell and white shell, total weight, and soft tissue weight of the clam was analyzed. Through correlation analysis, path analysis, and multiple regression equations, the influence of shell traits of differ-

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Table 1. Statistical analysis functions and functions of the R

Functions	Functions
<i>shapiro.test()</i>	Normality test
<i>aov()</i>	Analysis of variance
<i>compare_means()</i>	Multiple comparisons
<i>rcorr()</i>	Calculate the correlation coefficient
<i>cor_pmat()</i>	Correlation coefficient significance test
<i>path.analysis()</i>	Calculate the path coefficient
<i>lm()</i>	Establish regression equation
<i>step()</i>	Fit the optimal regression equation

ent shell colors on the total weight and soft tissue weight of the clam was determined, which could laid a theoretical foundation for clam breeding.

MATERIALS AND METHODS

MATERIALS

This experiment was performed in September 2024 at Lianyungang Hailang Aquaculture Limited Company. A total of 1000 vigorous 3rd-age clams with purple shells and white shells were randomly selected from a pond, and the dirt on their body surface was removed with running water. The clams were placed in the water for 12 hours to drain the food and feces in their bodies and then let dry in the shade for 12 hours to drain the stored seawater in their bodies as much as possible. We ensured that the measurement of total weight and soft tissue weight was more accurate.

MEASUREMENT METHODS

Surface of the clam was blotted with a paper towel before measuring its phenotypic traits. We divide the clams into the white - shelled group and the purple - shelled group and use an electronic vernier caliper to measure their shell length (L), height (H), shell width (W), and ligament length (A) (accurate to 0.01mm). And then used an electronic balance to weigh the total weight (BW), and shell weight (SW) (accurate to 0.0001g).

Software part weight = Full weight - shell weight

DATA ANALYSIS

R software (R version 4.2.0) was used for data statistical analysis. The functions and functions used are shown in [Table 1](#).

RESULTS AND ANALYSIS

STATISTICS OF BIOLOGICAL INDICATORS OF THE CLAM

The data statistics of shell length, shell width, shell height, ligament length, total weight, and soft tissue weight measured are shown in [Table 2](#). It can be seen from [Table 2](#) that the shell characteristics and quality properties of the

purple shell were greater than those of the white shell. In the white shell group, purple shell group, and mixed group, the coefficient of variation of quality traits was greater than that of other phenotypic traits, indicating that quality traits have great selection potential.

CORRELATION COEFFICIENT ANALYSIS AMONG VARIOUS CHARACTERS OF THE CLAM

Shapiro.test() function was used to test the normality of the biological indicators of the purple clam, and the analysis results showed that all the biological indicators were in line with the normal distribution. The Pearson correlation coefficient was calculated by the rcorr() function, and the correlation coefficient significance was tested by the cor_pmat() function. The results of different shell colors and mixing groups are shown in [Table 3-5](#). As shown in the results, there were extremely significant positive correlations between the biological traits of the different shell color groups and the mixed group ($P < 0.01$). Because it was impossible to measure the shell weight of the clam without damaging the clam in the actual experiment, the influence of shell weight was temporarily ignored. In the mixed and white shell groups, the correlation coefficients between shell height and total weight reached the maximum (0.925, 0.904), followed by shell length, shell width, and the correlation coefficients of ligament length were the smallest (0.822, 0.812). In the purple shell group, the correlation coefficient between total weight and shell length was the largest (0.939), followed by shell height, shell width, and the correlation coefficient of ligament length was the smallest (0.833). In both the mixed group and the white shell group, the correlation coefficient between the shell height and the soft tissue weight of the clam reached the maximum value (0.800, 0.766), followed by the shell length and shell width, while the correlation coefficient of the ligament length was the smallest (0.725, 0.700). In the purple shell group, the correlation coefficient between shell length and soft tissue weight was the largest (0.824), and the correlation coefficient of ligament length was the smallest (0.748).

Table 2. The phenotypic traits and indexes of the cockle *C. sinensis*

Taxa	Determinations	Indicators	Shell length /mm	Shell height /mm	Shell width /mm	Ligament length /mm	Full weight /g	Shell weight /g	Soft part weight /g
White Shell	500	Average	34.28	34.82	21.94	14.86	9.646	6.909	2.737
		SD	0.256	0.291	0.156	0.173	2.179	1.656	0.623
		Coefficient of variation CV/ 100%	7.457	8.360	7.114	11.623	22.588	23.976	22.776
Purple Shell	500	Average	34.47	34.98	21.95	15.17	9.868	7.079	2.786
		SD	0.298	0.307	0.199	0.191	2.830	2.142	0.786
		Coefficient of variation CV/ 100%	8.625	8.768	9.077	12.601	28.682	30.259	28.184
Mixed Group	1000	Average	34.38	34.90	21.95	15.01	9.757	6.994	2.763
		SD	0.278	0.299	0.179	0.183	2.527	1.916	0.709
		Coefficient of variation CV/ 100%	8.081	8.566	8.151	12.171	25.898	27.390	25.678

Note: Coefficient of variation = Standard deviation/mean

Table 3. Correlation coefficients of each character in the mixed group

Indicators	Shell length	Shell height	Shell width	Ligament length	Shell weight	Full weight	Soft part weight
Shell length	1	0.905**	0.840**	0.820**	0.904**	0.910**	0.792**
Shell height		1	0.812**	0.780**	0.876**	0.925**	0.800**
Shell width			1	0.763**	0.927**	0.879**	0.765**
Ligament length				1	0.816**	0.822**	0.725**
Shell weight					1	0.987**	0.814**
Body weight						1	0.898**
Soft-tissue weight							1

Note: ** It indicates that the correlation coefficient between traits is extremely significant ($P < 0.01$) (the same below)**Table 4. Correlation coefficients of each character in the white shell group**

Indicators	Shell length	Shell height	Shell width	Ligament length	Shell weight	Full weight	Soft part weight
Shell length	1	0.845**	0.784**	0.809**	0.880**	0.888**	0.762**
Shell height		1	0.726**	0.712**	0.810**	0.904**	0.766**
Shell width			1	0.742**	0.903**	0.816**	0.700**
Ligament length				1	0.806**	0.812**	0.696**
Shell weight					1	0.984**	0.782**
Body weight						1	0.881**
Soft-tissue weight							1

Table 5. Correlation coefficients of each character in the purple Shell group

Indicators	Shell length	Shell height	Shell width	Ligament length	Shell weight	Full weight	Soft part weight
Shell length	1	0.955**	0.879**	0.830**	0.922**	0.939**	0.824**
Shell height		1	0.883**	0.840**	0.932**	0.933**	0.819**
Shell width			1	0.785**	0.943**	0.927**	0.811**
Ligament length				1	0.827**	0.833**	0.748**
Shell weight					1	0.988**	0.833**
Body weight						1	0.908**
Soft-tissue weight							1

Table 6. Path analysis of shell character to total weight and soft tissue weight

Class Groups	Traits	Path coefficient					Correlation index R2
		Shell length	Shell height	Shell width	Ligament length	Shell weight	
White shell	Full weight	0.072	0.095	0.027	0.017	0.796	0.987
	Soft part weight	0.256	0.338	0.096	0.061	0.117	0.856
Purple Shell	Full weight	0.091	0.076	0.036	0.018	0.790	0.974
	Soft part weight	0.322	0.267	0.116	0.065	0.119	0.861
Mixed group	Full weight	0.081	0.086	0.028	0.017	0.796	0.989
	Soft part weight	0.286	0.305	0.098	0.059	0.128	0.867

PATH ANALYSIS OF THE EFFECT OF THE CLAM SHELL CHARACTERISTICS ON THE TOTAL WEIGHT AND SOFT TISSUE WEIGHT

The path analysis function was used to perform path analysis of the data. It can be seen from [Table 6](#) that the influence of phenotypic traits on total weight in the white shell group was shell weight, shell height, shell length, shell width, and ligament length in sequence. The influence of soft tissue weight on total body weight was shell height, shell length, shell width, and ligament length (soft tissue weight did not consider shell weight). In the Purple Shell group, the phenotypic traits influencing total weight, in order of impact, were shell weight, shell length, shell height, shell width, and ligament length. The order of influence on soft tissue weight was shell length, shell height, shell width, and ligament length (soft tissue weight did not consider shell weight). In the mixed group, the influence of phenotypic traits on total weight was shell weight, shell height, shell length, shell width, and ligament length. The order of influence on soft tissue weight was shell height, shell length, shell width, and ligament length (soft tissue weight did not consider shell weight).

ANALYSIS OF THE EFFECT OF THE CLAM SHELL CHARACTERISTICS ON TOTAL WEIGHT AND SOFT TISSUE WEIGHT

[Tables 7-9](#) show the influence of shell traits of different groups on body weight. As can be seen from [Table 7](#), for total body weight in the white shell group, shell weight had the largest direct effect (0.769), followed by shell height (0.095), shell length (0.072), shell width (0.027), and ligament length, which had the smallest effect (0.017). Among the indirect effects, the maximum influence on the total weight was the shell weight (3.427), where the shell weight mainly indirectly affected the total weight through shell width (0.906); followed by shell height (3.133), which mainly indirectly affected the total weight through the shell length (0.862), as well as shell length (3.015) and shell width (2.996). The least influential was ligament length (2.460), which mainly influenced total weight indirectly through shell length (0.628). However, in the actual experiment, it is impossible to measure shell weight without damaging *C. sinensis* itself, so the first influencing factor after removing the shell weight should be given priority consideration. From the perspective of direct and indirect effects, shell height is the first influencing factor after shell weight, indicating that shell height is the main trait affecting the total weight of the white shell group of *C. sinensis*. For soft tissue weight, shell height (0.338) was the most influential factor, followed by shell length (0.256), shell

weight (0.117), shell width (0.096), and ligament length (0.061). In the indirect effects, shell weight (2.734) was the most influential, and shell weight indirectly affected the soft tissue weight (0.723) mainly through shell width; the second most influential was shell height (2.666), mainly through the shell length which mainly affected the soft tissue weight (0.733), shell length (2.610), shell width (2.510); The least influential was ligament length (2.117), which indirectly affected the soft tissue weight (0.542) mainly through the shell height. From the perspective of direct and indirect effects, shell height has the greatest effect on soft tissue weight, and other characteristics have smaller effects, indicating that shell height is the main shell trait affecting soft tissue weight.

It can be seen from [Table 8](#) that in the purple shell group, shell weight (0.790) is the trait that has the greatest influence on total weight, followed by shell length (0.091), shell height (0.076), shell width (0.033), and ligament length, which has the least impact (0.018). In the indirect effects, shell weight had the largest influence on total weight (3.457), where shell weight mainly influenced total weight indirectly through shell width (0.916); the second most influential was shell height (3.190), which indirectly affected total weight (0.860), shell length (3.127) and shell width (3.086) through shell length. The least influential was ligament length (2.378), which indirectly affected total weight (0.617) through shell height. However, in the actual experiment, it is impossible to measure shell weight without damaging *C. sinensis*, so the first influencing factor after removing the shell weight should be given priority consideration. From the perspective of direct and indirect effects, shell length is the first influencing factor after shell weight, followed by shell height, and other characteristics have smaller effects, indicating that shell length is the main characteristic affecting total weight. For soft tissue weight, shell length (0.322) was the most important factor in the direct effect, followed by shell height (0.267), shell weight (0.119), and shell width (0.116). Ligament length had the lowest effect (0.065). Shell weight (2.835) was the most influential, where shell weight mainly influenced soft tissue weight through shell width (0.751); the second most influential was shell height (2.787), which mainly affects the soft tissue weight (0.751) and shell length (2.783) through shell length, and mainly affects the soft tissue weight (0.759) and shell width (2.626) through shell height; The least influential was ligament length (2.094), which mainly influenced soft tissue weight (0.543) by shell height; Combined with direct and indirect effects, shell length has the greatest influence on soft tissue weight, indicating that shell length is the main trait affecting soft tissue weight.

It can be seen from [Table 9](#) that in the mixed group, shell weight (0.796) has the greatest influence on total weight in direct effects, followed by shell height (0.086), shell length (0.081), shell width (0.028), and ligament length (0.017). In indirect effects, shell weight (3.427) has the greatest influence, where shell weight indirectly affects the total weight (0.906) mainly through shell width; the second most influential is shell height (3.133), which indirectly affects the total weight (0.862) through shell length, shell length (3.015)

and shell width (2.996). The least influential was ligament length (2.460), which indirectly affected total weight (0.630) mainly through shell height. However, in the actual experiment, it is impossible to measure shell weight without damaging *C. sinensis* itself, so the first influencing factor after removing the shell weight should be considered. From the perspective of direct and indirect effects, shell height is the first factor after shell weight, indicating that shell height is the main trait affecting the total weight of the mixed group of the clam. For soft tissue weight, shell height (0.305) was the most influential in the direct effect, followed by shell length (0.286), shell weight (0.128), shell width (0.098), and ligament length (0.059) were the lowest. In the indirect effects, shell weight (1.681) was the most important factor, and shell weight was mainly influenced by shell width (0.445); the second most influential was shell height (1.645), mainly through the shell length which mainly affected the soft tissue weight (0.448), shell length (1.628), and shell width (1.547). The least influential was ligament length (1.260), which indirectly affected the soft tissue weight (0.325) mainly through the shell height. Considering the direct and indirect effects, shell height is the main trait that affects soft tissue weight.

DECISION ANALYSIS OF THE SHELL CHARACTERISTICS OF THE CLAM ON THE TOTAL WEIGHT AND SOFT TISSUE WEIGHT

The coefficient of determination reflects the degree to which the independent variables of each shell are characteristic of the total weight and the weight of the soft tissue. [Tables 10-12](#) show the direct and indirect determinants of different shell traits on total weight and soft tissue weight. The total coefficient of determination of the white shell group, purple shell group, and mixed group is the same as the coefficient of determination R^2 of their corresponding multiple regression equations, indicating that each shell trait is the main factor affecting total weight and soft tissue weight, while other unmeasured shell traits have little influence on total weight and soft tissue weight.

'[@attachment](#)

[Table 10](#) analysis results of the white shell group show that in terms of the degree of direct determination, the degree to which each shell trait determines total weight is: shell weight > shell height > shell length > shell width > ligament length. It can be seen that shell weight and shell height are the main factors affecting total weight. In the co-determination coefficient, the maximum determining degree of shell height and shell weight on total weight is 7.9%. In terms of direct determination, the degree to which each shell trait determines soft tissue weight is: shell height > shell length > shell weight > shell width > ligament length. Shell height and shell length are the main factors affecting soft tissue weight. In the co-determination coefficient, the determining degree of shell height and shell length on soft tissue weight is 7.2%.

[Table 11](#) analysis results of the purple shell group show that in terms of the degree of direct determination, the degree to which each shell trait determines total weight is: shell weight > shell length > shell height > shell width > lig-

Table 7. Influence of shell characteristics on total weight and soft tissue weight of white shell *C. sinensis*

Total Body Weight									Soft part weight							
Traits	Correlation coefficient	Direct effect	Indirect effect						Correlation coefficient	Direct effect	Indirect effect					
			Σ	Shell length	Shell height	Shell width	Ligament length	Shell weight			Σ	Shell length	Shell height	Shell width	Ligament length	Shell weight
Shell length	0.914**	0.072	3.015	—	0.842	0.698	0.702	0.773	0.762**	0.256	2.61	—	0.729	0.604	0.608	0.669
Shell height	0.929**	0.095	3.133	0.862	—	0.737	0.720	0.814	0.802**	0.338	2.666	0.733	—	0.627	0.613	0.692
Shell width	0.848**	0.027	2.996	0.726	0.749	—	0.675	0.845	0.771**	0.096	2.51	0.608	0.628	—	0.566	0.708
Ligament length	0.671**	0.017	2.460	0.628	0.630	0.581	—	0.621	0.663**	0.061	2.117	0.541	0.542	0.500	—	0.534
Shell weight	0.915**	0.796	3.427	0.862	0.887	0.906	0.773	—	0.813**	0.117	2.734	0.687	0.707	0.723	0.616	—

Table 8. Influence of shell characteristics on total weight and soft tissue weight of purple shell *C. sinensis*

Total Weight									Software weight							
Traits	Correlation coefficient	Direct effect	Indirect effect						Correlation coefficient	Direct effect	Indirect effect					
			Σ	Shell length	Shell height	Shell width	Ligament length	Shell weight			Σ	Shell length	Shell height	Shell width	Ligament length	Shell weight
Shell length	0.894**	0.091	3.127	—	0.853	0.760	0.701	0.813	0.814**	0.322	2.783	—	0.759	0.676	0.624	0.724
Shell height	0.911**	0.076	3.190	0.860	—	0.772	0.726	0.832	0.782**	0.267	2.787	0.751	—	0.675	0.634	0.727
Shell width	0.864**	0.033	3.086	0.776	0.782	—	0.667	0.861	0.723**	0.116	2.626	0.660	0.665	—	0.567	0.733
Ligament length	0.646**	0.018	2.378	0.601	0.617	0.560	—	0.600	0.680**	0.065	2.094	0.529	0.543	0.493	—	0.528
Shell weight	0.922**	0.790	3.457	0.884	0.897	0.916	0.761	—	0.716**	0.119	2.835	0.725	0.735	0.751	0.624	—

Table 9. Influence of shell characteristics on total weight and soft tissue weight of *C. sinensis* in mixed group

Total Weight										Soft part weight						
Traits	Correlation coefficient	Direct effect	Indirect effect							Correlation coefficient	Direct effect	Indirect effect				
			Σ	Shell length	Shell height	Shell width	Ligament length	Shell weight	Σ			Shell length	Shell height	Shell width	Ligament length	Shell weight
Shell length	0.895**	0.081	3.015	—	0.842	0.698	0.702	0.773	0.787**		0.286	1.628	—	0.450	0.386	0.371
Shell height	0.909**	0.086	3.133	0.862	—	0.737	0.720	0.814	0.784**		0.305	1.645	0.448	—	0.392	0.376
Shell width	0.923**	0.028	2.996	0.726	0.749	—	0.675	0.845	0.780**		0.098	1.547	0.383	0.390	—	0.339
Ligament length	0.781**	0.017	2.460	0.628	0.630	0.581	—	0.621	0.680**		0.059	1.260	0.321	0.325	0.296	—
Shell weight	0.985**	0.796	3.427	0.862	0.887	0.906	0.773	—	0.798**		0.128	1.681	0.427	0.436	0.445	0.373

Table 10. The coefficient of determination of the shell characteristics of the white shell *C. sinensis* on the total weight and the soft tissue weight

Total Weight							Soft part weight					
Traits	CoDD	ICoD					CoDD	ICoD				
		Shell length	Shell height	Shell width	Ligament length	Shell weight		Shell length	Shell height	Shell width	Ligament length	Shell weight
Shell length	0.020	—	0.079	0.067	0.058	0.079	0.065	—	0.072	0.059	0.053	0.067
Shell height	0.026		—	0.066	0.056	0.079	0.086		—	0.060	0.052	0.068
Shell width	0.008			—	0.054	0.084	0.024			—	0.051	0.073
Ligament length	0.005				—	0.087	0.016				—	0.074
Shell weight	0.221					—	0.030					—
d	0.987						0.856					

Note: CoDD is the direct coefficient of determination; ICoD is the indirect coefficient of determination. d is the total coefficient of determination. (Table 10 is the same as Table 11 and 12)

Table 12. Determination coefficient of shell character on total weight and soft tissue weight in mixed group

Total Weight							Soft part weight					
Traits	CoDD	ICoD					CoDD	ICoD				
		Shell length	Shell height	Shell width	Ligament length	Shell weight		Shell length	Shell height	Shell width	Ligament length	Shell weight
Shell length	0.023	—	0.080	0.061	0.059	0.078	0.073	—	0.070	0.060	0.050	0.067
Shell height	0.025		—	0.065	0.057	0.076	0.078		—	0.061	0.061	0.068
Shell width	0.008			—	0.057	0.090	0.025			—	0.049	0.074
Ligament length	0.005				—	0.086	0.015				—	0.071
Shell weight	0.223					—	0.032					—
d	0.989						0.867					

ament length. Shell weight and shell length are the main factors affecting total weight. In the co-determination coefficient, the maximum determining degree of shell weight and shell length on total weight is 7.9%. In terms of direct determination, the degree to which each shell trait determines soft tissue weight is: shell length > shell height > shell weight > shell width > ligament length. Shell length and shell height are the main factors affecting soft tissue weight. In the co-determination coefficient, the determining degree of shell length and shell height on soft tissue weight is 6.9%.

Table 12 analysis results of the mixed group show that, in terms of direct determination, the degree to which each shell trait determines total weight is: shell weight > shell height > shell length > shell width > ligament length. Shell weight and shell height are the main factors affecting total weight. In the co-determination coefficient, the maximum determining degree of shell weight and shell height on total weight is 7.6%. In terms of direct determination, the degree to which each shell trait determines soft tissue weight is: shell height > shell length > shell weight > shell width > ligament length. It can be seen that the shell height and shell length are the main factors affecting soft tissue weight. In the co-determination coefficient, the determining degree of shell height and shell length on soft tissue weight is 7%.

ESTABLISHMENT OF MULTIPLE REGRESSION EQUATIONS OF SHELL PROPERTIES, TOTAL WEIGHT, AND SOFT TISSUE WEIGHT

According to the correlation analysis and path analysis, the relationship between shell traits and total weight and soft tissue weight is extremely significant. Total weight and soft tissue weight were used as dependent variables, and shell length, shell width, shell height, shell weight, and ligament length were used as independent variables to establish multiple regression equations. The regression equation was established using the `lm()` function, and the optimal regression equations were obtained by the backward method of the `step()` function. As can be seen from **Tables 13-15**, the partial regression coefficient of ligament length on total weight (deleted) was not significant ($p > 0.05$). The partial regression coefficients of shell weight and ligament length on soft tissue weight were not significant ($p > 0.05$). The partial regression coefficients of other parameters all reached a very significant level ($p < 0.01$). The regression equations of shell traits, total weight, and soft tissue weight for different shell color groups are as follows:

White shell: $Y_1 = -46.630 + 0.646L + 0.774H + 0.161W + 0.528 SW$

$Y_2 = -56.063 + 0.343L + 0.673H + 0.810W$

Purple shell: $Y_1 = -40.780 + 0.784L + 0.399H + 0.263W + 0.550 SW$

$Y_2 = -60.003 + 0.441L + 0.872 H + 0.659W$

Mixed group: $Y_1 = -46.292 + 0.594 L + 0.719H + 0.276 W + 0.640 SW$

$Y_2 = -57.895 + 0.385 L + 0.744H + 0.763W$

DISCUSSION

Path analysis for selective breeding has been widely used in aquaculture. There is a strong correlation between shell traits and body mass, and different shell traits have different effects on body mass and soft tissue quality.¹⁵ Huo et al.¹⁵ analyzed the influence of different shell traits of Manila clam on body weight and found that shell length had the greatest impact on body weight. Chen et al.¹³ analyzed the influence of different shell traits on the body weight of the razor clam *S. constricta* under high salinity and found that shell length and shell width had the greatest impact on body weight. Total weight and soft tissue weight are important indexes in the breeding of *C. sinensis*. In this study, multiple regression analysis and path analysis were used to study the correlation between shell length, shell height, shell width, shell weight, and ligament length of white shell, purple shell, and mixed third-age *C. sinensis*, and the degree of determination of the five shell traits and body weight traits, to provide a basic reference for more direct and effective breeding.

Total weight is an important index in breeding and soft tissue weight is an important index in the production of *C. sinensis*. Body quality is usually indirectly selected through other traits in breeding.¹⁶ The correlation coefficient between the two variables obtained by correlation analysis cannot completely indicate the degree of correlation between the variables, and there are usually other indirect influences of other variables.¹⁷ By conducting path analysis with body mass as the dependent variable and other shell traits as independent variables, it is an important goal of breeding goal to identify the main shell traits that affect the body mass of *C. sinensis*. In this study, the correlation coefficients between shell traits and total body weight as well as soft tissue weight in the three experimental groups of white shell, purple shell, and mixed group all reached a very significant level ($P < 0.01$), indicating that shell traits were closely related to body weight. This made subsequent path analysis and multiple regression analysis of the *C. sinensis* of practical significance. Based on the correlation analysis of shell traits, path analysis and determination coefficient analysis were carried out.¹⁸ When the sum of the individual variable-independent determination coefficients and the multiple co-determination coefficients of the dependent variable, denoted as $\sum d$, is $\geq 85\%$, it indicates that the main independent variables affecting the dependent variable have been identified.¹⁹ In this study, for the white-shell group of *C. sinensis*, the values of d for total weight and soft tissue weight were 0.987 and 0.856, respectively. For the purple-shell group, the values of d for total weight and soft tissue weight were 0.974 and 0.861, respectively. In the mixed-shell group, the values of d for total weight and soft tissue weight were 0.989 and 0.867, respectively. The results showed that shell length, shell height, shell width, and shell weight were the important traits affecting total weight. Shell length, shell height, and shell width are the important traits affecting soft tissue weight, while other traits have little effect. Determination degree analysis showed that different shell color groups had different

Table 13. Partial regression coefficient test of white shell characteristics on total weight and soft tissue weight

Indicators	Parameters	Partial regression coefficient B	Standard deviation SD	T-value	P value
Total weight	Constant	-46.630	0.542	-6.829	0.000
	Shell length	0.646	0.153	5.049	0.000
	Shell height	0.774	0.109	1.479	0.000
	Shell width	0.161	0.122	5.294	0.000
	Shell weight	0.528	0.015	34.523	0.000
Software part weight	Constant	-56.063	0.231	-18.738	0.000
	Shell length	0.673	0.204	3.305	0.000
	Shell height	0.810	0.208	1.649	0.000
	Shell width	0.343	0.088	9.145	0.000

Table 14. Partial regression coefficient test of purple shell character on total weight and soft tissue weight

Indicators	Parameters	Partial regression coefficient B	Standard deviation SD	T-value	P value
Total weight	Constant	-40.780	0.624	-5.279	0.000
	Shell length	0.784	0.222	3.539	0.000
	Shell height	0.399	0.230	1.144	0.000
	Shell width	0.263	0.141	2.822	0.000
	Shell weight	0.550	0.017	31.932	0.000
Software part weight	Constant	-60.003	0.226	-20.730	0.000
	Shell length	0.872	0.192	4.549	0.000
	Shell height	0.659	0.190	2.318	0.000
	Shell width	0.441	0.095	6.959	0.000

Table 15. Partial regression coefficient test of shell traits on total weight and soft tissue weight in mixed group

Indicators	Parameters	Partial regression coefficient B	Standard deviation SD	T-value	P value
Total weight	Constant	-46.292	0.401	-9.137	0.000
	Shell length	0.594	0.140	5.144	0.000
	Shell height	0.719	0.148	1.865	0.000
	Shell width	0.276	0.093	6.426	0.000
	Shell weight	0.640	0.062	44.484	0.000
Software part weight	Constant	-57.895	0.160	-27.980	0.000
	Shell length	0.744	0.139	5.507	0.000
	Shell height	0.763	0.140	2.753	0.000
	Shell width	0.385	0.064	11.622	0.000

shell traits affecting body weight. Because it is impossible to measure shell weight without damaging *C. sinensis* in the actual breeding process, the first influencing factor after removing the shell weight is considered. Therefore, among the five tested shell traits, combined with direct and indirect effects, shell height is the main trait affecting the white shell group and the mixed group. Shell length was the main trait affecting the purple shell group. For soft tissue weight, shell height is also the main trait affecting the white shell group and mixed group. Shell length was the main trait affecting the purple shell group. Multiple regression analysis showed that the partial regression coefficient

of shell height on body mass and soft tissue mass of the mixed group and white shell group was very significant ($P < 0.01$). The partial regression coefficient of shell length on body mass and soft tissue mass of the purple shell group was very significant ($P < 0.01$). According to the correlation analysis, path analysis, determination degree, and multiple regression analysis, the shell height of the mixed group and the white shell group was preferred when body mass or soft tissue mass was the target trait in different shell color selections of *C. sinensis*. The shell length of the purple shell group was the priority.

The outcomes of this research are highly consistent with those of prior studies. Yang et al.²⁰ in the analysis of 1-2-year-old *C. sinensis*, showed that shell length was the main trait affecting body mass, with a direct effect of 0.403 in path analysis and a determination coefficient of 0.163. In this study, the main trait affecting the body mass of purple *C. sinensis* was shell length. The results of Gao et al.²¹ showed that shell height was the main trait affecting the soft tissue weight of 1-year-old *C. sinensis*. The direct effect of shell length on diameter was 0.938, and the indirect effect of shell length was the largest, mainly through shell height. In this study, shell height was the main trait affecting the soft tissue weight of the mixed and white shell groups. To sum up, it can be concluded that different geographical groups, different ages, and different shell colors may lead to different shell traits affecting body weight and soft tissue weight, resulting in the above variations. Therefore, the selection and breeding of *C. sinensis* should be treated differently based on these factors.

This study indicates that different shell-colored *C. sinensis* should have distinct selection criteria during breeding. For white-shelled *C. sinensis*, shell height should be the focus during selection; for purple-shelled ones, shell length should be emphasized; and for those with mixed shell colors, shell length should also be the key consideration. The findings of this research offer certain guidance for the selection and production standards of *C. sinensis* with different shell colors.

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AUTHORS' CONTRIBUTION

Conceptualization: Hongxing Ge (Lead). Writing – review & editing: Hongxing Ge (Lead). Methodology: Chen Zhao (Lead). Formal Analysis: Yong Xie (Lead). Investigation: Yong Xie (Lead). Funding acquisition: Zhiguo Dong (Lead). Resources: Zhiguo Dong (Lead). Supervision: Zhiguo Dong (Lead).

ETHICAL CONDUCT APPROVAL – IACUC

We confirm that all efforts were made to ameliorate any suffering of the clam *Cyclina sinensis*.

During the experiment, all authors complied with the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

INFORMED CONSENT STATEMENT

All authors and institutions have confirmed this manuscript for publication.

DATA AVAILABILITY STATEMENT

All are available upon reasonable request.

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