



Effect of Different Dietary Levels of Protein on Growth Performance of *Penaeus monodon* Families

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ABSTRACT

An 8 weeks experiment was conducted to determine the effects of two fish meal protein level diets (Diet A and Diet B) on the growth and survival rates of 36 families of *Penaeus monodon*. The results showed that significant differences were observed in the weight gain of different *P. monodon* families fed with the same diet ($P < 0.05$). The AGR (absolute weight gain rate) of the fastest weight gain families was 97.16% and 95.46% higher than that of the slowest weight gain families fed with Diet A and Diet B, respectively, but the order of weight gain of different families in the different diet groups was not the same. The average survival rates of *P. monodon* fed with different diets were significantly different (80.59% and 77.88%, respectively). The order of survival rate of different families in the different diet groups was not the same, either. There were significant differences ($P < 0.05$) in production performance among families in different feed groups. The highest yield of families in Diet A group and Diet B group was 100% and 124.44% higher than that of the lowest families, respectively. The production of No.10 family and No.6 family ranked the top two at two diets. Therefore, the potential for selection for growth and survival is available and genetic materials for breeding selection are demanded in future.

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Authors' Contribution

SGJ, SJ and XBM designed the study. QBY and JHH took part in the execution of study. LSY, QBY, and XBM implemented the study and involved in sampling as well as testing. SJ, XBM and SGJ drafted the manuscript.

Key words

Penaeus monodon, Dietary levels, Growth, Survival, Production performance

INTRODUCTION

In shrimp culture, feed cost accounts for more than half of the total cost. At present, shrimp feed mainly relies on fish meal as protein source and the resource of fish meal is limited and the demand is increasing rapidly (Zhang *et al.*, 2018). The international market price of fish meal is rising sharply, and price of shrimp feed are increasing accordingly, which affects the economic benefit and sustainable development of shrimp culture industry (Liang *et al.*, 2017; Leelatanawit *et al.*, 2017). Some investigations have been carried out on the replaceable plant protein to reduce the demand of fish meal in shrimp feed (Yu *et al.*, 2016; Riche *et al.*, 2011; Liu *et al.*, 2012), while others have selected new shrimp varieties with low

fish meal protein requirement or high efficiency of feed protein by selective breeding (Jiang *et al.*, 2013). Selective breeding is one of the effective means to improve the important economic characters of aquatic animals, which has been widely used in the genetic improvement of fish and crustaceans (Moss *et al.*, 2001, 2010). Good results have been obtained in *Litopenaeus vannamei* by selective breeding, and new varieties with rapid growth, high density and resistance to Taura Syndrome Virus (TSV) have been obtained (Moss *et al.*, 2007, 2011; Argue *et al.*, 2002). The results also showed that there were genetic differences in growth (Huang *et al.*, 2009), feed utilization (Huang *et al.*, 2009), disease resistance (Wang *et al.*, 2011) and stress resistance (Sun *et al.*, 2011; Huang *et al.*, 2012) of *P. monodon* families, and the breeding of families was an effective way to obtain new *P. monodon* varieties.

Gong *et al.* (2012) have reported the effect of protein level and source in feed on the growth and survival of two selected strains of *L. vannamei*. The optimal protein

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content in the feed of *P. monodon* is about 30% ~ 50%, and the optimal protein demand of *P. monodon* cultured in seawater is about 40% (Miao *et al.*, 2001; Wang *et al.*, 1998). The rapid growth of new varieties of *P. monodon*, which are suitable for low fish meal protein feed culture, are selected by the method of family selection, in order to reduce the fish meal protein level in the feed, and save the cost of culture and increase the economic benefit, which will have a better application prospect. In this study, the growth and survival of *P. monodon* families were tested under different fish meal protein content feed culture, and the differences of growth and survival were evaluated under different feed diet conditions, in order to provide basic data for *P. monodon* to adapt to low fish meal protein level feed heritage breeding.

MATERIALS AND METHODS

Experimental materials

The experiment was carried out in the genetic and breeding center of *P. monodon* in the Ministry of Agriculture of the People's Republic of China. The *P. monodon* used in the experiment were selected as the core breeding family of the research group after several generations of continuous breeding. A total of 36 *P. monodon* families with similar spawning date were selected for the experiment. The average body weight of the experimental families was 1.96-2.06g.

Family construction

According to the mating plan, artificial insemination (Jiang *et al.*, 2013) was used to culture the *P. monodon* families. In order to reduce the impact of the environment in the process of family construction, standardized operating procedures were used during the cultivation of family seedlings. After artificial insemination, the female shrimps with mature gonads were put in a 500 L spawning bucket. After spawning, the female shrimps were transferred out of the spawning bucket, and the fertilized eggs were hatched at 30°C. After hatching the nauplii, each family randomly selected 10,000 nauplii and put them into a new 500 L incubation bucket for individual cultivation. During the process of metamorphosis, the larvae were fed costal algae (Guangdong Haid Group), shrimp chips and artemia. After the larvae metamorphosis to the 2nd day, a total of 2,000 shrimps were randomly selected from each family and were transferred into the new cultivation tank for independent cultivation. On the 10th day, a total of 500 shrimps were randomly selected from each family and transferred to a 3m³ tank for intermediate cultivation. After a period of time feeding, the uniform individuals were selected from each family with a length of more than

3 cm for fluorescent labeling (Jiang *et al.*, 2013), and then divided into groups according to the experimental design.

Table I. Composition and nutrient content of experimental diets.

Ingredients (%)	Diet A	Diet B
Fish meal	30	10
Soybean meal	18	18
Concentrated dephenolization cottonseed protein	0	20
Peanut meal	10	10
Wheat flour	21.99	17.1
Beer yeast	3	3
Shrimp head meals	5	5
Soybean protein concentrate	4.8	6.2
Soybean lecithin	1	1
Fish oil	1	1
Soybean oil	0.5	2.1
CAAscorbic phosphate ester	0.1	0.1
Cholesterol	0.5	0.5
Vitamin premix ^a	1	1
Mineral premix ^b	1	1
Ca(H ₂ PO ₄) ₂	1	1
Lysine	0	0.97
Methionine	0.1	0.47
Threonine	0	0.55
Carboxymethylcellulose	1	1
Y ₂ O ₃	0.01	0.01
Total	100	100
Proximate composition		
Moisture (%)	8.32	7.88
Crude protein (%)	39.65	39.29
Crude lipid (%)	5.70	6.09
Ash (%)	11.89	10.47

Note: (1) Vitamin premix (g·kg⁻¹): V_A 2.5; V_D 6.25; V_E 75; V_K 2.5; V_{B1} 0.25; V_{B2} 1.0; V_{B3} 5.0; V_{B6} 0.75; V_{B12} 2.5; folicacid 0.25; biotin 2.5; inositol 379; cellulose 500; (2) Mineral premix (g·kg⁻¹): KCl, 90; KI 0.04, NaCl, 40g; CuSO₄·5H₂O, 3; ZnSO₄·7H₂O, 4; CoSO₄·7H₂O, 0.02; FeSO₄·7H₂O, 20; MnSO₄·H₂O, 3; MgSO₄·7H₂O, 124; Ca(H₂PO₄)₂·2H₂O, 500; CaCO₃, 215.

Feed formula and preparation

Fishmeal, soybean meal, concentrated dephenolization cottonseed protein and peanut meal were used as the main protein sources, and the formula was designed according to the principle of equal energy and protein. Two kinds of diets (Table I) were prepared: Diet A (fishmeal content in

feed is 30%) and Diet B (fishmeal content in feed is 10%, concentrated dephenolized cottonseed protein content is 20%). All feed materials were crushed through 80 mesh sieve, mixed step by step, and then stirred with water to make 1.00 and 1.50 mm diameter pellet feed, baked in 90 °C oven (put some water in the oven) for 2 h, dried in the air-conditioned room, stored in - 20 °C refrigerator for standby.

Growth performance test under different feeds

A total of 36 families with similar incubation date were tested. The shrimps of each family were labeled by fluorescence and then mixed cultured in a 500 cm × 400 cm × 150 cm cement tank. Each feed group was set up with three parallel groups. A total of 150 shrimps in each family were randomly selected and each feed group was randomly allocated 50 shrimps.

Feeding management

Shrimps were feed 3 times a day at 8:00, 17:00 and 22:00. The daily feeding amount was 7 - 8% of the shrimp weight and the feeding amount was adjusted according to the weather and feeding conditions. The aquaculture water was sand filtered seawater. The water was changed 1/3 every week, and the test period was 56 days. During the experiment, the micro tube aerator was used for 24 h to aerate and increase oxygen. The water temperature was 27-32 °C, the salinity was 31-33 PPT, the pH was 7.8-8.2, and the dissolved oxygen was 6.6-7.0 mg / L during the whole test period.

Data collection

After the test, the body length and weight of each shrimp in each feed group were measured, and the fluorescent color of each shrimp was identified, and the survival number of each family was counted.

Data calculation and processing

Spss19.0 software was used to calculate the phenotypic parameters of growth and survival of *P. monodon* in different diet groups. ANOVA was used to analyze the weight traits. LSD method was used to compare the weight of different families. The significance test level was set to $P < 0.05$, and the test data was expressed by mean ± SD.

Calculation formula of AGR: $A (g/d) = (W_2 - W_1) / t$

In formula, A was the absolute weight gain rate, t was the test days, W_1 was the initial weight; W_2 was the harvested weight.

Survival calculation formula: $S(\%) = n/N \times 100$

In formula, S was the survival rate%, n was the survival mantissa and n was the initial mantissa.

RESULTS

Phenotypic parameters of growth traits of *P. monodon* in different feed groups

The phenotypic parameters of body length and body weight of each *P. monodon* family harvested in different feed groups are shown in Table II. In different feed groups, the variation coefficient of body length was larger than that of body weight, in which the variation coefficient of body length was 32.45 - 37.36%, and the variation coefficient of body weight was 22.71 - 22.84%. The variation coefficient of body length and body weight of test group in Diet B group was 22.71 - 22.84% and both of them were larger than that in Diet A group. The survival rate of *P. monodon* families in Diet A group and Diet B group were 76.52 - 85.91% and 51.20 - 86.34%, respectively, and the average survival rate of the Diet B group was lower than that of the Diet A group and the coefficient of variation of the Diet B group was higher than that of the Diet A group.

Table II. The phenotypic data of growth-related traits and survival rate of *P. monodon* in different diet groups.

Traits	Groups	Mini- mum	Maxi- mum	Aver- age	Standard deviation	Coefficient of variation (%)
Body length (mm)	Diet A	44.94	125.53	82.81	26.87	32.45
	Diet B	41.52	110.30	79.17	29.58	37.36
Body weight (g)	Diet A	3.23	18.34	13.08	2.97	22.71
	Diet B	2.96	16.22	11.21	2.56	22.84
Survival rate (%)	Diet A	72.51	86.52	80.59	10.21	12.67
	Diet B	70.68	84.65	77.88	10.20	13.10

Comparison of growth performance of *P. monodon* families in different feed groups

The results of one-way ANOVA of body weight of *P. monodon* families in different feed groups were shown in Table III. The difference of body weight at harvest time among families in different feed groups were significant ($P < 0.01$).

LSD multiple comparison results of the mean body weight at harvest in different feed groups of *P. monodon* were shown in Table IV, the AGR range of the Diet A group and the Diet B group were 0.14-0.28 and 0.13-0.27, respectively. The AGR of the families with the fastest weight gain in the Diet A group and the Diet B group was 100.00% and 107.69% higher than that of the families with the slowest weight gain. At the same significant level, the top 10% of the families were selected as fast-growing families, and No. 10 and No. 6 families performed well in two different feed groups.

Table III. ANOVA for body weight among families of *P. monodon* in different diet groups.

Groups	Source of variation	Degree	Sum of squares	Mean square	F	P
Diet A	Between families	1136.54	35	180.48	16.57	0.00
	Within families	4086.37	752	12.83		
	Total	5222.91	787			
Diet B	Between families	2049.24	35	98.54	10.84	0.00
	Within families	3567.94	638	8.97		
	Total	5617.18	673			

Survival of P. monodon families

The results of survival rate of *P. monodon* families in different feed groups are shown in Table V. The average survival rates of *P. monodon* families in the Diet A group and the Diet B group were 80.59 and 77.88%, respectively. The χ^2 test showed that there were no significant difference between the two diet groups ($P > 0.05$). The survival rates of the Diet A group and the Diet B group were 72.51 - 86.52% and 70.68 - 84.65%, respectively. In the same significant level, No. 14 and No. 10 families all performed well in two different feed groups.

Production performance of Penaeus monodon family

The yield of each family calculated by combining the body weight at harvest and the number of surviving tails is quite different. The highest yield of each family in the control group and the test group is 100% and 124.44% higher than the lowest, respectively (Table VI). No. 10 and No. 6 were in the top 10% in two different feed groups, and the two families performed better production performance.

DISCUSSION

As a traditional breeding method, selective breeding technology has been widely used in the study of animal and plant genetic improvement and has become one of the effective means of breeding new varieties and new strain (Lou, 2001). Family selection is an important means of selection and breeding (Li, 2007). Through the directional construction of families and the performance test under the common environment, and then the selection between families and within families, and the breeding according to the pedigree and the performance test results during the subculture, the effect of inbreeding controllable and sustainable breeding can be achieved. The technology of family selection and breeding has been applied in many aquatic animals and cultivated breeding a large number of good aquatic animals (Luo *et al.*, 2015; Chen *et al.*, 2008; Gao *et al.*, 2010; Zhang *et al.*, 2007, 2008) which has become one of the most important breeding methods.

Table IV. LSD multiple range test for comparisons of multi-average of harvest body weight in different diet groups.

Families no.	Diet A		Families no.	Diet B	
	Body weight (g)	Absolute growth rate (g·d ⁻¹)		Body weight (g)	Absolute growth rate (g·d ⁻¹)
10	16.68±3.25 ^a	0.28	6	15.93±2.56 ^a	0.27
22	16.35±4.15 ^a	0.28	10	15.90±3.14 ^a	0.27
6	16.05±2.16 ^a	0.27	36	14.26±2.58 ^{ab}	0.24
14	15.88±3.85 ^{ab}	0.27	4	13.68±2.36 ^b	0.23
5	15.63±4.56 ^{ab}	0.26	20	13.52±2.86 ^b	0.23
20	15.26±2.48 ^b	0.26	1	13.50±2.46 ^b	0.23
21	15.22±3.55 ^b	0.26	29	13.03±3.14 ^b	0.22
36	15.16±2.68 ^b	0.26	13	12.68±1.24 ^{bc}	0.21
24	14.69±4.56 ^{bc}	0.25	11	12.34±1.26 ^{bc}	0.21
1	14.63±2.18 ^{bc}	0.25	27	12.29±1.58 ^{bc}	0.2
25	14.60±2.36 ^{bc}	0.25	30	12.16±1.63 ^{bc}	0.2
3	14.35±3.14 ^{bc}	0.24	21	11.68±3.24 ^c	0.19
4	14.26±3.58 ^{bc}	0.24	24	11.66±2.36 ^c	0.19
29	14.19±4.51 ^c	0.24	17	11.52±2.38 ^c	0.19
27	14.03±3.25 ^c	0.24	9	11.34±2.44 ^c	0.19
28	13.56±3.68 ^{cd}	0.23	31	11.15±1.65 ^c	0.18
30	13.26±3.14 ^{cd}	0.22	32	11.06±3.47 ^{cd}	0.18
9	13.2±3.47 ^{cd}	0.22	35	10.92±4.02 ^{cd}	0.18
17	13.09±3.55 ^d	0.22	23	10.83±3.46 ^{cd}	0.18
13	12.89±3.55 ^{de}	0.21	19	10.53±3.84 ^{cd}	0.17
35	12.85±4.17 ^{de}	0.21	26	10.51±2.18 ^{cd}	0.17
31	12.65±3.57 ^{de}	0.21	16	10.35±2.22 ^{cd}	0.17
32	12.58±2.56 ^{de}	0.21	22	10.26±2.56 ^{cd}	0.17
26	12.42±1.44 ^{de}	0.21	8	10.21±2.94 ^d	0.17
11	12.39±1.88 ^{de}	0.21	12	10.13±3.04 ^d	0.17
16	11.38±1.64 ^e	0.19	7	10.11±3.09 ^d	0.17
7	11.26±2.54 ^e	0.19	5	10.05±2.74 ^d	0.16
23	11.14±3.01 ^e	0.18	3	9.69±2.76 ^{de}	0.16
8	10.95±2.59 ^{ef}	0.18	33	9.62±1.82 ^{de}	0.16
34	10.83±2.46 ^{ef}	0.18	28	9.56±1.92 ^{de}	0.16
19	10.65±2.88 ^{ef}	0.17	15	9.43±1.94 ^{de}	0.15
33	10.43±2.17 ^f	0.17	34	9.35±1.33 ^{de}	0.15
12	10.26±1.48 ^f	0.17	14	9.06±2.56 ^e	0.15
2	10.08±2.67 ^f	0.16	25	8.86±2.36 ^e	0.14
15	9.63±1.44 ^{fg}	0.16	18	8.33±3.41 ^f	0.13
18	8.46±2.68 ^g	0.14	2	8.15±3.76 ^{fg}	0.13

All values are presented as means±SD. Different superscript letters indicate significant differences among groups within each treatment.

Table V. Survival rate of family of *P. monodon* in different diet groups.

Families no.	Control group	Families no.	Test group
	Survival rate (%) \pm SD		Survival rate (%) \pm SD
32	86.52 \pm 8.65 ^a	34	84.65 \pm 9.23 ^a
6	85.36 \pm 8.21 ^a	10	84.62 \pm 8.15 ^a
14	84.95 \pm 7.65 ^a	14	84.53 \pm 12.63 ^a
3	84.82 \pm 7.16 ^a	24	83.51 \pm 10.25 ^a
10	84.76 \pm 9.25 ^a	25	82.56 \pm 14.62 ^{ab}
28	84.53 \pm 9.14 ^a	21	82.26 \pm 13.25 ^{ab}
26	84.25 \pm 12.34 ^a	6	81.63 \pm 8.31 ^b
18	83.62 \pm 10.69 ^{ab}	23	81.56 \pm 8.68 ^b
1	83.6 \pm 11.54 ^{ab}	19	80.65 \pm 9.56 ^b
29	83.43 \pm 8.26 ^{ab}	16	79.82 \pm 9.54 ^{bc}
30	84.41 \pm 7.16 ^{ab}	1	79.62 \pm 7.16 ^{bc}
35	84.25 \pm 8.36 ^{ab}	12	79.51 \pm 12.04 ^{bc}
8	84.13 \pm 9.14 ^{ab}	33	79.34 \pm 13.05 ^{bc}
2	83.24 \pm 13.58 ^{ab}	11	79.26 \pm 10.66 ^{bc}
21	82.51 \pm 12.41 ^b	28	78.62 \pm 8.14 ^c
25	82.36 \pm 8.03 ^b	3	78.53 \pm 9.39 ^c
34	81.92 \pm 13.24 ^b	27	78.51 \pm 7.25 ^c
24	81.62 \pm 10.52 ^b	7	78.26 \pm 8.48 ^c
16	80.92 \pm 9.24 ^{bc}	32	78.16 \pm 12.64 ^c
20	80.64 \pm 9.68 ^{bc}	9	78.05 \pm 10.34 ^c
33	80.62 \pm 7.26 ^{bc}	29	77.28 \pm 12.55 ^{cd}
4	79.65 \pm 13.57 ^{bc}	22	77.13 \pm 13.75 ^{cd}
17	79.51 \pm 12.45 ^{bc}	20	76.25 \pm 12.47 ^d
27	78.62 \pm 10.35 ^c	13	76.21 \pm 6.74 ^d
13	77.92 \pm 13.25 ^c	17	76.15 \pm 8.25 ^d
19	77.65 \pm 12.46 ^c	30	76.06 \pm 9.43 ^d
22	77.3 \pm 9.35 ^c	36	75.62 \pm 10.46 ^{de}
15	76.56 \pm 8.16 ^{cd}	18	75.26 \pm 12.47 ^{de}
12	76.41 \pm 12.54 ^{cd}	4	74.23 \pm 10.55 ^e
31	76.32 \pm 13.51 ^{cd}	15	73.69 \pm 10.63 ^f
23	76.28 \pm 8.16 ^{cd}	2	73.25 \pm 12.74 ^f
11	75.62 \pm 13.02 ^d	5	72.46 \pm 8.55 ^{fg}
36	75.34 \pm 10.26 ^d	35	72.16 \pm 7.96 ^{fg}
5	74.68 \pm 11.28 ^e	8	71.96 \pm 9.55 ^g
7	74.25 \pm 8.64 ^e	31	71.53 \pm 9.11 ^g
9	72.51 \pm 9.18 ^f	26	70.68 \pm 8.64 ^h
Average	80.59	Average	77.88

All values are presented as means \pm SD. Different superscript letters indicate significant differences among groups within each treatment.

Table VI. Family production of *P. monodon* in different diet groups.

Families no.	Control group			Families no.	Test group		
	Body weight (g)	Survival number	Family production		Body weight	Survival number	Family production
10	16.68	127	2.12	10	15.90	127	2.02
6	16.05	128	2.06	6	15.93	122	1.95
14	15.88	127	2.02	36	14.26	113	1.62
22	16.35	116	1.9	1	13.50	119	1.61
21	15.22	124	1.88	20	13.52	114	1.55
20	15.26	121	1.85	4	13.68	111	1.52
1	14.63	125	1.83	29	13.03	116	1.51
3	14.35	127	1.83	11	12.34	119	1.47
25	14.60	124	1.8	24	11.66	125	1.46
24	14.69	122	1.8	13	12.68	114	1.45
29	14.19	125	1.78	27	12.29	118	1.45
5	15.63	112	1.75	21	11.68	123	1.44
28	13.56	127	1.72	30	12.16	114	1.39
36	15.16	113	1.71	9	11.34	117	1.33
4	14.26	119	1.7	23	10.83	122	1.32
30	13.26	127	1.68	17	11.52	114	1.32
27	13.09	118	1.65	32	11.06	117	1.3
32	12.58	130	1.63	19	10.53	121	1.27
35	12.85	126	1.62	16	10.35	120	1.24
26	12.42	126	1.57	12	10.13	119	1.21
17	13.09	119	1.56	31	11.15	107	1.2
13	12.89	117	1.51	34	9.53	127	1.19
31	12.65	114	1.45	22	10.26	116	1.19
9	13.20	109	1.44	7	10.11	117	1.19
11	12.39	113	1.41	35	10.92	108	1.18
8	10.95	126	1.38	14	9.06	127	1.15
16	11.38	121	1.38	33	9.62	119	1.14
34	10.83	123	1.33	3	9.69	118	1.14
23	11.14	114	1.27	28	9.56	118	1.13
33	10.43	121	1.26	26	10.51	106	1.11
2	10.08	125	1.26	8	10.21	108	1.1
7	11.26	111	1.25	25	8.86	124	1.1
19	10.65	116	1.24	5	10.05	109	1.09
12	10.26	115	1.18	15	9.43	111	1.04
15	9.63	115	1.11	18	8.33	113	0.94
18	8.46	125	1.06	2	8.15	110	0.9

All aquatic animals have a certain range of adaptation to the protein content in the diet. They can survive and grow normally within the appropriate range of protein content. If the protein content in the feed is too high or too low, it will affect the survival rate and normal growth of aquatic animals (Paripatananont *et al.*, 2015). *P. monodon* is a kind of omnivorous aquatic organism. Under the condition of artificial culture, the protein content in feed is generally 30%-50% (Jiang *et al.*, 2013). However, the growth rate and survival rate of *P. monodon* fed with different protein content are quite different (Jiang *et al.*, 2013). In this experiment, there are significant differences in the growth of different *P. monodon* families when they are fed the same feed, and there are very significant differences among individual families, which is consistent with the previous research results on *P. monodon* (Jiang *et al.*, 2013) and *Penaeus chinensis* (Zhang *et al.*, 2007), and there were significant differences in the growth of different families of *P. chinensis* in the development period. This shows that there are differences in gene level among different families of *P. monodon*, therefore, the different families are good breeding materials.

The level of fish meal in feed will affect the growth performance and feed utilization of the shrimp (Zhang *et al.*, 2013; Lim *et al.*, 1990). Zhang *et al.* (2013) replaced 6% of the fish meal with the mixed plant protein composed of soybean protein concentrate and peanut bran, so that the growth and feed coefficient of *P. monodon* were not significantly affected after the fish meal level was reduced from 30% to 24%, with the declining of the fish meal level, the growth and feed coefficient of *P. monodon* were significantly affected. Alvarez *et al.* (1997) used soybean meal instead of 7% of fish meal to reduce the level of fish meal from 29% to 22%, the growth and feed coefficient of *P. vannamei* were not affected. Similarly, Lim *et al.* (1990) used soybean meal instead of 10.7% of fish meal to reduce the fish meal level from 32% to 21.3%, which did not affect the growth, feed coefficient and protein efficiency of *P. vannamei*, but with the increase of substitution level, the fish meal level decreased and the weight gain rate decreased significantly. In this study, 36 families in the same diet group had different growth and survival performance and the absolute growth rate of the fastest growing families was 97.16% and 95.46% higher than that of the slowest growing families in two diet groups. The difference of growth and survival between families in the same diet group may be caused by the genetic difference of families. By carrying out family selection and breeding according to the feed, families with good growth and survival characteristics can be better obtained. The growth and survival performance of the same *P. monodon* family fed with different diets were not the same and the growth

rate of family No.22 was the 2nd in Diet A, but the growth rate is 23rd in Diet B. The growth rate and survival rate of family No.10 were both in the top 10 in two diet groups, which had the characteristics of good adaptability to feed with low protein level. Through the test and selection of large-scale families fed with different feeds, a group of families with wide adaptability to protein level can be obtained, which can lay a good foundation for further breeding.

According to the results of the yield index of each family, the yield of each family was still quite different. The yield order of each family in each feed group was not the same. The yield of family No.10 and family No.6 were in the top three of the two diet groups. Family yield could be used as an index to evaluate the production performance of *P. monodon* fed with different diets. Families adapted to low fish meal protein level diet performed certain advantages in growth rate and survival rate in the breeding process and showed good production performance.

CONCLUSION

In this study, *P. monodon* families were established by artificial insemination and seedling standardized cultivation. The growth, survival and production performance of different families in different diet groups were compared and analyzed. The results showed that the growth and survival characteristics of *P. monodon* families were quite different and had the potential for further genetic improvement. The results of this study could be used for the next step of feeding *P. monodon* at low fish meal protein level the breeding of new material varieties laid the foundation.

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Statement of conflict of interest

The authors have declared no conflict of interests.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

REFERENCES

- Alvarez, J.S., Hernández-Iñamas, A., Galindo, J., Fraga, L., García, T. and Villarreal, H., 1997. Substitution of fishmeal with soybean meal in practical diets for juvenile white shrimp *Litopenaeus schmitti*. *Aquacult. Res.*, **38**: 689–695. <https://doi.org/10.1111/j.1365-2109.2007.01654.x>
- Argue, J., Arce, M., Lotz, M. and Moss, M., 2002. Selective breeding of Pacific white shrimp (*Litopenaeus vannamei*) for growth and resistance to Taura syndrome virus. *Aquaculture*, **204**: 447–460. [https://doi.org/10.1016/S0044-8486\(01\)00830-4](https://doi.org/10.1016/S0044-8486(01)00830-4)
- Benzie, H., 1997. A review of the genetics and environment on the maturation and larval quality of the giant prawn *Penaeus monodon*. *Aquaculture*, **155**: 69–85. <http://linkinghub.elsevier.com/retrieve/pii/S0044848697001105>. [https://doi.org/10.1016/S0044-8486\(97\)00110-5](https://doi.org/10.1016/S0044-8486(97)00110-5)
- Chen, S.L., Tian, Y.S., Xu, T.J., Deng, H., Liu, S.T., Liu, B.W., Ji, X.S. and Yu, G.C., 2008. Development and characterization for growth rate and disease resistance of disease-resistance population and family in Japanese flounder *Paralichthys olivaceus*. *J. Fish. China*, **32**: 665–673.
- Gao, B.Q., Liu, P., Li, J., Dai, F.Y. and Wang, X.Z., 2010. Growth comparison between families of *Portunus trituberculatus*. *Period. Ocean Univ. China*, **40**: 47–51.
- Gong, H., Jiang, D.H., Alig, F. and Lawrence, A.L., 2012. Effects of dietary protein level and source on the growth and survival of two genetic lines of specific-pathogen-free Pacific white shrimp, *Penaeus vannamei*. *Aquaculture*, **338**: 118–123. <https://doi.org/10.1016/j.aquaculture.2012.01.030>
- Huang, J.H., Li, Y., Yang, Q.B., Su, T.F., Zhu, C.Y. and Jiang, S.G., 2012. Comparison of tolerance to ammonia-N in *Penaeus monodon* families. *South China Fish. Sci.*, **8**: 37–43.
- Huang, Z., Lin, H.Z., Huang, J.H., Yang, Q.B., Wen, W.G., Chen, X., Zhou, F.L. and Jiang, S.G., 2009. Growth, feed utilization and whole-body composition of six *Penaeus monodon* families. *South China Fish. Sci.*, **5**: 42–47.
- Jiang, S., Huang, J.H., Lin, H.Z., Yang, Q.B., Zhou, F.L., Qiu, L.H., Su, T.F. and Jiang, S.G., 2013. Effects of dietary protein levels on the growth and survival of *Penaeus monodon* from different families. *J. Shanghai Ocean Univ.*, **22**: 349–356.
- Leelatanawit, R., Uawisetwathana, U., Klanchui, A., Khudet, J., Phomklad, S., Wongtriphop, S., Jiravanichpaisal, P. and Karoonuthaisiri, N., 2017. Transcriptomic analysis of male black tiger shrimp (*Penaeus monodon*) after polychaete feeding to enhance testicular maturation. *Mar. Biotechnol.*, **19**: 125–135. <https://doi.org/10.1007/s10126-017-9738-8>
- Liang, X.F., Hu, L. and Dong, Y.C., 2017. Substitution of fish meal by fermented soybean meal affects the growth performance and flesh quality of Japanese seabass (*Lateolabrax japonicus*). *Anim. Feed Sci. Tech.*, **229**: 1–12. <https://doi.org/10.1016/j.anifeedsci.2017.03.006>
- Lim, C. and Dominy, W., 1990. Evaluation of soybean meal as a replacement for marine animal protein in diets for shrimp (*Penaeus vannamei*). *Aquaculture*, **87**: 53–63. [https://doi.org/10.1016/0044-8486\(90\)90210-E](https://doi.org/10.1016/0044-8486(90)90210-E)
- Liu, X.H., Ye, J.D., Wang, K., Kong, J.H., Yang, W. and Zhou, L., 2012. Partial replacement of fish meal with peanut meal in practical diets for the Pacific white shrimp, *Litopenaeus vannamei*. *Aquacult. Res.*, **43**: 745–755. <https://doi.org/10.1111/j.1365-2109.2011.02883.x>
- Li, Y.F., 2007. Application of family selection in aquatic animals. *J. Beijing Fish.*, **5**: 44–46.
- Lou, Y.D., 2001. *Fish breeding*. Chinese Agricultural Press, Beijing, pp. 102–106.
- Luo, K., Xia, Y.T., Wang, B., Kong, J., Su, X.X., Xu, S.J. and Zhang, D.H., 2015. Construction and comparison in growth performance among different families of *Acipenser gueldenstaedtii*. *Oceanol. Limnol. Sin.*, **46**: 464–469.
- Miao, Y.T., Wang, W.N., Wang, A.L. and Hu, J.R., 2001. Research progress on nutritional requirements of *Penaeus monodon*. *Fish. Sci. Technol. Inf.*, **28**: 207–209.
- Moss, M., Arce, M., Argue, J. and Otoshiet, A., 2001. Greening of the blue revolution: Efforts toward environmentally responsible shrimp culture. *World Aquacult. Soc.*, **25**: 1–19.
- Moss, R., Arce, M., Otoshiet, A., Doyle, W. and Moss, M., 2007. Effects of inbreeding on survival and growth of Pacific white shrimp *Litopenaeus vannamei*. *Aquaculture*, **27**: 30–37. <https://doi.org/10.1016/j.aquaculture.2007.08.014>
- Moss, R., Arce, M., Otoshiet, A. and Moss, M., 2011. Shrimp breeding for resistance to Taura syndrome virus. *Glob. Aquacult. Advocate*, **36**: 40–41.
- Moss, M., Moss, R. and Otoshiet, A., 2011. An integrated approach to sustainable shrimp farming. *Asian Fish. Sci.*, **23**: 591–605.
- Paripatananont, T., Boonyaratpalin, M., Pengseng, P. and Chotipuntu, P., 2015. Substitution of soy protein

- concentrate for fishmeal in diets of tiger shrimp *Penaeus monodon*. *Aquacult. Res.*, **32**: 369-374. <https://doi.org/10.1046/j.1355-557x.2001.00045.x>
- Riche, M. and Williams, T.N., 2011. Fish meal replacement with solvent-extracted soybean meal or soy protein isolate in a practical diet formulation for Florida pompano (*Trachinotus carolinus*, L.) reared in low salinity. *Aquacult. Nutr.*, **17**: 368-379. <https://doi.org/10.1111/j.1365-2095.2010.00808.x>
- Sun, M.M., Huang, J.H., Yang, Q.B., Zhou, F.L., Wen, W.G., Chen, X. and Jiang, S.G., 2011. Comparison on characteristics on growth and resistance to ammonia among 13 families of *Penaeus monodon*. *J. Shanghai Ocean Univ.*, **20**: 510-516.
- Wang, H.W., Wang, A.L. and Wang, L.N., 1998. Oversea research on nutrition of *Penaeus monodon*. *J. Hebei Univ.*, **18**: 98-104.
- Wang, Z.W., Huang, J.H., Yang, Q.B., Zhou, F.L., Zhu, C.Y., Yang, L.S., Qiu, L.H. and Jiang, S.G., 2011. Analysis on growth and white spot syndrome virus (WSSV) resistance of 15 *Penaeus monodon* families. *Adv. Mar. Sci.*, **29**: 521-528.
- Yu, Y.Y., Chen, W.D., Liu, Y.J., Niu, J., Chen, M. and Tian, L.X., 2016. Effect of different dietary levels of *Gracilaria lemaneiformis* dry power on growth performance, haematological parameters and intestinal structure of juvenile Pacific white shrimp (*Litopenaeus vannamei*). *Aquaculture*, **450**: 356-362. <https://doi.org/10.1016/j.aquaculture.2015.07.037>
- Zhang, C.S., Yang, X.G., Song, J., Jiang, S.G. and Yin, X.X., 2008. Establishment of families and their early growth of Japanese scallop (*Patinopecten yessoensis*). *South China Fish. Sci.*, **4**: 44-50.
- Zhang, C.X., Rahimnejad, S., Wang, Y.R., Lu, K.L., Song, K., Wang, L. and Mai, K.S., 2018. Substituting fish meal with soybean meal in diets for Japanese seabass (*Lateolabrax japonicus*): Effects on growth, digestive enzymes activity, gut histology, and expression of gut inflammatory and transporter genes. *Aquaculture*, **483**: 173-182. <https://doi.org/10.1016/j.aquaculture.2017.10.029>
- Zhang, J.R., Lin, H.Z., Huang, Z., Niu, J., Zhou, F.L., Chen, X., Wang, Y. and Xia, D.M., 2013. Effects of plant protein supplemented with amino acids on growth and non-specific immunity of *Penaeus monodon*. *South China Fish. Sci.*, **9**: 44-50.
- Zhang, T.S., Kong, J., Liu, P., Wang, Q.Y. and Zhang, Q.W., 2007. Preliminary study of establishment of families and their growth and development for *Fenneropenaeus chinensis*. *Acta Oceanol. Sin.*, **29**: 120-124.