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# Least-Cost Feed Formulation for Juvenile *Macrobrachium rosenbergii* (De Man) by Using the Linear Programming Technique

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## ABSTRAK

*Pemprograman kos-terkecil linear telah digunakan ke atas juvana* M. rosenbergii *untuk merumuskan satu formula makanan dengan menggunakan bahan-bahan asli (hampas ikan, hampas udang, kelapa kering, hampas kacang soya, tepung gandum dan minyak kelapa sawit). Berikut adalah kriteria yang digunakan: Kandungan asid amino perlu adalah hampir sama dengan kandungan asid amino perlu dalam juvana* M. rosenbergii, *lemak kasar 5-10% dan tenaga kasar 4,400 cal/g dengan kos yang minimum. Empat jenis makanan dihasilkan dengan julat protein di antara 25% hingga 50%. Tindakbalas kadar pertumbuhan juvana* M. rosenbergii *ke atas makanan yang dirumus ini, menunjukkan bahawa makanan yang mempunyai 40% kandungan protein (P40) memberikan kadar pertumbuhan dan nisbah penukaran makanan yang terbaik. Makanan P40 adalah disyorkan sesuai untuk juvana* M. rosenbergii.

## ABSTRACT

*Linear least-cost programming was used in juvenile* M. rosenbergii *feed formulation using locally available feed ingredients (fish meal, shrimp meal, copra meal, soybean meal, wheat flour and palm oil). The following constraints were established: the essential amino acid contents were closely similar to those of juvenile* M. rosenbergii, *crude fat 5-10% and gross energy 4,400 cal/g with least cost. Four types of feed were produced with protein ranges from 25% to 50%. Growth responses of juvenile* M. rosenbergii *fed these formulated feeds showed that the 40% protein feed (P4O) supported the best specific growth rate and feed conversion ratio. P4O feed is recommended for juvenile* M. rosenbergii.

## INTRODUCTION

Feed costs for *M. rosenbergii* production can account for 30-40% of total operation costs (Liao and Chao 1982). Formulation of a least-cost nutritionally balanced feed would offer an opportunity of reducing overall production cost as well as increasing production. The application of linear programming in least-cost feed formulation for livestock and poultry has gained wide recognition. Its use in fish diet formulation was described by Chow *et al.* (1980). The linear programming technique in feed formulation for *M. rosenbergii* has not yet been reported. There is a paucity of information on the nutritional requirements for prawns including *M. rosenbergii* in the literature (New 1976; Sick and Millikin 1983). Therefore, a study was undertaken to make use of the available information on prawn nutrition to formulate a least-cost and nutritionally balanced feed from locally available ingredients for *M. rosenbergii* juveniles.

The constraints for the linear programme were set as follows: (1) The amino acid content of the feed was similar to that obtained from the muscle of juvenile *M. rosenbergii.* Many studies have indicated that artificial diets containing essential amino acid profiles that were similar to those of the cultured prawns including *M. rosenbergii* produced better growth (Farmanfarmaian and Lauterio 1979 and 1980; Kanazawa 1985; Pascual 1989) (2) Crude fat content of the diet was confined between 5 to 10%. Diets which have 10 % or more lipid have an adverse effect on the growth and survival of penaeid prawns (Bautista 1986; Sheen and D'Abramo 1991); (3) The gross energy of 4,400 cal/g was based on the reports by Sedgwick (1979); and (4) Based on the wholesale price of the ingredients, the feed production cost was minimal.

## MATERIALS AND METHODS

*Proximate Analyses*

Fish meal, shrimp meal, soybean meal, copra meal and wheat flour were the ingredients used for this study. Their moisture contents, crude fat and crude protein compositions were analyzed according to the methods of A.O.A.C. (1975). Gross energy content was determined by using a bomb calorimeter (Parr Adiabatic Calorimeter). For palm oil, only the crude fat and gross energy contents were determined. *M. rosenbergii* of two different sizes, i.e. 4.5-5.4 cm orbital length (1.35-1.55g) and 6.2-6.8 cm orbital length (1.92-2.20g) and other formulated feeds were also subjected to the same analyses. Six replicates were conducted on each sample.

*Amino Acid Analysis*

Amino acid contents in the ingredients, juvenile *M. rosenbergii*, and the formulated diets were analyzed following the method of Spitz (1973). A Technicon amino acid analyser (TSM) was used for the analysis with Sigma standard amino acid solution (A.A.S. 18) as a reference. Three replicates were run on each sample.

*Linear programming for feed formulation*

Four types of feed, i.e. P25 (25% protein), P30 (30% protein), P40 (40% protein), and P50 (50% protein) were formulated. The following constraints were established for the programming: essential amino acid contents were similar to those of the muscle of juvenile *M. rosenbergii*, crude fat 5-10%, gross energy 4,400 cal/g, and least-cost for the ingredients. The wholesale price for fish meal, shrimp meal, soybean meal, copra meal, wheat flour, and palm oil at the time of this study was RM 1.40, RM 1.00, RM 0.88, RM 0.35, RM 0.60, and RM 1.00 (Malaysian Ringgit) per kilogram, respectively. The linear programming was executed using the Functional Mathematical Programming System (FMPS) software package(Sperry Univac). Three per cent of mineral mix, 0.2% vitamin premix, 0.5% basfin (as binder) and 0.25% of calcium propionate (as fungicide) were included for the final feed preparation.The cost of the additives was added to the least-cost of the individual feed to give the final cost of the prepared feed.

*Growth Response of Prawns Fed with the Formulated Feeds*

Weight gains were used as the criterion for evaluation of the growth responses of prawns fed with the formulated feeds. The initial weight of prawns used for this study ranged from 0.014g to 0.336g. The prawns were fed at 5% body weight twice a day at 0900 and 2100. Triplicate experiments were conducted on each diet. The water quality parameters of the culture water were as follow: temperature 27-28 °C; dissolved oxygen 6.8-7.8 ppm; pH 6.9-7.3; total ammonium-nitrogen, < 0.02 ppm. Three culture systems were used for the experiments: the aquarium series, basin series and circular tanks. The aquarium series consisted of fifteen glass aquariums measuring 100cm x 60cm x 50cm (length, width and height). Each aquarium was partitioned off 1/3 of its length to form a biological filter section comprising limestone chips and cockle shells with a filtration rate of 6 litres of water per minute. Fifty postlarvae were randomly assigned to each aquarium with adequate shelters as hiding places.

The basin culture system consisted of a series of twelve basins receiving water from the same recirculating system. The flow rate of water into each basin was 500 ml per minute.The dimension of each culture unit was 49cm x 60cm x 30cm (bottom diameter, top diameter and height). The depth of water in each basin was 24 cm. Forty-two and fifteen postlarvae were randomly assigned to each basin in series 1 of 11 experiments respectively. For the circular tanks, the dimension of each unit was 150 cm diameter x 40 cm height (water depth). The culture system consisted of an undergravel filter 10 cm thick and the water flow rate was 1.5 litres per minute.

## RESULTS

The proximate analyses of crude protein, fat, ash, moisture, and gross energy of the ingredients and the juvenile *M. rosenbergii* are shown in Table 1. The essential amino acid composition of the ingredients as well as that of the fresh muscle content of the juvenile prawns and the formulated feeds are shown in Tables 2 and 3

TABLE 1
Proximate analyses of feed ingredients and juvenile *M. rosenbergii*

| | Ash (%)[1] | Crude fat (%)[1] | Crude protein (%)[1] | Gross energy (cal/g) | Moisture (%) |
|---|---|---|---|---|---|
| Ingredients | | | | | |
| Fish meal | 26.90 ± 0.42[2] | 9.95 ± 0.07 | 65.32 ± 0.09 | 4433.6 ± 43.4 | 11.91 ± 0.05 |
| Shrimp meal | 27.90 ± 0.24 | 2.26 ± 0.09 | 42.35 ± 0.81 | 3843.0 ± 35.2 | 16.29 ± 0.14 |
| Soybean meal | 6.09 ± 0.05 | 4.97 ± 0.05 | 45.14 ± 0.28 | 4808.5 ± 7.2 | 9.73 ± 0.14 |
| Copra meal | 6.28 ± 0.02 | 13.12 ± 0.15 | 24.97 ± 0.08 | 4926.5 ± 12.9 | 10.19 ± 0.12 |
| Wheat flour | 0.45 ± 0.00 | 1.17 ± 0.03 | 14.24 ± 1.11 | 4358.2 ± 14.0 | 3.11 ± 0.18 |
| Palm oil | –[3] | 100 | – | 9480.2 ± 0.0 | – |
| *M. rosenbergii* | | | | | |
| 6.20 – 6.82 cm[4] (1.92 - 2.20)[5] | 18.87 ± 0.07 | 5.84 ± 0.08 | 63.32 ± 0.33 | 4609.6 ± 11.3 | – |
| 4.50 – 5.35 cm (1.35 – 1.55 g) | 20.09 ± 0.09 | 5.28 ± 0.17 | 63.59 ± 0.12 | 4468.0 ± 30.9 | – |

1: On dry weight basis. 2: Mean ± S.D. (n ± 6). 3: Not determined
4: Post-orbital length. 5: Body weight

TABLE 2
Essential amino acid content of feed ingredients

| | Fish meal | Shrimp meal | Soybean meal | Copra meal | Wheat flour |
|---|---|---|---|---|---|
| | % Protein (% dry weight) | | | | |
| Histidine | 2.43[1] (1.59)[2] | 2.06(0.93) | 3.11(1.40) | 4.76(1.19) | 5.75(0.82) |
| Arginine | 6.02(3.93) | 5.75(2.60) | 6.82(3.08) | 9.63(2.41) | 2.41(0.34) |
| Valine | 4.79(3.25) | 4.36(1.97) | 4.34(1.96) | 3.62(0.90) | 3.51(0.50) |
| Methionine | 2.77(1.65) | 3.06(1.38) | 2.06(0.93) | 1.28(0.32) | 1.76(0.25) |
| Isoleucine | 3.74(2.44) | 2.64(1.19) | 3.11(1.40) | 2.27(0.57) | 2.52(0.36) |
| Leucine | 7.42(4.85) | 5.29(2.39) | 6.36(2.87) | 4.81(1.20) | 5.53(0.79) |
| Tyrosine | 2.64(1.72) | 7.29(3.29) | 3.80(1.72) | 1.29(0.32) | 0.93(0.13) |
| Phenylalanine | 3.65(2.38) | 3.89(1.76) | 5.35(2.41) | 3.57(0.89) | 3.93(0.56) |
| Lysine | 7.82(5.11) | 8.07(3.65) | 6.67(3.01) | 7.41(1.85) | 10.85(1.55) |
| Threonine | 4.58(2.99) | 4.01(1.81) | 3.41(1.54) | 2.48(0.62) | 2.35(0.33) |

1: Calculated from % of essential amino acid on dry weight basis x (1/% crude protein on dry weight basis).
2: Mean value from three analyses, on dry weight basis.

TABLE 3
Essential amino acid content of the formulated feeds and juvenile *M. rosenbergii* (1.55g - 2.20g)

| | *M. rosenbergii* | P25 | P30 | P40 | P50 |
|---|---|---|---|---|---|
| | % Protein (% dry weight) | | | | |
| Histidine | 1.61[1] (1.07)[2] | 1.80(0.45) | 2.31(0.69) | 1.40(0.56) | 1.23(0.61) |
| Arginine | 3.84(2.55) | 4.24(1.06) | 4.63(1.39) | 3.90(1.56) | 3.72(1.86) |
| Valine | 3.11(2.06) | 3.20(0.80) | 3.10(0.93) | 3.09(1.24) | 3.08(1.54) |
| Methionine | 2.91(1.56) | 2.66(0.67) | 3.42(1.04) | 2.06(0.81) | 1.79(0.89) |
| Isoleucine | 2.92(1.94) | 2.92(0.73) | 2.57(0.77) | 2.69(1.08) | 2.78(1.39) |
| Leucine | 5.05(3.34) | 6.52(1.63) | 5.70(1.71) | 6.05(2.42) | 5.61(2.80) |
| Tyrosine | 3.87(2.57) | 1.48(0.37) | 1.23(0.37) | 1.63(0.65) | 1.76(0.88) |
| Phenylalanine | 3.04(2.02) | 4.24(1.06) | 3.73(1.12) | 3.64(1.46) | 3.13(1.56) |
| Lysine | 6.41(4.26) | 4.24(1.06) | 4.10(1.23) | 3.83(1.53) | 4.50(2.25) |
| Threonine | 2.50(1.66) | 2.92(0.73) | 2.03(0.61) | 3.24(1.30) | 2.72(1.36) |

1: Calculated from % of essential amino acid on dry weight basis x (1/% crude protein on dry weight basis)
2: Mean value from three analyses

respectively. The ingredient composition, proximate analyses and cost of the formulated feeds are presented in Table 4. The growth responses of *M. rosenbergii* postlarvae and juveniles fed with the formulated feeds in the different culture systems are given in Table 5. The apparent digestibility of the feeds is given in Table 6.

## DISCUSSION

Many studies have shown that prawns including *M. rosenbergii* require dietary sources of essential amino acids for growth (Watanabe 1975; NRC 1983; Kanazawa 1985). Depressed appetite and reduced growth rate of the prawns are usually reported when the prawns are fed with diets deficient in any of the essential amino acids. Farmanfarmaian and Lauterio (1979, 1980) reported that the Purina Marine Ration (M20) was insufficient in some of the essential amino acids such as isoleucine, lysine and arginine for juvenile *M. rosenbergii.* However, when it was adjusted to the amino acid pattern of the prawn, it became the effective source of protein.This clearly supported the phenomenon that the

TABLE 4
Ingredient composition, proximate analyses and cost of the formulated feeds

| | Formulated feeds | | | |
|---|---|---|---|---|
| | P25 | P30 | P40 | P50 |
| Ingredients, kg/kg of feed. | | | | |
| Fish meal | 0.096 | 0.116 | 0.154 | 0.456 |
| Shrimp meal | 0.200 | 0.224 | 0.439 | 0.309 |
| Soybean meal | 0.050 | 0.200 | 0.100 | 0.100 |
| Copra cake | 0.010 | 0.114 | 0.150 | 0.013 |
| Wheat flour | 0.503 | 0.346 | 0.133 | 0.100 |
| Palm oil | 0.076 | 0.050 | 0.025 | 0.023 |
| Fine sand | 0.065 | 0.050 | 0.000 | 0.000 |
| Proximate analyses (on dry weight basis) | | | | |
| Crude protein (%) | 25.37 ± 0.12[1] | 30.34 ± 0.47 | 39.50 ± 0.07 | 49.48 ± 0.41 |
| Crude fat(%) | 8.09 ± 0.09 | 8.35 ± 0.09 | 6.91 ± 0.14 | 8.07 ± 0.03 |
| Ash (%) | 18.15 ± 0.11 | 17.52 ± 0.03 | 19.64 ± 0.00 | 22.03 ± 0.06 |
| Gross energy (cal/g) | 4283.6 ± 0.5 | 4229.3 ±46.2 | 4206.7 ± 39.2 | 4344.1 ± 5.5 |
| Cost with additives (RM/kg)[2] | 0.94 | 0.95 | 1.08 | 1.30 |

1: Mean ± S.D. (n = 6). 2: US $1 ± RM 2.5 (Malaysian Ringgit)

closer the amino acid composition of the feed to that of the prawn, the more effective is the protein source. Therefore, based on this phenomenon, four types of feeds with protein levels ranging between 25 % to 50 % where the amino acid content was similar to that of the whole fresh muscle of juvenile *M. rosenbergii* were formulated.

The nutrient contents of the formulated feeds were remarkably close to the constraints set by the linear programme (Table 4). The feeds were isocaloric with gross energy content of about 4,400 cal/g. The amino acid contents in the feeds, in terms of per cent protein, were very close to the values obtained from the fresh muscle amino acid content of juvenile *M. rosenbergii*, except for tyrosine which was about 50% lower. The reason for lower tyrosine levels in the feed is not known. Most probably, it was lost during the feed preparation. The water stability of the feeds was greater than 3 hours at 28°C.

The performance of the feeds was evaluated by using the growth responses and feed conversion ratio of postlarvae and juvenile *M. rosenbergii* fed with these feeds in the aquarium and basin culture systems for a period of 33-61 days. The results indicated that under both culture systems, all formulated diets produced specific growth rates that were significantly different (P< 0.01) where P40 feed supported the highest growth rate followed by P50, P30, and P25 feeds. In general, P40 feed also showed better feed conversion ratio (1.68-2.03) among all the feeds, except for P30 feed which was comparable or sometimes better (Table 5). The decline in growth rate and feed conversion ratio of P50 feed suggested that the optimal protein level in the diet for *M. rosenbergii* postlarvae and juveniles was around 40% with a gross energy of 4,400 cal/g, a protein:gross energy ratio of 1:110 and an amino acid profile similar to that of the prawn. The cost of ingredients required for the production of 1 kilogram of P40 feed was RM 1.08 (US$1.00 = RM 2.50).

It is difficult to compare the results of this study with those of other studies on the growth of juvenile *M. rosenbergii* on the pelleted feed because of the diverse culture systems, stocking densities, and different protein levels in the feed. However, it is interesting to note that the feeds used in this study seemed to give a higher specific growth rate and conversion ratio as compared to the studies conducted elsewhere with feeds of the same protein level, and under similar culture conditions. The better performance of the feeds used in the study may be due to the

TABLE 5
Growth responses of postlarvae and juvenile *Macrobrachium rosenbergii* fed on the formulated diets

| Culture system | Type of feed | Stocking density (no/unit) | Initial weight (g) | Final weight (g) | Culture period (days ) | Specific growth rate (% per day) | FCR | Survival rate (%) | |
|---|---|---|---|---|---|---|---|---|---|
| Aquarium series | P50 (3)[1] | 50 (111)[2] | 0.014 | 0.541 ± 0.0393 | 61 | 5.99 ± 0.12 | 2.13 ± 0.03 | 80.67 ± 5.03 | |
| | P40 (3) | 50 (111) | 0.014 | 0.652 ± 0.017 | 61 | 6.30 ± 0.04 | 2.03 ± 0.09 | 82.00 ± 2.00 | |
| | P30 (3) | 50 (111) | 0.014 | 0.487 ± 0.18 | 61 | 5.82 ± 0.06 | 1.98 ± 0.05 | 82.67 ± 4.16 | |
| | P25 (3) | 50 (111) | 0.014 | 0.338 ± 0.22 | 61 | 5.22 ± 0.11 | 2.39 ± 0.24 | 83.33 ± 3.06 | |
| | RBS (3) | 50 (111) | 0.014 | 0.300 ± 0.028 | 61 | 5.02 ± 0.11 | 2.55 ± 0.06 | 80.67 ± 9.02 | |
| Basin series-I | P50 (3) | 42 (221) | 0.104 ± 0.006 | 0.347 ± 0.036 | 35 | 3.43 ± 0.22 | 1.89 ± 0.09 | 90.47 ± 8.60 | |
| | P40 (3) | 42 (221) | 0.103 ± 0.004 | 0.389 ± 0.024 | 35 | 3.66 ± 0.17 | 1.86 ± 0.07 | 82.80 ± 4.10 | |
| | P30 (3) | 42 (221) | 0.108 ± 0.011 | 0.327 ± 0.034 | 35 | 3.16 ± 0.18 | 1.81 ± 0.19 | 93.80 ± 4.42 | |
| | P25 (3) | 42 (221) | 0.100 ± 0.006 | 0.263 ± 0.034 | 35 | 2.72 ± 0.20 | 2.48 ± 0.16 | 83.30 ± 9.80 | |
| Basin series-II | P50 (3) | 15 (79) | 0.347 ± 0.008 | 1.842 ± 0.054 | 58 | 2.88 ± 0.07 | 1.89 ± 0.45 | 84.47 ± 3.87 | |
| | P40 (3) | 15 (79) | 0.336 ± 0.015 | 2.072 ± 0.169 | 58 | 3.13 ± 0.11 | 1.68 ± 0.02 | 82.23 ± 3.87 | |
| | P30 (3) | 15 (79) | 0.342 ± 0.013 | 1.543 ± 0.061 | 58 | 2.60 ± 0.02 | 1.67 ± 0.02 | 86.70 ± 0.00 | |
| | P25 (3) | 15 (79) | 0.345 ± 0.003 | 1.117 ± 0.030 | 58 | 2.11 ± 0.05 | 2.43 ± 0.07 | 80.00 ± 0.00 | |
| Circular | P30 (1) | 50 (28) | 1.590 ± 0.050 | 4.822 ± 0.250 | 50 | 2.70 | 1.78 | 90.00 | |
| Tank | P30 (1) | 100 (56) | 1.35 | | 15.05 | | 159 | 1.52 | 2.55 |
| 60.00 | | | | | | | | | |

1: Parenthesis indicates the number of replicates
2: Number of prawns per unit of culture system (Number of prawns per $m^2$); 3: Mean ± S.D.

TABLE 6
Apparent nutrient digestibility of P30 and P40 feeds by juvenile (0.495 g–1.271g) and adult (7.954 g–25.588 g) *M. rosenbergii*

| | Apparent digestibility (%)[1] | | | | | |
|---|---|---|---|---|---|---|
| | Protein | Fat | Carbohydrate | Ash | Gross energy | Dry matter |
| P30 Feed | | | | | | |
| Juvenile | 66.02 ± 4.25[2] | 83.48 ± 6.11 | 82.16 ± 1.83 | 27.27 ± 9.37 | 78.77 ± 6.03 | 62.83 ± 3.84 |
| Adult | 72.59 ± 2.37 | 84.12 ± 2.86 | 72.15 ± 4.07 | 41.34 ±12.61 | 70.89 ± 2.66 | 64.94 ± 2.15 |
| P40 Feed | | | | | | |
| Juvenile | 66.50 ± 3.30 | 79.61 ± 0.69 | 63.81 ± 6.86 | 33.27 ± 4.49 | 65.77 ± 3.67 | 57.17 ± 3.23 |
| Adult | 75.93 ± 0.36 | 85.78 ± 0.51 | 70.35 ± 4.50 | 43.10 ± 3.47 | 74.44 ± 3.19 | 65.77 ± 1.13 |

1: On dry weight basis. 2: Mean ± S.D. (n = 6)

amino acid pattern in the feed which was similar to that of the muscle of the prawn. A specific growth rate of 5.22 % per day in the aquarium experiment using P25 feed was comparable to that of a 25% protein feed as reported by Willis *et al.* (1976). They obtained a specific growth rate of 5.71 % per day and a feed conversion ratio of 5.50, while we obtained a similar growth rate but a much better feed conversion ratio of 2.39.

Millikin *et al.* (1980) reported a specific growth rate of 2.59% per day for *M. rosenbergii* fed on a 40% protein feed and grown in basin. Using the similar culture system, we obtained a specific growth rate of 3.80 % per day with the P40 feed. In the basin experiment, our P25 feed produced a much better feed conversion ratio of 2.43 compared to that of 3.16-8.16 for 25% protein feed reported by Sandifer and Smith (1977). Even among the treatments in the aquarium experiments of this study, P25 feed produced a comparable higher specific growth rate and a better feed conversion ratio( 5.22 % per day & 2.39) than the repelleted broiler starter (RBS) which had the same levels of protein, fat and gross energy (5.02% & 2.55).

In the circular tank experiments, the juvenile *M. rosenbergii* weighing 1.35 g achieved an average weight of 15.05 g after 159 days when fed with the P30 feed. The specific growth rate was 1.52 % per day and the feed conversion ratio was 2.55. These values were better than those obtained from juvenile *M. rosenbergii* that were fed with the Purina Marine 25 which was supplemented with fresh beef liver; the specific rate and conversion ratio were 0.81 % per day and 5.18 respectively (Farmanfarmaian and Lauterio 1979). These results seem to support the phenomenon that feeds containing protein having a similar amino acid pattern to the culture species will be a more effective source of protein for growth.

The findings of this study revealed that the 40 % protein formulated feed (P40) supported the optimal growth of *Macrobrachium rosenbergii.* In fact, many studies have also indicated that the optimal protein requirement for *M. rosenbergii* is about 40 % (Pandian 1989). Millikin *et al.*(1980) demonstrated that juvenile *M. rosenbergii* fed with a 40% protein diet had a better weight gain than those fed with 49%, 32% and 23% protein diets over a period of 14 weeks. The results of the protein requirement studies of juvenile *M. rosenbergii* by Chao (1979) suggested that a protein level in excess of 35% was required for optimum growth of the prawn. Willis *et al.* (1976) showed that a 40% protein diet (trout chow) produced better growth than the 25% protein diet of Purina Marine Ration 25. Natural productivity in the pond plays an important role in providing supplemental diets for the growth of *M. rosenbergii* fed on pelleted feed (Fair and Fortner 1981). Therefore, in practice, farmers found that pelleted feeds containing 15-25% protein were satisfactory for the culture of *M. rosenbergii* in earthern ponds that had been fertilized with manure (New 1976; New 1990). Feed cost accounts for a high percentage of the production cost for *M. rosenbergii.* To reduce the cost of production, P30 feed has been successfully used along with chicken manure fertilization of the pond for *M. rosenbergii* production (Maclean *et al.* 1989).

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