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蛋白質與能量間之關係對海水飼育草蝦之影響

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Effects of Dietary Protein and Energy on Growth Performance of Tiger Shrimp *Penaeus monodon* Reared in Seawater

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ABSTRACT

A feeding trial was conducted to determine the optimum protein: energy (P/E) ratio for tiger shrimp *Penaeus monodon* under seawater rearing conditions. Two dietary protein levels, 40 and 36% and six energy levels, 280, 300, 320, 340, 360, and 380 kcal/100 g diet at each protein level, were employed. Carbohydrate (dextrin) was used to adjust the dietary energy level. After an initial 8 week conditioning period, the experimental diets were fed for 8 weeks to triplicate groups of 10 shrimp having average weights of 0.82±0.10 g stocked in aquarium of which salinity was maintained at 32-34 ppt. The weight gain, feed conversion ratio (FCR), and protein gain of shrimp improved as dietary energy level was raised up to around 330 kcal/100 g when 36% protein diet was fed and up to around 320 kcal/100 g when 40% protein diet was fed, respectively. Further elevation in dietary energy content had no beneficial effect in either protein level. These data suggest that when the energy level of the diet increased to 330 kcal/100 g, the dietary protein level for tiger shrimp reared in seawater can be lowered from 40 to 36%.

INTRODUCTION

In a previous study, we demonstrated that tiger shrimp *Penaeus monodon* required 40% protein level producing maximum growth when reared in seawater[1]. Protein is the largest part of the cost of prepared feeds. If insufficient non-protein energy is available (excess amount of protein in relation to the amount of energy), the excess protein is not used for growth but as an energy source[2,3]. Several studies have shown that an adequate energy supply with dietary lipid can minimize the use of more costly protein as an energy source[4,5]. whereas excess energy may reduce feed consumption and thus reduce total protein intake[3,7-10].

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Therefore, it is critical to obtain the proper protein energy (P/E) ratio in a diet for the most economical production of shrimp. Reduction of excess protein in the diet will also reduce the amount of ammonia being excreted by the shrimp.

In Taiwan, *P. monodon* is cultured in brackish water (around 16 ppt salinity) pond. However, due to recent increased conflict over the use of limited freshwater for aquaculture, the importance of seawater rearing practices for aquatic species including *P. monodon* has emerged.

This study was designed to determine the optimum protein to energy ratio (P/E) for tiger shrimp reared in seawater when dietary protein is optimum (40%)[1)] and suboptimum(36%).

MATERIALS AND METHODS

Thirty six glass aquaria (45×60×60cm-H× L × W) were used in this feeding trial. Three rows of wooden stand with three layers were constructed to contain the glass aquarium. Eacth aquarium was provided with continuous aeration by an air stone connected to an air pump. Two thirds of the water in the aquaria was exchanged every week to remove impurities and maintain the water quality. The dissolved oxygen level was checked every week and was kept at least 7.0 ppm throughout the experimental period. Water temperature ranged from 26 to 29°C, salinity was ranged from 32 to 34 ppt. Photoperiod was kept on a 12 h light/dark (08: 00-20: 00) cycle.

P. monodon juveniles obtained from a commerical propagation company were acclimated to laboratory conditions for two months in a plastic tank (74×95×45cm-W×L ×H). During this period, shrimp received a commercial diet. At the beginning of the experiment, 36 glass aquaria were each stocked with 18 shrimp with an average individual weight of 0.82 ±0.10 g.

Two dietary protein levels, 40 and 36 %, were used in the study. For each protein level, six energy contents of 280, 300, 320, 340, 360, and 380 kcal/100 g diet were included to formulate 12 experimental diets. Each diet was fed to triplicate groups. The composition of the experimental diets and the proximate analysis of these diets are shown in Tablel 1 and 2, respectively. The moisture, crude protein, ether extract, ash, and fiber were determined by standard AOAC methods[11)]. Energy levels were adjusted by varying the ratio of carbohydrate to cellulose in the diets. The physiological values used for calculation of the energy level were 5 kcal/g protein, 9 kcal/g lipid, and 4 kcal/g carbohydrate.

The diets were prepared and handed as previously described[1)]. The shrimp were fed twice daily (half of the ration at 10: 00-11: 00 and the other half at 17: 00-18: 00) at a rate of 8% of the body wight per day. Each morning, before feeding, feces and other detritus in each aquarium were siphoned out and mortality was recorded. Whenever the shrimp were

Table 1. Composition of experimental diets

Ingredients	36 % Protein						40 % Protein					
	1	2	3	4	5	6	7	8	9	10	11	12
Casein	22.37	22.37	22.37	22.37	22.37	22.37	27.00	27.00	27.00	27.00	27.00	27.00
Dextrin	5.00	10.00	15.00	20.00	25.00	30.00	0.00	5.00	10.00	15.00	20.00	25.00
Cellulose	25.75	20.75	15.75	10.75	5.75	0.75	26.12	21.12	16.12	11.12	6.12	1.12
Common ingredients*1	46.88	46.88	46.88	46.88	46.88	46.88	46.88	46.88	46.88	46.88	46.88	46.88
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Energy*2 (kcal/100g)	280.00	300.00	320.00	340.00	360.00	380.00	280.00	300.00	320.00	340.00	360.00	380.00
P/E ratio (mg/kcal)	128.50	120.00	112.50	105.80	100.00	94.70	142.80	133.30	125.00	117.60	111.10	105.20

*1 Soybean meal, 5.00; fish meal 10.00; shrimp meal, 10.00; squid meal, 10.00; cod liver oil, 0.79; corn oil, 4.09; cholesterol, 0.50; vitamin mixture*3, 2.00; mineral mixtrue*3, 2.00; carboxymethylcelluose (CMC), 2.00; chromic oxide, 0.50.

*2 Metabolizable energy (kcal/g) was calculated based on protein, 5 kcal/g; fat, 9 kcal/g; carbohydrate, 4 kcal/g.

*3 Vitamin mixture and mineral mixture, according to Alava and Pascual[24].

Table 2. Proximate analysis of experimental diets

Ingredients	36 % Protein						40 % Protein					
	1	2	3	4	5	6	7	8	9	10	11	12
Moisture	18.83	11.25	11.96	12.09	12.46	12.49	11.77	10.57	12.52	11.70	12.55	13.82
Protein	36.01	36.10	35.84	35.54	36.31	36.44	39.73	39.73	39.15	39.73	39.53	39.76
Ether extract	8.75	8.68	8.91	8.87	8.81	8.83	8.73	8.80	8.71	8.93	8.79	8.84
Ash	9.46	10.03	9.59	9.47	9.66	9.74	10.51	10.45	10.45	10.73	10.36	10.01
Crude fiber	21.48	18.25	14.68	10.86	7.74	3.95	22.16	18.45	14.96	11.67	8.11	4.47
N-free extract	11.46	15.69	19.02	23.17	25.02	28.54	7.09	12.00	14.04	17.25	20.66	23.10
CME*	304.64	321.38	335.47	350.20	360.92	375.83	305.58	325.85	330.30	348.02	359.40	370.76
P/E ratio	118.21	112..33	106.84	101.48	100.60	96.96	130.02	121.93	118.53	114.16	109.99	107.24

* CME: Calculated metabolizable energy (kcal/100g diet).

removed for weighing, the aquaria and the air stone were cleaned thoroughly. Water temperature and salinity readings were taken daily before the shrimp were fed.

The shrimp were fed test diets for 8 weeks and the weight gain (%), feed conversion ratio (FCR), protein efficiency ratio (PER), and protein gain were calculated as previously described[1]. The apparent protein digestibility was determined using diets containing 0.5% chromic oxide as indicator[10]. To determine diet digestibilities, feces were collcted from the water and those of each dietary group were pooled. The fecal material was freeze-dried and ashed at 550°C. A sample of the ashed material was used for chromium analysis[12]. The digestibility was also calculated as described previously[1]. All data were analyzed using analysis of variance (SPSS/PC program). Multiple comparisons among means were made with Duncan New Multiple Range Test[13].

RESULTS AND DISCUSSION

The characteristics of general performance in different dietary protein groups are presented in Table 3. They seemed to improve as the dietary energy level was raised until

Table 3. The effect of protein and energy levels on weight gain (%), feed conversion ratio (FCR), protein efficiency ratio (PER), and protein gain (g) of shrimp*[1,2]

Diet code	Energy (kcal/100g)	P/E ratio (mg/kcal)	Weight gain (%)	FCR	PER	Protein gain
36%Protein						
1	280	128.5	272.39±18.36^{bc}	2.79±0.11^{ab}	0.86±0.66^{ab}	0.33±0.02^{bc}
2	300	120.0	291.01±20.62^{a}	2.60±0.18^{b}	0.91±0.10^{ab}	0.35±0.03^{b}
3	320	112.5	296.99± 3.32^{b}	2.83±0.03^{ab}	0.87±0.04^{b}	0.34±0.01^{bc}
4	340	105.8	375.99±28.22^{a}	2.30±0.01^{c}	1.06±0.01^{a}	0.47±0.04^{a}
5	360	100.0	291.73±36.19^{b}	2.52±0.30^{ab}	1.00±0.13^{a}	0.39±0.04^{b}
6	380	94.7	248.69± 9.85^{c}	3.18±0.20^{a}	0.78±0.05^{b}	0.29±0.02^{c}
40%Protein						
7	280	142.8	262.45±55.21^{bc}	2.83±0.43^{ab}	0.90±0.28^{ab}	0.39±0.08^{b}
8	300	133.3	296.52±39.16^{b}	2.80±0.33^{ab}	0.90±0.11^{ab}	0.40±0.06^{ab}
9	320	125.0	382.38±14.85^{a}	2.41±0.15^{c}	1.00±0.10^{a}	0.47±0.02^{a}
10	340	117.6	264.16±50.87^{bc}	3.12±0.16^{a}	0.76±0.08^{b}	0.36±0.07^{b}
11	360	111.1	254.62±25.72^{c}	3.18±0.10^{a}	0.70±0.03^{b}	0.31±0.03^{bc}
12	380	105.2	206.07±25.32^{cb}	3.22±0.55^{a}	0.62±0.06^{bc}	0.26±0.03^{c}

*1 Mean ± S.D.
*2 Figures in the same column having the same superscript are not significantly different *(p>0.05)*.

Table 4. The effect of protein and energy levels on the apparent digestibility (%) of protein and survival rate of shrimp

Diet code	Energy (kcal/100g)	P/E ratio (mg/kcal)	Protein digestibility	Survival rate (%)
36%Protein				
1	280	128.5	98.14±0.52ª	68.33±12.58ª
2	300	120.0	98.28±0.02ª	63.33± 2.89ª
3	320	112.5	98.00±0.21ª	70.00±10.00ª
4	340	105.8	98.06±0.05ª	70.00± 8.66ª
5	360	100.0	97.33±0.64ª	68.33± 2.89ª
6	380	94.7	97.49±0.20ª	65.00± 5.00ª
40%Protein				
7	280	142.8	98.79±0.17ª	61.67±10.41ª
8	300	133.3	98.59±0.36ª	71.67± 7.64ª
9	320	125.0	98.60±0.19ª	66.67± 2.89ª
10	340	117.6	98.53±0.26ª	71.67± 7.64ª
11	360	111.1	98.39±0.19ª	66.67±10.41ª
12	380	105.2	98.17±0.28ª	65.00± 8.66ª

*1,2 Same as Table 3.

reaching a plateau, and declined thereafter. In 36% protein diet groups, the shrimp fed a diet containing energy of 340 kcal/l00g showed significantly higher ($p \leqq 0.05$) weight gain, FCR, and protein gain than those of the remaining groups. PER also showed a similar pattern. In 40% protein diet groups, the shrimp fed diet containing energy of 320 kcal/100 g achieved the best performance. The protein digestibility and survival rate was not affected ($p \geqq 0.05$) by various level of P/E ratio in the diet as shown in Table 4.

The relationship between growth and dietary energy level of the present study is best expressed statistically by a second order curve (polynomial quadratic equation) [18]. When the growth rate (Fig. 1) and protein gain (Fig. 2) were plotted against the dietary energy level, a growth peak was reached when dietary energy level was around 320 kcal/100g in the 40% protein diet. Whereas, in the 36% protein diet, a peak was reached when the energy level was around 330 kcal/100g. Figures of 324% (weight gain) and 0.42g (protein gain) and 330% (weight gain) and 0.41g (protein gain) were obtained in the 40% and 36% protein diet, respectively. When the FCR was plotted against the dietary energy level (Fig 3), the best FCR value was reached when the dietary energy level was around 310 kcal/100 g in the 40% protein diet. Whereas, in the 36% protein diet, the best FCR was reached when the energy level was around 327 kcal/ 100g. Figures of 2.72 and 2.47 were obtained in the 40 and 36% protein diet, respectively.

Utilization of lipid in shrimp seem to be low. Many workers have shown that when shrimp were fed lipid higher than the normal amount they can tolerate lipids may accumulate rapidly. Thus, the dietary lipid would not provide th energy value as it should be and this would in turn cause an imbalance in the P/E ratio. This could adversely affect normal metabolic function and result in decreased growth or death of the shrimp. Increased fat in the hepatopancreas is synonymous with the "fatty liver" condition associated with nutritional deficiencies of animals[14]. Andrews et al[15]. reported that the addition of 10% supplemental lipid had an adverse effect on growth and survival. Forster and Beard[16] also showed that 15% lipid was detrimental to the growth of *Palaemon serratus*. Deshimaru and Kuroki[17] reported that improvements in the growth of *Penaeus japonicus* with the inclusion of polluck liver oil up to 6% of the diet, but inhibition occurred at the 12% level. In the present study, the lipid content was kept below 10% in each experimental diet (Table 1) and dextrin was used to adjust the energy level of each diet.

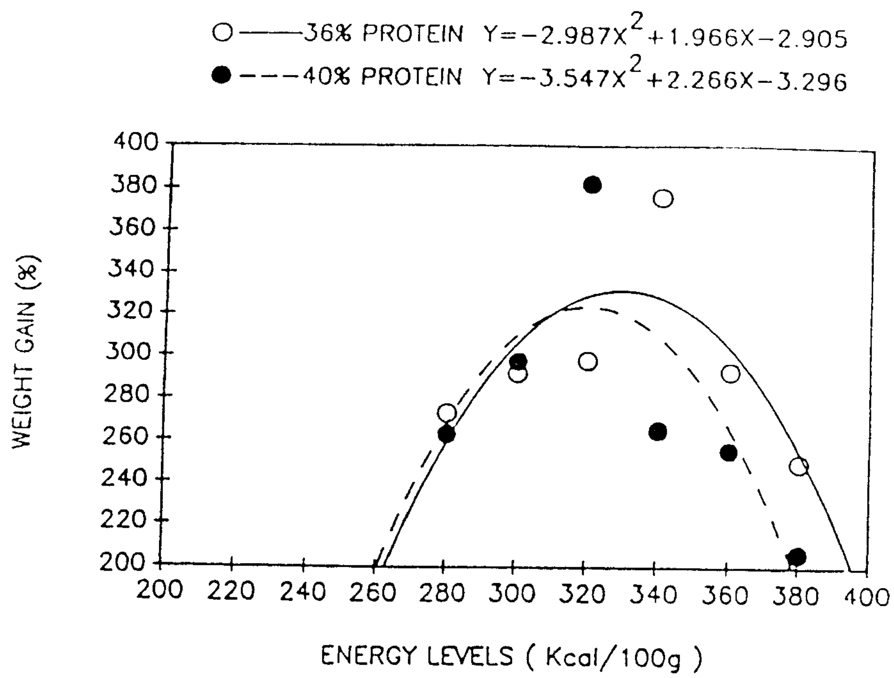

Fig. 1. Weight gain (%) of *P. monodon* fed diets containing various levels of protein and energy.

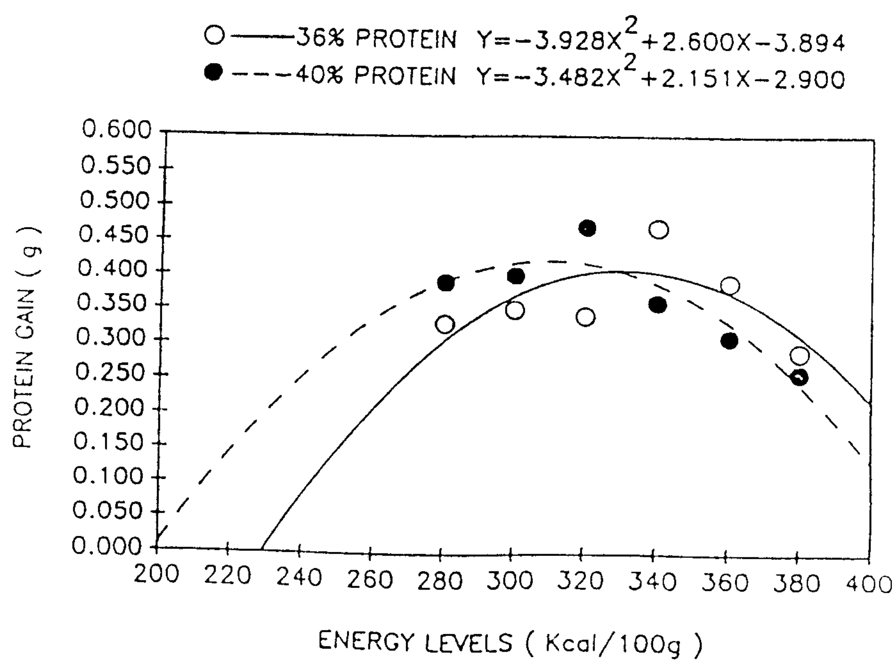

Fig. 2. Protein gain (g) of *P. monodon* fed diets containing various levels of protein and energy.

Carbohydrate is the most economical energy source. There is little information for the carbohydrate nutrition of shrimp[19,20]. The type and level of carbohydrate in the diet havebeen shown to affect tile growth of *P. japonicus*[21,22], and *P. aztecus*[15]. For *P. monodon*, Pascual *et* al. [23], observed significant difference between the type and level of carbohydrate in the diet on the survival of juveniles. Alava and Pascual [24] indicated that *P. monodon* utilized trehalose and surcose better than glucose.

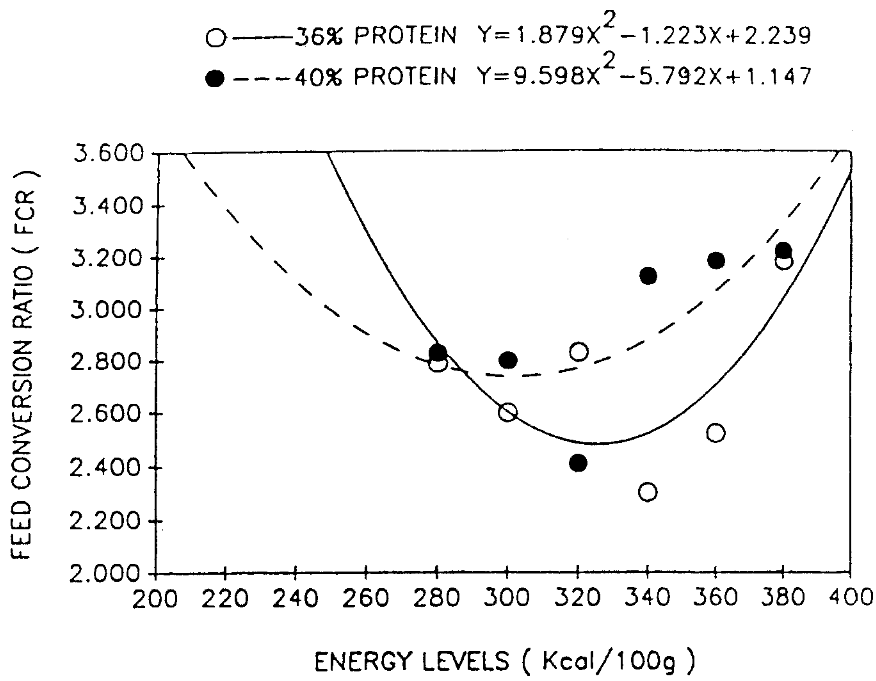

Fig. 3. Feed conversion ratio of *P. monodon* fed diets containing various levels of protein and energy.

Bautista[25] has reported that the protein content of the diet could be reduced from 50 to 40 % while maintaining an energy level of 330 kcal/ 100 g diet. In his study, sucrose was used to adjust the dietary energy level. From the results in our study, the non-significant change in growth, FCR and protein gain shrimp reared in seawater despite reduction in dietary protein content from 40 to 36% while maintaining energy level of around 330 kcal/100 g, suggests that protein may be spared by carbohydrate (dextrin) as long as the caloric requirements are met, thus permitting more efficient utlization of protein.

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蛋白質與能量間之關係對海水飼育草蝦之影響

蕭錫延・周本善

摘　　要

為測定海水養殖草蝦之適當蛋白質與能量比，以兩組蛋白質含量；40% 及36% ，每組蛋白質含量分別給予六組能量含量；280, 300, 320, 340, 360, 380 仟卡/100克飼料。飼料中以碳水化合物(糊精)調整飼料的能量。餵飼經過八週馴養後之草蝦，實驗於水族缸中進行八週，每缸十尾蝦，三重覆，平均體重為0.82±0.10g，鹽度為32-34 ppt。結果顯示：當餵以36% 蛋白質之飼料其能量提高至330 仟卡/100克飼料 及餵以40% 蛋白質之飼料能量為320 仟卡/100克飼料時，蝦體之增重百分率、飼料轉換率、及蛋白質效益可獲得改善。而不論蛋白質為36% 或40% ，其飼料中能量再提高並無更多的助益。此結果建議飼養於海水的草蝦，當其飼料能量提高至330 仟卡/100克飼料 時，則飼料中的蛋白質比例可從40% 降至36% ，而不影響草蝦之成長。