Effects of dietary carbohydrates on growth and body components of the giant freshwater prawn, *Macrobrachium rosenbergii*

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Abstract

The availability of various dietary carbohydrate sources for juvenile giant freshwater prawn, *Macrobrachium rosenbergii,* was evaluated according to weight gain and body composition. Different carbohydrate sources, α-potato starch, soluble starch, dextrin, sucrose, glucose and glycogen were separately included in a purified diet. After 60 days the greatest weight gain was achieved in the groups fed potato starch or soluble starch. The group receiving glucose as the carbohydrate source had low weight gain. Food conversion efficiency and the protein efficiency ratio were higher in the group receiving soluble starch as the dietary carbohydrate source. Muscle lipid consisted mainly of phospholipids and partial glycerides; midgut gland lipids were composed of triglycerides and phospholipids. A change in dietary carbohydrates had a minor influence on muscle lipid levels but caused variations in lipid class composition of the midgut gland. Comparatively high levels of free fatty acids and phospholipids were found in the midgut gland of groups fed soluble starch and potato starch, respectively. No major differences in fatty acid compositions were apparent. Soluble starch and potato starch were efficiently utilized by the prawn as dietary carbohydrate sources.

Keywords : *Macrobrachium rosenbergii,* giant freshwater prawn, nutrition, carbohydrate requirements, growth, lipid composition.

Efectos de hidratos de carbono en el pienso sobre el crecimiento y la composición quimica corporal de langostinos juveniles, Macrobrachium rosenbergii.

Resumen

La disponibilidad de varios hidratos de carbono en el pienso para langostinos juveniles (*Macrobrachium rosenbergii*) fué investigada y comparada en términos de crecimiento y composicion quimica corporal. Como fuentes de hidratos de carbono se incluyeron en el pienso almidón de patata, almidón soluble, dextrina, sacarosa, glucosa y glicógeno derivado de ostras. Los langostinos fueron alimentados durante 60 días. En los grupos alimentados con pienso suplementado con almidón de patata y almidón soluble, el crecimiento fué mejor, y por otra parte la gludosa rindió el menor crecimiento. La eficiencia de conversión de alimento y la eficiencia de conversión de proteina fueron mejores en el grupo alimentado con almidón soluble. La composición de lípidos en el músculo abdominal consistió principalmente de fosfolipidos, mono- y diglicéridos; en tanto que los lípidos del hepatopáncreas estaban compuestos principalmente por triglicéridos y fosfolípidos. La diferente composición de hidratos de carbono en el pienso aparentemente tuvo poca influencia en el nivel de lípidos del músculo; sin embargo provocó variaciónes en la composición de los lípidos del hepatopáncreas. El nivel de ácidos grasos en el hepatopáncreas fué característicamente alto en el grupo alimentado con almidón soluble, mientras que en el grupo alimentado con almidón de patata el contenido de fosfolípidos fué dominante. No se hallaron diferencias notables en la composición de ácidos grasos de las distintas classes de lípidos. Los resultados sugieren que el almidón soluble es utilizado eficientemente por el langostino como fuente de hidratos de carbono.

Palabras claves : *Macrobrachium rosenbergii*, langostino, nutrición, hidratos de carbono, crecimiento, composición de lípidos.

INTRODUCTION

Although many practical diets are currently used for culturing giant freshwater prawn, *Macrobrachium rosenbergii*, the complete nutritional requirements remain undefined (Sandifer and Smith, 1985). In particular, the carbohydrate requirements for the species are not fully understood. Deshimaru and Yone (1978) reported that sucrose and glycogen are desirable carbohydrate sources for kuruma prawn *Penaeus japonicus;* moreover Abdel-Rahman *et al.* (1979), found that di- and polysaccharides are more suitable for the growth of this species. Carbohydrate requirements for larvae were investigated by Teshima and Kanazawa (1984). Pascual *et al.* (1983) obtained the highest survival of *P. monodon* when diets contained 10% sucrose. More recently Alava and Pascual (1987) found that both trehalose and sucrose-containing diets promoted growth and protein deposition in *P. monodon.*

Gómez *et al.* (1988) determined the optimum dietary protein/starch ratio for *M. rosenbergii* using α-potato starch as a carbohydrate source. Accordingly, the purpose of the present work is to determine the nutritional value of various dietary carbohydrate sources for this species. The quality of the carbohydrate sources was judged according to growth, food efficiency and body composition, especially lipids which are an indicator of energy reserve.

MATERIALS AND METHODS

Rearing and freeding conditions

Giant freshwater prawn, *Macrobrachium rosenbergii*, were acclimated to laboratory conditions for one week in an indoor tank and were fed with short-necked clam, *Ruditapes philippinarum*, meat prior to the experiments. In each experiment 20 prawns ranging from 1.8 to 2.3 cm in total body length were assigned to a 45 l aquarium, equipped with a sand filter recirculating system and plastic-covered chicken wire as the habitat to minimize cannibalism. Duplicate aquaria were set up for each test group. 10 to 20% of the water was removed daily and replaced with fresh tapwater. Water temperature was kept constant at 28°C throughout the experiments, but photoperiod was kept under natural light conditions without artificial control. The purified diets were prepared with a fixed protein/carbohydrate ratio of 1:1 as shown in *table* 1, according to the method of Gómez *et al.* (1988). Potato starch, soluble starch, dextrin, sucrose, glucose and glycogen were added to each diet as the exclusive carbohydrate source. The mixture was inserted into a sausage packing and boiled at 80-85°C and subsequently stored at −20°C until feeding. This method of diet preparation (sausage type diet) minimizes loss of nutrients during feeding, and residual (uneaten) diet weight can be more accurately determined. Clam meat, *Ruditapes philippinarum*, was a reference diet. Prawns were daily fed an amount of diet equivalent to 10% of the body weight and residual food was weighed. Duration of the experiment was 60 days. Food efficiency (FE) and protein efficiency ratio (PER) were calculated as follows:

FE = (weight gain/weight of food eaten) × 100

PER = weight gain/dry weight of protein eaten

Chemical analyses

At the experiment's end, the abdominal muscle and midgut gland tissue were obtained from about 10 prawn from each treatment, which were pooled and submitted to biochemical analyses. Care was used to select only prawns in intermolt stage C, and of similar size. Molt stage was identified following Peebles (1977). Proximate analysis was performed by the methods of Gómez *et al.* (1988). Lipid extraction was performed according to Bligh and Dyer (1959). Lipid classes were isolated on Chromarod-S Π with *n*-hexane/diethyl ether/acetic acid (80:20:1, v/v/v) as the developing solvent, and the composition was analyzed using an Iatroscan TH-10 (Iatron Laboratories).

For analysis of fatty acid composition, phospholipids (PL), partial glycerides (PG) and triglycerides (TG) were isolated by thin layer chromatography on Kieselgel 60-F 254 S plates (Merck Darmstadt) using *n*-hexane/diethyl ether/acetic acid (80:20:1, v/v/v) as the developing solvent. Saponification and methylation were performed using 2 N NaOH-methanol and 2 N HCl-methanol, respectively. Fatty acid composition was determined by gas-chromatography using a Hitachi 263-30 Gas Chromatograph with a 2 m column packed with Unisol 3000 at a temperature of 230°C, and a Hitachi D-2000 Chromato-Integrator. Identification was done by comparing retension time

Table 1. – Composition of experimental diets for *Macrobrachium rosenbergii*.

Ingredient (%)	Dietary group						
	1	2	3	4	5	6	7
Protein [a]	40	40	40	40	40	40	–
Potato starch	40	–	–	–	–	–	–
Soluble starch	–	40	–	–	–	–	–
Dextrine	–	–	40	–	–	–	–
Sucrose	–	–	–	40	–	–	–
Glucose	–	–	–	–	40	–	–
Glycogen	–	–	–	–	–	40	–
Others [b]	20	20	20	20	20	20	–
Clam meat	–	–	–	–	–	–	100
Total [c]	100	100	100	100	100	100	100
Energy (kcal/100 g) [d]	431	431	439	451	443	443	387 [e]
Carbohydrate [f]	32	32	33	35	33	33	–
Proximate composition (% dry weight):							
Crude protein	25.2	27.3	25.1	25.2	25.0	26.0	15.3
Lipid	3.2	3.1	3.0	3.2	3.4	3.3	0.9
Ash	2.6	3.4	3.4	3.4	3.4	3.9	1.7
Moisture	46.4	46.7	46.4	44.2	47.1	42.6	76.8

[a] Casein, 30; gelatin, 5; gluten, 5.
[b] $CaHPO_4$ 2 (H_2O), 5; *Spirulina* powder, 2.5; pollack liver oil, 5; cholesterol, 1; mineral mixture No. 2 (ICN Biochemicals), 2; vitamin mixture (Halver premix), 2; sodium carboxy methylcellulose, 2.5.
[c] Contains trimethylamine hydrochloride as an attractant.
[d] Gross energy, measured by bomb calorimetry.
[e] Calculated, assuming calorific equivalent of 4 kcal/g of protein and 9 kcal/g of lipid.
[f] Percentage of gross energy supplied by carbohydrates.

with authentic fatty acid standards, including 18:3 ($n-3$), 20:3 ($n-3$), 18:3 ($n-6$) and 20:3 ($n-6$).

Gross energy was estimated from the energy value of each dietary ingredient, measured by bomb calorimetry. Estimated digestible energy values for the short necked clam meat were calculated on the basis of the standard physiological fuel values of 9 kcal/g for lipids and 4 kcal/g for proteins (Maynard and Loosli, 1956).

Statistical analyses

The data were subjected to a *t*-test to determine if differences among means were significant. Data on growth, survival, FE and PER were analyzed for significance using Duncan's multiple range test. Similarity the patterns of lipid classes and fatty acid compositions was evaluated by the method of Tamura and Osawa (1969), which is based up on the correlation between linear regression lines for each composition. Probabilities of 0.05 or less were considered statistically significant.

RESULTS

In all dietary groups, survival exceeded 70% (*table* 2); the groups fed with dextrin and glucose were relatively high in survival. However, high weight gain was not always accompanied by high survival, because low survival is occasionally due to cannibalism. Results of weight gain, FE and PER associated with the different treatments are presented in *table* 2. Initial body weight of each group is somewhat different, but the percentage of body weight gain was not correlated with initial body weight. Weight gain of the groups fed either potato starch or soluble starch was higher than that of groups fed glycogen and clam meat. Relatively high values for both FE and PER were found in the soluble starch-fed group. Polysaccharides, including glycogen, yielded high FE and PER.

Midgut gland ratio (MGR) ranged from 2.9 to 3.8% (*table* 2). Some differences were observed among the groups. Dextrin or sucrose-fed groups were somewhat higher compared to other groups. There was little difference in protein or lipid compositions for abdominal muscles between the prawn groups fed artificial diets; however, the clam meat-fed group was characterized by a low lipid content (*table* 3).

Lipid class composition of the muscle and midgut gland are presented in *table* 3. Free fatty acids were found only in small amounts in the abdominal muscle. Differences in the source of dietary carbohydrate did not significantly influence proportion of sterols, partial glycerides (PG) or phospholipids (PL) in this

Table 2. – Effect of carbohydrates on growth, food efficiency (FE) and protein efficiency ratio (PER) of juvenile prawn, *Macrobrachium rosenbergii.*

Dietary group	Carbohydrate	Initial body weight (g) [1]	Weight gain (%) [2, 3]	Survival (%) [3]	FE (%) [3]	PER [3]	Midgut gland ratio (%) [1, 4]
1	Potato starch	0.13±0.04	692 [a]	77.5 [a, b]	25.3 [a]	1.01 [a]	2.9±1.2
2	Soluble starch	0.17±0.05	659 [a]	90.0 [c, d, e]	30.0 [b]	1.10 [a]	3.3±1.2
3	Dextrin	0.15±0.06	573 [b]	97.5 [c, e]	26.8 [a, b]	1.07 [a]	3.8±1.0 [a, c]
4	Sucrose	0.14±0.07	550 [b]	85.0 [b, c, d]	20.9 [c, d]	0.83 [b, c]	3.6±1.3 [b]
5	Glucose	0.16±0.08	431 [c]	95.0 [c,d, e]	19.3 [d]	0.77 [c]	3.5±1.5
6	Glycogen	0.20±0.08	410 [c]	85.0 [b, c, d]	23.3 [a, c]	0.90 [b, c]	2.9±1.2
7	Clam meat	0.27±0.14	389 [c]	72.5 [a]	14.7	0.97 [a, b]	3.2±1.0

[1] Mean & SD.
[2] Body weight gain (g)/initial body weight (g) × 100.
[3] values in the same column followed by different letters are significantly different ($p<0.01$).
[4] Midgut gland ratio = (midgut gland weight/body weight) × 100.
[a] different ($p<0.01$) to groups 1 and 6.
[b] different ($p<0.05$) to groups 1 and 6.
[c] different ($p<0.05$) to group 7.

Table 3. – Lipid class composition of abdominal muscles and midgut gland in prawn *Macrobrachium rosenbergii* fed diets containing different sources of carbohydrates.

	Dietary group						
	1	2	3	4	5	6	7
Abdominal muscle:							
Lipid content (%) *	2.5	2.2	2.3	2.5	2.4	2.3	1.1
Lipid class composition (%):							
Sterol esters	tr.	tr.	tr.	tr.	tr.	tr.	tr.
Triglycerides	tr.	tr.	tr.	tr.	tr.	tr.	tr.
Free fatty acids	tr.	tr.	tr.	0.6	tr.	tr.	1.1
Sterols	4.3	3.5	3.0	2.1	2.5	2.5	3.2
Partkal glycerides	23.9	24.8	20.4	20.9	22.7	23.3	21.5
Phospholipids	71.8	71.7	76.6	76.4	74.8	74.2	74.2
	a	*a*	*a*	*a*	*a*	*a*	*a*
Midgut gland:							
Lipid content (%) *	5.6	12.6	8.7	9.6	7.9	10.8	9.3
Lipid class composition (%):							
Sterol esters	tr.	tr.	tr.	tr.	tr.	tr.	tr.
Triglycerides	36.0	61.8	74.5	66.8	57.4	60.9	72.2
Free fatty acids	5.9	15.1	2.7	3.5	5.6	7.0	3.4
Sterols	5.4	3.6	2.5	3.5	3.3	4.2	2.7
Partial glycerides	tr.	tr.	tr.	tr.	tr.	tr.	tr.
Phospholipids	52.7	19.5	20.3	26.2	33.7	27.9	21.7
	b	*a*	*a*	*a, d*	*d*	*a, d*	*a, d*

* Wet basis.
a, b, c, d Figures with different subscripts are significantly different ($p<0.05$).

tissue. However, lipid class composition of the midgut gland showed some statistical differences between the groups fed with different dietary carbohydrates.

For total lipid content, the potato starch-fed group showed a comparatively low value (5.6%), whereas the highest content was observed in the group fed the dietary treatment that contained soluble starch (12.6%). Also, lipids of this latter group were characterized by very high percentages of free fatty acids (15.1%); the group fed glycogen followed the soluble starch fed group in levels of total lipids and free fatty acids. However, the percentage of free fatty acids was only half that of the former group. The proportions of sterols, TG and PL were fairly distinct between the groups. The group fed with potato starch was relatively low in TG amounts but high in PL, whereas a rather low PL percentage was characteristic of the soluble starch-fed group.

Table 4 shows fatty acid composition of PL and PG in the muscle. Most of the fatty acids in the PL and PG were represented by 16:0, 18:1, 18:2, 20:5 and 22:6. Fatty acid composition found between the

Table 4. — Fatty acid composition * in muscle lipids of prawn, *Macrobrachium rosenbergii.*

	Phospholipids							Partial glycerides						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
14:0	2.1	2.1	1.6	1.5	1.6	2.0	1.2	2.2	2.3	3.8	2.4	3.1	2.7	1.1
16:0	17.8	21.6	19.2	17.3	18.5	21.2	17.6	19.1	24.3	25.9	22.5	22.2	25.2	22.5
18:0	6.9	7.3	7.4	7.3	7.2	7.7	8.8	6.0	6.7	8.8	7.0	6.2	6.9	9.2
16:1	6.4	7.3	6.7	7.2	5.7	5.8	6.1	6.8	10.9	8.7	9.4	9.9	10.6	12.0
18:1	24.4	24.7	23.9	23.3	23.0	22.2	15.9	29.1	31.0	18.7	28.8	20.3	23.1	22.4
20:1	3.6	3.7	3.7	3.4	3.7	3.6	1.4	3.9	3.9	1.5	3.3	1.8	2.0	2.0
18:2	7.7	7.6	7.4	9.5	8.0	7.8	1.5	7.2	9.5	10.8	11.2	10.3	11.3	1.8
18:3 *n*−3	–	–	–	–	–	–	–	tr.	tr.	1.2	0.5	0.9	1.0	–
18:3 *n*−6	0.6	tr.	0.9	0.8	0.9	0.8	tr.	tr.	0.6	1.5	0.9	1.1	1.3	–
20:4	2.0	1.4	2.8	2.1	2.3	2.0	5.1	1.0	1.2	1.6	1.4	1.2	1.0	4.5
20:5	18.9	15.5	17.2	18.1	19.1	17.4	18.6	7.5	7.5	12.7	9.8	14.4	9.1	9.3
22:5	0.6	0.7	0.9	0.8	0.9	0.9	1.0	tr.	tr.	0.7	tr.	tr.	0.8	0.6
22:6	7.9	7.0	8.0	8.2	8.6	8.0	16.0	12.9	2.1	3.6	2.8	3.6	3.0	7.9
Others	1.1	1.1	0.5	0.6	0.5	0.6	6.8	4.3	–	0.5	–	2.9	2.0	6.7

* Data expressed as percentages of the total fatty acids present.

groups fed purified diets. Fatty acid composition of prawns fed clam meat was slightly different from that of the other groups, being characterized by lower amounts of 18:2 and higher in amounts of 20:4 and 22:6. Fatty acid composition of midgut gland lipids is shown in *table* 5. Fatty acid composition of PL for the midgut gland was similar to that of muscle, but proportions of the 16:0, 18:1 and 20:1 in PL were slightly lower than those in TG.

Table 5. — Fatty acid composition * of midgut gland lipids of prawn, *Macrobrachium rosenbergii.*

	Phospholipids							Triglycerides						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
14:0	3.0	4.7	4.1	3.5	2.1	3.9	3.1	6.7	8.0	5.8	6.9	6.7	6.7	5.9
16:0	14.4	16.2	16.2	16.0	14.4	15.6	15.5	22.1	29.1	25.1	25.1	24.3	25.8	26.3
18:0	8.3	7.2	7.6	8.4	10.3	8.5	8.1	6.6	5.4	8.1	6.0	6.7	8.4	7.4
14:1	tr.	0.9	1.1	0.6	–	0.6	0.9	1.2	1.2	1.2	1.1	0.6	0.8	tr.
16:1	6.9	9.6	8.6	9.0	6.9	7.7	11.6	5.9	13.9	9.6	12.7	8.3	8.9	13.8
18:1	20.2	21.7	19.2	21.6	21.0	19.9	19.5	24.2	26.2	25.8	27.1	24.6	24.2	19.8
20:1	5.0	4.9	4.5	4.5	3.8	5.1	2.3	12.6	5.7	10.5	8.4	12.8	10.7	7.9
18:2	6.2	5.9	5.9	6.5	7.1	7.3	2.0	3.2	4.4	3.4	4.4	3.4	4.6	1.8
18:3 *n*−3	0.5	0.5	tr.	0.6	0.7	0.7	tr.	1.0	tr.	–	tr.	tr.	–	–
20:4	2.3	1.4	2.0	2.6	2.4	1.5	5.0	–	–	–	–	–	–	–
20:5	19.2	14.2	17.1	16.1	18.3	16.6	12.4	9.5	3.6	8.3	5.0	10.4	8.6	–
22:5	1.2	0.7	0.9	0.7	0.9	0.8	tr.	tr.	tr.	–	tr.	tr.	tr.	0.6
22:6	10.9	9.3	11.0	9.1	11.1	10.1	15.7	1.2	2.5	1.1	1.1	1.3	1.4	4.7
Others	1.7	1.1	1.8	0.8	1.0	1.0	3.9	3.8	–	0.5	–	–	–	9.1

* Data expressed as percentage of the total fatty acids present.

DISCUSSION

Growth was relatively high in the prawns fed diets containing potato starch, soluble starch or dextrin. Soluble starch feeding, in particular, showed high PE and PER. Additionally, prawns fed a diet having soluble starch as the carbohydrate source had less weight variation. Growth of crayfish (Hubbard *et al.*, 1986) and *P. monodon* (Bautista, 1986) correlated to dietary energy content. Growth of *P. monodon* increased as long as dietary energy was maintained within certain limits (Alava and Pascual, 1987). In our experiment, the total dietary energy content and calorific amounts supplied by carbohydrates were similar between diets. Therefore, the differences in weitht gain cannot be ascribed to dietary energetic content, but most probably are the result of the nutritive value of the carbohydrate source.

Survival was not directly influenced by the type of carbohydrate. The low survival caused by cannibalism might not be related to poor nutritional value, because high cannibalism occurrence is associated with physiologically active prawns. In our experience, high survival could be obtained from groups reared with diets known to be of low nutritional value.

Abdel-Rahman *et al.* (1979) found that polysaccharides were nutritionally superior to monosaccharides for *P. japonicus*; however, Deshimaru and Yone (1978) reported that diets containing starch and dextrin were associated with high mortality of this species. Sucrose was reported as a desirable dietary carbohydrate source for *P. japonicus* (Deshimaru and Yone, 1978) and *P. monodon* (Alava and Pascual, 1979). Our results indicate that soluble starch is the most suitable carbohydrate source for the giant freshwater prawn. Thus species specific differences in the quality of different carbohydrate sources can be attributed to feeding habits. The prawn can ingest a lot of plants. While Fair *et al.* (1980) suggested that cellulose might contribute to the nutritional requirement of the prawn, the prawn could not utilize cellulose as a carbohydrate source (Gómez *et al.*, 1988). Cellulose may contribute to efficient utilization of dietary proteins.

Effects of the dietary regime on the body composition of *Macrobrachium rosenbergii* have not been satisfactorily investigated. The results of this study and of Alava and Pascual (1987) both indicate that different types of dietary carbohydrates can influence the proximate composition of muscle and the hepatopancreas of prawn. Lipid levels of the prawn seem to be unaffected by the types of carbohydrate. Low body weight gain of the clam fed group accompanied by low muscle lipid seemed to be attributed to a dietary energy deficiency. Lipid content of the whole body of freshwater prawn ranged from 1.63 to 3.2% (Reddy *et al.*, 1981; Chanmugam *et al.*, 1983). Hilton *et al.* (1984) reported that carcass lipid content significantly increased with increasing dietary lipids in prawn, but their results also showed the possibility of excess dietary lipids and/or energy content causing a slight growth retardation.

Lipid class composition of muscles and midgut glands were markedly different. The bulk of the lipids in the midgut gland tissue was composed of TG. Absence of TG in the muscle would imply a specialized lipid metabolism. Teshima and Kanazawa (1978) found a relatively higher proportion of TG than PG in midgut glands and more DG than TG in muscles. Therefore, lipid metabolism in crustaceans appears to be similar. The group fed a diet containing soluble starch had a higher free fatty acid content than the other groups. This high level of free fatty acids may be an indicator of active metabolism and a high degree of lipolysis as suggested by Ota and Takagi (1977) for young sweet smelt, *Plecoglossus altivelis*. The midgut gland is an important energy stock in crustaceans and can serve as a sensitive indicator of nutritional condition. Ingested carbohydrates should be assimilated as an energy stock in the form of glycogen and lipids. The groups with high growth did not always show a high midgut gland weight nor a high lipid level and no relationship was obvious.

Chanmugan *et al.* (1983) and Sandifer and Joseph (1976) reported that the tissue of freshwater prawns had comparatively greater percentages of 16:0, 18:1 and 18:2, and lesser amounts of $n-3$ polyunsaturated fatty acids. In our experiment, polyunsaturated fatty acids were found in place of low amounts of 18:2. Reddy *et al.* (1981) reported high amounts of 16:0, 18:1, 18:2, 22:1 and 20:5 in whole lipids of the prawn. These results imply that the fatty acid composition is likely to be responsive to dietary regime and rearing conditions. The fatty acid composition was not highly differenciated by dietary carbohydrate sources, but the clam meat-fed group was characteristic in low 18:1. As to 18:1 in muscle PL, the proportion decreased as growth decreased. Accumulation of fatty acid in the muscle PL probably related to growth.

CONCLUSION

A feeding trial using potato starch, soluble starch, dextrin, sucrose, glucose and glycogen as carbohydrate sources was performed using freshwater prawn, *Macrobrachium rosenbergii*. Potato starch and soluble starch were judged to be utilized most efficiently as carbohydrate sources through evaluation of growth, food efficiency and body components responses.

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